METEOROLOGY (Management Level)

Chief Mate-FG (Phase-1)

Notes by: Anupam Singh Rajput

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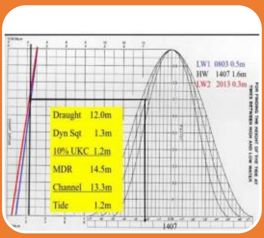
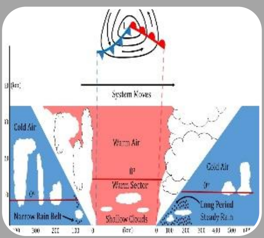


Q NO 1

- Tide Calculations for Standard and Secondary Ports (including shorter method of SHM)

Q NO 2

- Tropical Revolving Storm (TRS)



Q NO 3

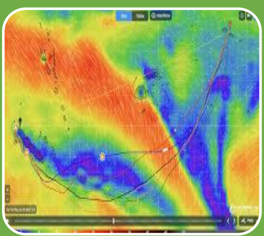
- Climatology/ Frontal / Non Frontal depressions

Q NO 4

- Ice/ Atmosphere

Q NO 5

- Ocean Currents/ Waves



Q NO 6

- Weather Forecasting/ Weather Routeing

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GOVERNMENT OF INDIA

FIRST MATE OF A FOREIGN GOING SHIP (PHASE - I)

FUNCTION: NAVIGATION (Management Level)

PAPER: METEOROLOGY

TIME: 2 HOURS **PASS MARKS: 50** **MAX.MARKS: 100**

NOTES:

1. Question No.1 is compulsory.
2. Attempt any FOUR questions from the remaining 5 Questions.
3. All questions carry equal marks i.e. 20 marks each.
4. Use Admiralty Tide Tables 1992 Edition (ATT 1992).

Q.1. Tide calculations for Standard Port and Secondary Port (including shorter method of harmonic method)

1. Calculate by SHM Shorter method the HOT at Port Adeliade (Outer Harbour) on 20th February 1992 at 0930 Hours LT. (Ans: 1.096 mtr)
2. Calculate by SHM Shorter method the HOT at MASQAT on 10th April 1992 at 0600 Hours LT. (Ans: 1.28 mtr)
3. Calculate the HOT at Sultanpur (No. 4344, ATT-2) at 0900 Hours Local Time on 19th April 1992 by SHM Method.
4. Find the HOT at Cape Town Harbour on 6th March 1992 at 0830 Hrs by SHM method.
5. Find the HOT at DERBY (ATT No 6278, ATT-III) on 4th Feb 1992 at 1330 Hrs by SHM method.
6. Using the Harmonic Constant method find the Height of Tide at 0430 Hours on 2nd Jan 1992 at VLISSINGEN (FLUSHING).
7. Find the Height of Tide at 1330 hours on 14/02/1992 at 1330 Hours at Sunday Island.
8. Find the Height of Tide at Bhavnagar (#4346) on 9th Feb 1992 at 1200 hrs by SHM Method.
9. Find the HOT at Cape Town (ATT Vol 2- #3782) on 12th Jan 1992 at 0600 Hrs
10. Find the HOT at Cape Town (ATT Vol 2- #3782) on 19th March 1992 at 1430 Hrs using SHM Method of Tidal prediction.
11. By using SHM Method, find the HOT at Woods Hole (#2790) on 10th March 1992, at 1730 Hours LT
12. Calculate by SHM method, the HOT at Good’s Island (ATT-3) on 20th January 1992 at 1300 Hrs LT.
13. Calculate the HOT by Harmonic Constant method for the port of Mumbai, Apollo Bandar at 0630 hours GMT on 15th January 1992 (Use Shorter Method)
14. Find the HOT by SHM method at 0518 hrs LT on 23rd April 1992 at HONGKONG, Port No, 7110 (ATT Vol-III)
15. Using Simplified Harmonic Constant Method, find HOT at Hoek Van Holland (No. 1505, ATT Vol-1) at 0800 hours on 13th March 1992.
16. Find the HOT for Coconut Island (#5807) at 2030 hours on 26th February, using shorter method of SHM Tide calculation.

Q.2. Tropical Revolving Storm (TRS)

1) State the conditions favourable for the formation of a Tropical Revolving Storm. (19 times)

(OR),

State the factor affecting movement of TRS? (4 times)

2) What are the warning signs of an approaching Tropical Revolving Storm and the weather associated with it. (12 times)

(OR),

What type of weather is associated with 'EYE' and 'EYE WALL' of a TRS

3) With respect to a TRS explain: i) Tropical depression ii) Track iii) Path iv) Trough v) Vertex vi) Dangerous Semi Circle vii) Navigable semi-circle viii) Dangerous Quadrant +1 ix) Navigable quadrant x) Vertical wind shear xi) Characteristic and Alternate path

4) What is TRS? With suitable sketch describe its structure, formation, development and decay. (3 times)

(OR),

With suitable diagram, Explain the structure of TRS? (4 times)

(OR),

Draw a cross section of TRS showing areas of cloud and precipitations (2 times)

(OR),

Explain well developed TRS structure with diagrams.

5) Explain with a suitable sketch the movement of a tropical revolving storm in the Northern and Southern Hemisphere. (4 times)

(OR),

Explain with the help of suitable sketches the most probable path of a cyclone in the North and South Hemisphere (2 times)

(OR),

Describe with a neat sketch, typical path of a TRS in Southern hemisphere. Why does TRS not always follow such a track? (4 times)

6) Draw the isobaric pattern of a well-developed TRS. (2 times)

7) Give the names of the TRS in different parts of the world. (3 times)

(OR),

List the areas where tropical storms frequently occur and their approximate yearly frequency together with local names. Mention against each areas the period of the year when TRS generally develop. Which are the regions in the world free of tropical storms and why?

8) Avoiding actions in NH:

a) With the diagram, explain avoiding action for TRS in Northern Hemisphere (7 times)

(OR),

Explain the actions to be taken by own vessel in the dangerous quadrant of a TRS in Northern Hemisphere (4 times)

(OR),

Describe the avoiding action in northern hemisphere for a ship in (i)in dangerous semicircle +1 (ii)Navigable semicircle

(OR),

Avoiding action to be taken if you are in the right hand semi-circle of a TRS in Northern Hemisphere.

b) Explain your actions in avoiding a TRS in Northern Hemisphere when it is near the point of re-curvature with the help of safety sector method.

(OR),

Your ship is bound from Norway to Miami (Florida) in the month of October. You are receiving storm warning giving you the position of eye of TRS every 6 hourly. How would you avoid the influence of TRS by the use of "Safety Sector Method"?

(OR),

If you were receiving weather reports giving position of centre of TRS with its movement, how will you keep your vessel safe?

If know the position of storm's centre, Use Safety Sector Method

9) Avoiding actions in SH:

State your actions to avoid getting closer to the eye of TRS if you were in Southern Hemisphere. (5 times)

(OR),

Describe the practical rules for avoiding eye of a TRS in the southern hemisphere. Support your answer with neat sketches. (4 times)

(OR),

Explain the evasive actions to be taken by own vessel in the path of a TRS in Southern Hemisphere.

(OR),

What action to be taken if vessel in southern hemisphere is in the path of the storm and presently experiencing winds BF scale 5. Assume navigable waters all around.

(OR),

What action to be taken if vessel is inside navigable quadrant in the southern hemisphere

Other Avoiding actions:

b) Action to be taken when the approach of TRS is confirmed. (2 times)

Write joint answer from 8 & 9

b) If the position of your ship is in the dangerous semicircle of a TRS what action you would take to keep your vessel safe. (2 times)

Write joint answer from 8 & 9

b) With respect to Tropical Resolving Storm (TRS) explain the following: You are bound from Amsterdam to the West Indies and you receive weather bulletin and visual warning of hurricane moving N.E., and that its centre will pass over or near your position. State what action you would take, giving your reasons.

Write answer from 8: Avoiding action in NH

b) While heading N.E. in the North Atlantic (Latitude 10° N) at 10 knots, you receive information that a tropical storms in the vicinity is travelling at 15 knots, wind variable moderate SW'ly swell. What action would you take? (2 times)

Write answer from 8: Avoiding action in NH

10)a) What are the causes for curving and re-curving of TRS? (2 times)

b) Why does a TRS re-curve and what is the importance of cyclostrophic wind in TRS?

c) Why does the speed of TRS increase after re-curving? (2 times)

11) State the regulation given in SOLAS regarding reporting a TRS & list the information which must be included in such a report. (4 times)

(OR),

Describe the messages required to be sent as per SOLAS. (2 times)

12) Describe the following in respect to Tropical Revolving Storm (TRS):

a) Why ITCZ cannot be termed as an Equatorial Front or Inter-tropical front. (3 times)

b) What is the reason for fewer occurrences of T.R.S. formation in South Atlantic and eastern part of South Pacific?

c) Why do TRS usually form on the Western extremities of the ocean?

Q.3) Climatology/ Frontal / Non Frontal depressions

1) Write short notes on following: a) Depletion of ozone layer and its impact on environment b) Frontolysis and its significance to the mariner. (9 times)

2) What are the causes and effects of Global Warming? How it is affecting the change in the weather? (7 times)

(OR),

Describe the effect of accumulation of greenhouse gas in the atmosphere

3) Describe the characteristics and weather associated with various types of clouds? (3 times)

(OR),

Describe the characteristic and weather associated with the following types of clouds: i) Altocumulus ii) Nimbostratus iii) Cumulonimbus (5 times)

4) Describe the weather associated with the passage of warm front and Occluded front. (4 times)

(AND),

Describe the sequence of clouds and weather at cold & Warm front (3 times)

(OR),

Explain the sequence of weather when a cold front passes over an observer in the Northern Hemisphere.

5) Explain the term "air mass" and "front". With suitable sketches, explain the life cycle of a frontal depression. (3 times)

6) Explain why ITCZ cannot be termed as an Equatorial front or an Inter-tropical front.

7) Make plan and cross sectional sketches of a typical frontal depression in the Southern hemisphere, showing the probable path, fronts, isobars with pressures, wind directions & forces and clouds.

8) Describe in detail the probable sequence of weather that would be experienced during the passage of the warm (or), cold front by an observer to the north (or), south of this depression. (2 times)

9) Explain in detail weather sequence on-board a vessel in Southern Hemisphere as it passes north of a SE moving frontal depression a) On passing the warm front b) Within warm air mass c) On passing the cold front Illustrate your answer with a neat sketch

10.a) 'Frontal Depressions are encountered in a row'. Justify your answer with the help of suitable sketches (4 times)

b) How is a frontal depression formed?

c) Sketch and describe isobars and wind circulation in a frontal depression. (2 times)

d) Describe in stages the formation of 'non-frontal' depression+2

11) Explain the process of frontogenesis.

12) What is an air mass? How are air masses classified? b) What will be the effect on weather when an air mass situation over North America moves towards the Atlantic Ocean in summer and winter. (3 times)

13) Describe the characteristics of a region acting as the source region for an Air Mass

14) Define adiabatic changes & environmental lapse rate. Describe how lapse rate and condensation level determine the formation of different types of clouds. (2 times)

15) What is adiabatic and isothermal changes and it's significance to weather?

16) Describe the effects of temperature changes over land and sea? (3 times)

17) Explain the importance of humidity, temperature and wind shear on atmosphere equilibrium

18) Explain Buy's Ballots Law, Veering and Backing.

19) Describe the characteristics and location of Trade Winds.

20) With suitable diagram, Describe the local winds for the Mediterranean Sea

21) Why is it that in some ocean there are Trade winds and in others in the same Latitudes there are monsoons (2 times)

23) Write short notes on: (a) Geostrophic Winds (8 times) (b) Cyclostrophic wind (c) Absolute Instability of Air (3 times) (d) Refraction of Sea Waves. (e) Warm & Cold Front (3 times) (f) Occluded Front

24) Write short notes on: i) Air mass types ii) Types of clouds associated with warm front of a TLD iii) Global warming.

25) Write short notes (Any Five) (i) Col. (ii) Semi-diurnal Variation of Atmospheric Pressure (iii) Advection Fog (iv) Thunderstorm (v) Fohn Wind Effect (vi) Families of Depression (2 times)

26) Write notes on following: a) Coriolis Force (5 times) b) ITCZ c) Pressure Gradient (4 times)

27) Write short notes on: i) Wave nomogram ii) Wave refraction iii) Occlusion

28) Write short notes on: i) Synoptic charts ii) Prognostic charts

FOG

29) Define surface analysis and prognosis charts. Explain how you would use these charts for: i) Determination of surface winds ii) Forecasting the movements of fronts iii) Forecasting of sea fog. (8 times)

30) What are the causes of sea fog? State the localities in which it is most frequent. (2 times)

31) List the area and seasons in which sea fog is to be expected. Explain how the occurrence of sea for can be predicted on board ship (3 times)

32) Write notes on: a) List different types of FOG. b) Explain why there is persistent fog off the Grand banks of Newfoundland.

33) Explain how advection fog and radiation fog are formed. Which one does not form over the sea and why?

<u>Q.4) Ice/ Atmosphere</u>

1) Explain the purpose, duties and responsibilities of International Ice Patrol? (7 times)

(OR),

Describe the function of International Ice Patrol. (7 times)

2.a) Explain the formation of **sea ice** (5 times)

(OR),

Explain with block diagram the various stages in the development of sea ice. (2 times)

(OR),

Explain with help of a suitable diagram the sequential formation of sea ice. (2 times)

b) Describe the factors on which the movement of sea ice is dependent upon. (2 times)

c) State the limitations of radar as a means of detecting ice. (2 times)

d) Explain the precautions to be taken when navigating in or near an area affected by sea ice. (3 times)

e) Describe the signs which may indicate proximity of ice on clear days and nights

(OR),

Explain signs of approaching Ice bergs and actions will you take on seeing these signs.

3) What do you understand by Fast Ice & Pack Ice? Explain with help of a sketch the different manners in which river water (fresh water) and sea water (salt water) freeze as air temperature falls. (6 times)

4.a) What is an **iceberg** and how it forms?

b) Write down different types of icebergs found at sea

c) Explain the formation of icebergs from floating glaciers, ice shelf and characteristics of each.

(OR),

Define an iceberg. Describe the icebergs of Arctic and Antartic

5) Describe the Ice bergs of Arctic region and usual path they take. Describe the life span of Arctic region Icebergs (5 times)

6) Discuss with the aid of suitable sketches the normal season and probable movement of North Atlantic Icebergs from birth/origin to decay. (8 times)

(OR),

How do icebergs of the northern hemisphere form and decay? (2 times)

7) How is sea ice different from icebergs?

8.a) Describe the factors which may give rise to **ice accretion** and methods of reducing ice accretion. (8 times)

(OR),

Describe the accretion of Ice and what precaution are required to be taken to avoid ice accretion on-board?

(OR),

What is ice accretion? What are the conditions when this can occur on board? (2 times)

(OR),

Explain the three mechanisms of ice accretion on board a ship.

b) What are the duties of Master when such conditions are encountered at sea? (2 times)

9.a) What do you understand by **"Ice Accumulation"**? (2 times)

b) What precautions would you take to minimize ice accumulation on board? (3 times)

10) Hazards associated with ice accretion and ice accumulation (2 times)

11) Explain the phenomenon of freezing spray and actions to be taken to minimize its effects

Ques) Briefly explain the formation of sea ice, icebergs in higher latitudes in Northern Waters? (3 times)

Write joint answers from Ques 2.a & 4.a

12) Information given in ice charts

13) What all details are promulgated in the ice report?

(OR),

What report you will file on encountering ice at Sea.

14) Write down the obligation of Ship's Master for reporting dangerous ice

ATMOSPHERE

1) Describe in detail (with the help of a neat sketch) the conditions and values of lapse rates, which lead to stability / instability at atmosphere. (5 times)

(OR),

What is an adiabetic process? Discuss Stability of atmosphere in detail giving suitable sketch

2) Write short notes on Diurnal variation of temperature and atmospheric pressure? (4 times)

3) What is atmosphere? Write its constituents and structure. Atmosphere remains in contact with the earth's surface – explain how.

4.a) Give a graphical representation of how atmospheric temperature varies with height in different layers of atmosphere.

b) With the help of a sketch, explain "General distribution of surface temperature and atmospheric pressure" on Earth's surface. (2 times)

5) Write short notes on (with neat diagrams)

a) Isobars b) Isallobars c) Atmospheric pressure RIDGE +1 (d) Anticyclone +1 (e) Ridge and trough isobaric pattern

6) Write notes on: i) Geostrophic wind ii) Gradient wind +1 iii) Katabatic wind iv) Sea breeze

7) Write short notes on the following: i) Eckman spiral ii) Vector mean current iii) Corona (2 times)

ANSWERS FOR ATMOSPHERE ARE COMBINED WITH Q.3(CLIMATOLOGY) ANSWERS

Q.5) Ocean Currents/ Waves

Ocean Currents

1) Explain main causes of ocean currents. Give example of two warm ocean currents and two cold currents and causes of these currents. (2 times)

(OR),

What are the primary factors influencing the motion of surface currents. What is the indirect effect of wind on the surface currents & how do they affect the strength of currents as well as local climate? (2 times)

(OR),

a) Explain reasons of current. (6 times) b) Identify any two major ocean currents and write short notes on them.

2)a) Describe the effect of wind blowing over a long coastline and how this influences the currents in the South Pacific Ocean. (2 times)

b) Describe the effect that the rotation of earth has on ocean currents. Why is the direction of the surface current in any particular area parallel to the isobars there?

3) What are the differences between a drifts and stream current? Mention a good example of each. Name the prominent currents of South Pacific Ocean? (3 times)

4) Explain briefly: (i) Drift Current (ii) Upwelling Current (iii) Gradient Current (6 times)

(OR),

Explain the cause of Gradient Current. (2 times)

(OR),

Briefly explain Gradient Current and Up-welling current. Give suitable examples (4 times)

(OR),

Explain with a suitable example upwelling current and its effect on weather. (3 times)

5)a) Why the surface currents attain higher rates in Western side of oceans as compared to Eastern side of Ocean (2 times)

b) Eastern shore of large Ocean are prone to which currents? Give some examples.

6) Describe how the weather is affected by various currents?

7) Describe the surface current circulation in the **North & South Atlantic Ocean** along with the causes of formation of these currents. (4 times)

(OR),

Describe with suitable sketch the Ocean currents of North Atlantic Ocean. Identify the warm and cold currents. (3 times)

8)a) Explain with reason the flow of surface and under current in strait of Gibraltar. (5 times) : North Atlantic Ocean

b) Explain with sketches, the formation of Benguela Current on the West coast of Africa. (3 times) : South Atlantic Ocean

9.a) Describe with suitable sketch the Ocean currents of **North and South Pacific Ocean**. Also identify the warm and cold currents.

b) Describe the cause of formation of Kuroshio Current in North Pacific Ocean. (2 times)

10.a) Sketch and describe the currents of the **South Indian Ocean.** Also identify the warm and cold currents.

b) Describe the current circulation in **Bay of Bengal** during SW Monsoon and NE Monsoon. (3 times)

c) Give a brief description of the currents in the **Arabian Sea** for January and July. Explain the reasons for the difference during these months? (2 times)

11)a) What are the wind and current a ship will face in its journey from Liverpool to Cape Town? (2 times)

b) Describe the current prevailing in Mediterranean Sea and Black Sea. Give necessary sketches (2 times)

Ques) Discuss about the various names of ocean currents in different ocean areas? (2 times)

Write joint answer from Ques 7,9 & 10

12) Describe the forms of display which are commonly used to depict ocean current (2 times)

(OR),

Describe the various forms of depicting ocean currents on charts.

13) How does the ocean current charts help the mariners?

Waves

1) Explain: (i) Trough (ii) Crest (iii) Wave Length (iv) Wave Height (3 times)

2) Define speed, period, length and significant wave height. What is their relationship? What are the factors governing wave height and direction.

3) Explain methods of estimating wave heights and wave periods. (3 times)

4) Explain the shallow water effects on a wave when it is approaching a coast line.

5) Write short notes on: i) Storm surge ii) tsunami iii) freak waves iv) Refraction of Sea Waves

6) State the causes of Southwest Monsoon in the Arabian Sea. What effect does it have on the general surface current circulation in the Arabian Sea? (2 times)

Q.6) Weather Forecasting/ Weather Routeing

1) Describe various types of Weather Facsimile Charts / Weather related information available to the mariner. How are these charts used for Weather Routeing purposes? What do you understand by Vessel's performance curves and their use? (8 times)

(OR),

What is the different weather information available from the charts received by a facsimile receiver? (2 times)

(OR),

Describe Ship's Performance Curves and their use in ship's weather routeing. (2 times)

2) What is Ship Weather Routeing? Write its objectives. Also write the process of carrying out Weather Routeing. (5 times)

(OR),

Explain the method of Shipboard weather routing with suitable diagrams. (5 times)

(OR),

What are the objectives of Ship Weather Routeing? Describe the method of the shipboard weather routeing taking an appropriate example. (2 times)

(OR),

a) Describe the method of weather routeing using forecast data. b) Describe the information which can be used from routeing charts, sailing directions and Mariner's Handbook for weather routeing. *(Write answer from Q.5)*

3) Enumerate the factors to be taken into consideration for ship's weather routeing? (3 times)

(OR),

Your ship, a bulk carrier, carrying steel cargo is due to sail from Southampton to New York in the month of December. What all are the factors you will consider regarding weather routeing for your passage across the Atlantic Ocean? (3 times)

4) a) What are the advantages of ship's weather routeing?
b) What are the limitations of weather routing? (2 times)

5) Identify the various types of weather routing services available for shipping and describe any one of them. (6 times)

6) Describe optimum routeing. How would you achieve the objective of weather routeing in optimum routeing? (6 times)

7) a) Describe the procedures for climatological routeing. b) Explain the purpose for Maritime Forecast Code and data given by MARFOR. (3 times)

8) State the differences between weather routeing and climatologically routeing. Explain how you will carry out weather routeing on board your vessel. (2 times)

Q.6) a) Describe briefly the importance of weather routing discussing the factors that are taken into consideration for weather routing. (2 times)

Write answer from 5: Factor to be taken into consideration

b) Discuss how weather routing helps in the safe navigation of the vessel.

Write answer from 2: Objective of weather routing

Q.6) Describe optimum routing and explain the methods used on board ship for weather routing. (2 times)

Write answer from 6: Optimum routeing

Write answer from 2: Method for weather routeing

b) Explain the information contained on a Surface Analysis Chart.

Write answer from 1: Surface weather analysis chart

9) List the information given in Shipping Forecast issued for coastal areas. (2 times)

(OR),

Explain the contents of coastal weather bulletin issued by Indian Meteorological Department

10) a) List the information given in Synoptic Weather Chart. What information can a mariner obtain from it? How would you find the pressure gradient from it? (4 times)

b) List out various information given in weather fax charts and wave charts? (2 times)

c) Write down the information given in a weather routeing chart

11) Describe various methods/ sources of information inputs for making of analytical weather for synoptic hour.

12) How is weather forecasting carried out? Show by an example how you would make a short time weather forecast. Use a simple weather map of a frontal depression locating your vessel in the warm sector in the Northern Hemishere

13) Describe Significant wave height and fetch. (5 times)

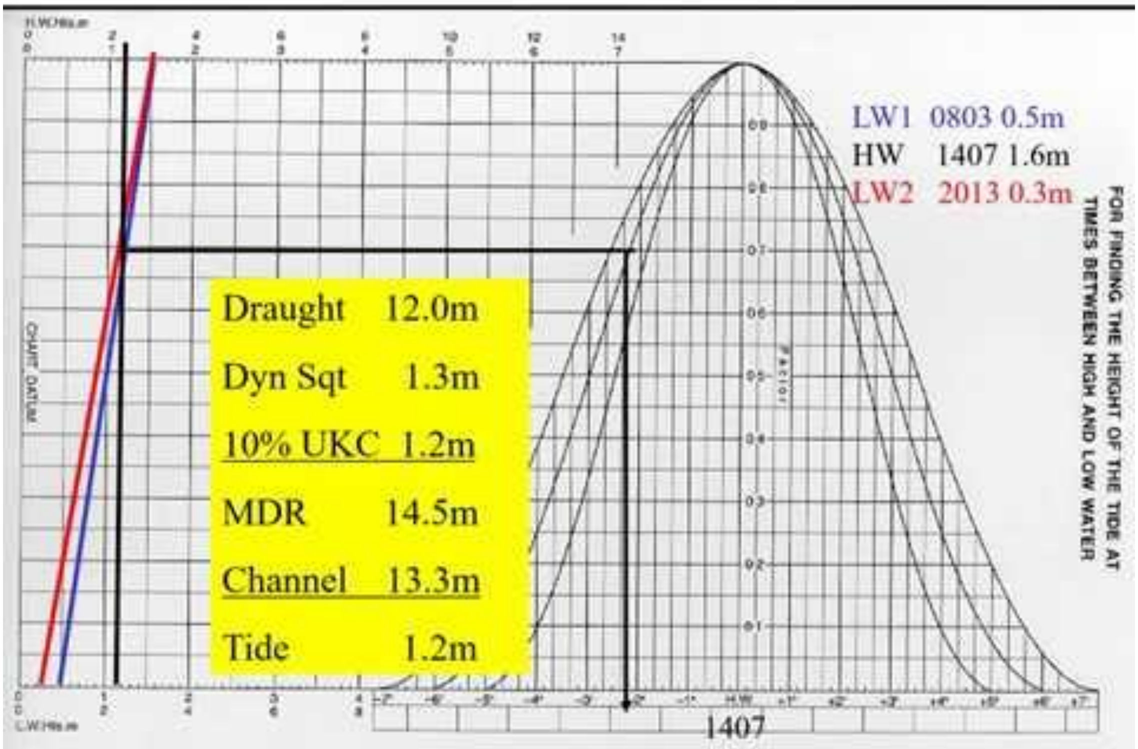
(OR),

Describe significant wave height and the factors that influence the height of wave. (4 times)

14) a) Explain: i) Wave Chart ii) MAFOR Chart iii) Significant wave height b) Explain wind rose chart. (5 times)

Q.1 Tide calculations for Standard Port and Secondary Port (including shorter method of harmonic method)

(Page No 14 to 25)



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for smart sailors

FUNCTION-1

PAPER: METEOROLOGY

18/03/2025

Q.1 TIDE CALC^n FOR STANDARD & SECONDARY PORT

CAPT. S. BANARJEE

* Condition to calculate Tide by SHM

→ For certain ports in vol. 2 & 3, If duration of rise of tide & fall of tide doesn't lie b/w 5 hours or 7 hours we have to calculate H.O.T by SHM method.

Example: If we need to calculate H.O.T of Bhaunagar on 09 Feb, 1992 at 1200 hrs, the duration of fall of tide is 07h 29m, we can not use graph.

→ For certain secondary ports, if P is mentioned under the time difference, we can not calculate the time for those secondary port. Hence, we need to calculate H.O.T using S.H.M method.

Example: Port - Cabosan Antonio (P-306 of vol.2)

→ For certain secondary port, if C is mentioned in last column, for intermediate height we need to calculate using S.H.M method.

Example: Port - Littlehampton (P-304 of vol. 2)

→ If in a question, it is mentioned S.W corr^n are applicable for that port. Then, we have to calculate using S.H.M method.

* Way to solve problems * First collect information in this order

1) Line 11
2) Line 28
3) Line 35
4) Line 38

} Tide table Part 3

5) Line 4 - A1 : on same day
6) Line 5 A2 : on next day

} Take value of A (Table VII)

7) Line 13 - F2 : on next day
8) Line 14 - F1 : on same day

} Take value of F (Table VII)

9) Line 6 - (4) - (5)

10) Line 8 : M_2 & S_2 should be more than 600
K_1 & O_1 should be more than 300

11) Line 7 : 360.n
n to be selected by own to complied with line 8 requirement

LINE 10 = LINE 4

LINE 12 = (10) + (11)

18/03/2025

12) Line 9 : p/24 i.e line 8/24

(OR)

we can take

M_2 - 29

S_2 - 30 taken from ATT (XXvii)

K_1 - 15

S_1 - 13.9

13) 31 K_1 to be written in 300$_1$

FOR 32 : $32 M_2 = 30 M_2 + 30 S_2$

$32 S_2 = 31 M_2 + 31 S_2$

$32\, O_1 = 32 S_2$

FOR 33 : $33 M_2 = 30 O_1 + 31 O_1 + 32 O_1$

① $R \sin r = x$ $R \cos r = y$

$R = \frac{x}{\sin r}$ $R = \frac{y}{\cos r}$

② $\frac{R \sin r}{R \cos r} = \frac{x}{y}$

③ $\tan r = \frac{x}{y}$

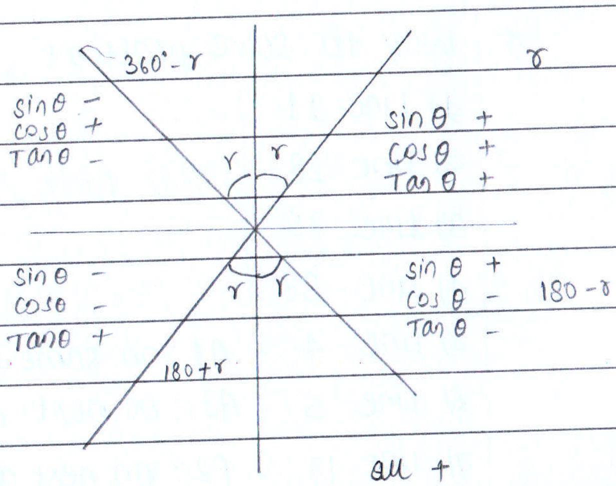
④ $r = \tan^{-1}\left(\frac{x}{y}\right)$

⑤ $r = \tan^{-1}\left(\frac{R \sin r}{R \cos r}\right)$

⑥ $r = \tan^{-1}\left(\frac{32 M_2}{32 S_2}\right)$

$r = 15.6$ (2nd Quad)

$= 164$



all +

sin +

Tan +

cos +

⑦ R → $R \sin r = 0.378$

$R = \frac{0.378}{\sin 164}$

FOR 36 : − 360° if value comes more than 360°

* Explanation ATT squence number wise

Line 4 : A1 - on same day } Take value of A (Table VII)
Line 5 : A2 - on next day }

Line 6 : A1 - A2 ⇒ (4) - (5)

Line 7 : 360·n

n to be selected by own (1 or 2). It is necessary to make M_2 & S_2 more than 600 & K_1 & O_1 more than 300

Line 8 : (A1 + A2) + 360·n = p
⇒ (6) + (7) = p

Line 9 : p/24 ⇒ (8)/24

Line 10 : A1 ⇒ Line (4)

Line 11 : g ⇒ g° (Tide table Part III)

Line 12 : A1 + g ⇒ (10) + (11)

Line 13 : F2 - on next day } Take value of F (Table VII)
Line 14 : F1 - on same day }

Line 15 : F2 - F1 = P
⇒ (13) - (14) = P

Line 16 : P/24 ⇒ (15)/24

Line 17 : Time = T (Time at which we need to find HOT)

Line 18 : p/24 ⇒ Line (9)

Line 19 : p/24 × T ⇒ (18) × (17)

Line 20 : A1 + g ⇒ (12)

Line 21 : (A1 + g) - p·T/24 = θ
⇒ (12)/(20) - (19) = θ

Line 22 : sin θ

Line 23 : cos θ

Line 24 : P/24 ⇒ Line (16)

Line 25 : P/24 × T ⇒ (16)/(24) × (17)

Line 26 : F1 ⇒ Line (14)

Line 27 : F1 + P·T/24 = Ft
⇒ (14)/(26) + 25 = Ft

Line 28 : H ⇒ H·m (Tide Table Part III)

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Line 29: HXFt ⇒ (28) X (27)

Line 30: (HXFt) sin θ ⇒ (29) X (22)

Note: Compute only for M_2 & S_2

Line 31: (HXFt) cos θ ⇒ (29) X (23)

Note :- Compute for all four, but $31 K_1$ to be written in $30\ O_1$

Line 32: R sin r : R cos r

$32\ M_2 \Rightarrow 30\ M_2 \pm 30 S_2 = R \sin r$

$32\ S_2 \Rightarrow 31\ M_2 \pm 31 S_2 = R \cos r$

Note: compute only for M_2 & S_2

Line 33: r : R

$33\ M_2 \Rightarrow Tan^{-1}\left(\frac{32\ M_2}{32\ S_2}\right) = r$ / $r = Tan^{-1}\left(\frac{R \sin r}{R \cos r}\right)$ also see quadrant

$33\ S_2 \Rightarrow R \sin r = 32 M_2$

$R = \frac{32 M_2}{\sin 33 M_2}$ / $R = \frac{R \sin r}{\sin r}$ $R = \sqrt{32 M_2^2 + 32 S_2^2}$

Note: compute only for M_2 & S_2

Line 34: $2r : R^2$

$34 M_2 \Rightarrow 2 \times 33 M_2 = 2r$

$34\ S_2 = (33 S_2)^2 = R^2$

Line 35: $f_4 : F_4$

f_4, F_4 } Tide table Part III

0 - If no data take value zero

Line 36: $d_4 : D_4$

$d_4 = 2r + f_4$ = $34 M_2 + 35 M_2$ | $D_4 = R^2 \times F_4$ $= 34 S_2 \times 35 S_2$

Note :- Substract by 360°, if value is more than 360°

Line 37: $3r : R^3$

$37\ M_2 \Rightarrow 3r = 3 \times 33 M_2$

$37\ S_2 \Rightarrow R^3 = (33 S_2)^3$

Line 38: $f_6 : F_6$

f_6, F_6 } Tide table Part III

0 - If no data take value zero

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Line 39 : $d_6 : D_6$

$d_6 = 3r + f_6$ | $D_6 = R^3 \times F_6$

$= 37M_2 + 38M_2$ | $= 37S_2 + 38M_2$

Line 36 → : $D_4 \cos d_4$

Line 39 → : $D_6 \cos d_6$

Line 40 : $H.O.T = M.L + \Sigma H.ft \cos\theta + D_4 \cos d_4 + D_6 \cos d_6$

* S.H.M (shorter method)

4	A1 (Tab VII)
11	g (Part III)
19	$p/24 \times T$
21	$(A1+g) - p.T/24 = \theta$
22	$\sin\theta$
23	$\cos\theta$
27	$F1 + P.T/24 = Ft$ (same as F1)
28	H
30	$(H \times Ft) \sin\theta$
31	$(H \times Ft) \cos\theta$
32	$R \sin r : R \cos r$
33	$r : R$ (also see quadrant)
34, 37	$2r : R^2$, $3r : R^3$
35, 38	$f_4 : F_4$, $f_6 : F_6$
36, 39	$d_4 : D_4$, $d_6 : D_6$
36 →	$D_4 \cos d_4$
39 →	$D_6 \cos d_6$
40	H.O.T

(Rows 34, 37 to 36, 39:) substract by 360°, if more than 360°

27/03/2025

Question: Calculate H.O.T by using S.H.M method of Goods Island on 20th Jan, 1992 at 1300 H.R.S L.T

Port	GOOD'S ISLAND
ATT NO.	5820
DATE	20.01.1992
TIME ZONE	−1000

MEAN LEVEL	
Zo	2.18
Seasonal correction	+0.1
Sum = M.L	2.28

		M_2	S_2	K_1	O_1
4	A1 (Tab VII)	358	017	338	043
11	g (Part III)	127	319	201	138
19	$P/24 \times T$ → Time at which we have to find H.O.T	29×13 377	30×13 390	15×13 195	13.9×13 180.7
21	$(A1+g) - P.T/24 = \theta$	108	−54	344	0.3
22	$\sin\theta$	+0.951	−0.809	X	X
23	$\cos\theta$	−0.309	+0.588	+0.961	+0.999
27	$F1 + PT/24 = Ft$ (same as F_1)	1.23	1.02	1.26	1.35
28	H (H.m Part III)	0.50	0.23	0.68	0.42
30	$(H \times Ft)\sin\theta$	+0.585	−0.190	X	X
31	$(H \times Ft)\cos\theta$	−0.190	+0.138	+0.823	+0.566
32	$R\sin r : R\cos r$	$30M_2+30S_2$ +0.395	$31M_2+31S_2$ −0.0052		
33	$r : R$ $r = \tan^{-1}\left(\frac{R\sin r}{R\cos r}\right)$, 2nd Quad = 180° − r	97.5 (180−r)	0.398		
34 & 37	$2r : R^2$, $3r ; R^3$	195	0.158	292.5	0.063
35 & 38	$f_4 : F_4$, $f_6 : F_6$	324	0.061	0	0
36 & 39	$d_4 : D_4$, $d_6 : D_6$	$d_4 = 2r + f_4$ 159	$D_4 = R^2 \times F_4$ 0.009	$d_6 = 3r + f_6$ 292.5	$D_6 = R^3 \times F_6$ 0
36 →	$D_4 \cos d_4$	−0.008			
39 →	$D_6 \cos d_6$	0			

$$H.O.T = M.L + \Sigma H.Ft\cos\theta + D_4\cos d_4 + D_6\cos d_6$$

(3 + 31 + 36→ + 39→)

$$= 2.28 + 1.337 + (-0.008) + 0$$

$$= 3.609\,m$$

$R\sin r = 0.395$

$$R = \frac{0.395}{\sin 97.5} = 0.398$$

18/04/2025

Ques:- Find the height of tide at 1930 hrs for BOOM (ATT. Vol. I #1539c) on 24th Feb 1992.

Soln:-

Remarks	HW	HW ✓	LW	LW ✓
Time at standard port	0720	1944	0131	1357
Time difference for secondary port	+0115	+0116	+0154	+0153
Time at secondary port	0835	2100	0325	1550
Height at standard port	5.6	5.3	0.4	0.2
Seasonal corrn of standard port (-)	(-) 0.0	(-) 0.0	(-) 0.0	(-) 0.0
Uncorrected height at standard port	5.6	5.3	0.4	0.2
Height diff. for secondary port	(-) 0.2	(-) 0.1	(-) 0.2	(-) 0.2
Uncorrected height for secondary port	5.4	5.2	0.2	0.0
Seasonal corrn for secondary port	+ 0.0	(+) 0.0	(+) 0.0	(+) 0.0
Height at secondary port	5.4	5.2	0.2	0.0

Note:-

(i) 1539c Port BOOM is not there in Part-III, that's why we will not use S.H.M

(ii) Standard port for BOOM is ANTWERP

(iii) To calculate H.O.T at 1930hrs, use antwerp graph

H.W

	0000	+0125
	0500	+0110
0720		+0115
	1200	+0125
	1700	+0110
1944		

~~7 hrs = 15 min~~
1 hrs : 15/7
2hr 20min : $\frac{15}{7} \times$ 2h20min = 5 min

$\frac{15}{7} \times$ 2h 44min = 5.86 min = 6 min

L.W

	0000	+0155
0131		+0154
	0600	+0150
	1200	+0155
1357		+0153
	1800	+0150

$\frac{5}{6} \times$ 0131 = 1.26 = 1 min

$\frac{5}{6} \times$ 0157 = 1.625 min = 2 min

5.8	−0.2	0.8	−0.4
5.6	−0.2		
5.3	−0.1		
4.8	0.0	0.3	−0.2

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H.O.T at BOOM on 24th Feb 1992

0325	0.2
0835	5.4
1550	0.0
2100	5.2

H.O.T at 1930 hrs = ?

Use graph :-

1550 0.0
2100 5.2 } Range of tide : 5.2

Spring 5.5
Neap 4.0

1.8cm = 1.5

1 $\frac{1.5}{1.8}$

0.3 $\frac{1.5}{1.8} \times 0.3 = 0.25cm$

so take the 1930 vertical line 0.25cm above of spring curve
↓
From there draw horizontal line upto when it touches the H.W-L.W line
↓
Draw vertical line (up or down)

H.O.T at 1930 hrs is 3.4m

18/04/2025

Ques:- July 24

Find the height of Tide at Bhavnagar (#4346) on 9^{th} Feb 1992 @ 1200hrs by Harmonic constant method.

Port	Bhavnagar
ATT NO.	4346
Date	09^{th} Feb, 1992
Time zone	−0530

	Mean level	
1	Z0 (Part-III or Table VI)	6.04
2	Seasonal correction	−0.1
3	M.L	5.94

Note :- in column Z0 given ω, that means see Table VI

Step 1 : Check the new or full moon nearest to 9^{th} Feb i.e. on 3^{rd} Feb

Step 2 : See value of x from Table VI i.e. x = 2

That mean spring tide will take place on Full moon + x

3^{rd} feb + 2 = 5^{th} Feb

Step 3 : We are calculating tide for 9^{th} Feb i.e. 4 days after spring tide

Check on 4^{th} day column against Port No. i.e. value of Z0

Time: 1200hrs

	No.	H.C	M_2	S_2	K_1	O_1	
	4	A1 (Tab VII)	118	014	327	178	
	11	g (Part III)	143	190	092	075	
	19	p/24 × T	29.0×12 348	30×12 360	15.0×12 180	13.9×12 166.8	
	21	(A1+g) − p.T/24 = θ	−87	−156	239	86.2	
	22	sin θ	−0.999	−0.407	X	X	
	23	cos θ	0.052	−0.914	−0.515	0.066	
	27	Ft (F1)	0.90	1.20	1.01	0.97	
	28	H	3.14	0.96	0.76	0.34	
	30	(H×Ft) sin θ	−2.823	−0.469	X	X	
	31	(H×Ft) cos θ	0.147	−1.053	−0.395	0.022	−1.279
	32	R sin r : R cos r	30 M2 + 30 S2 −3.292	31 M2 + 31 S2 −0.906	−	−	
sin θ − } 3rd quad cos θ − } 180+r	33	r : R (also see quadrant)	r = Tan⁻¹(R sin r / R cos r) 254.6 (180+74.6)	3.414			
−360°	34 & 37	2r : R² & 3r : R³	149.2	11.655	43.8	39.792	
	35 & 38	f4 : F4 & f6 : F6	265	0.032	133	0.003	
−360°	36 & 39	d4 : D4 & d6 : D6	2r + f4 54.2	R² × F4 0.373	3r + f6 176.8	R³ × F6 0.119	
	36 →	D4 cos d4	0.218				
	39 →	D6 cos d6	−0.118				

R sin r = −3.292

R = −3.292 / ⎯⎯ = 3.414

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$$H.O.T = M.L + \Sigma H.ft \cos\theta + D_4 \cos d_4 + D_6 \cos d_6$$
$$= 5.94 + (-1.279) + 0.218 + (-0.118)$$
$$= 4.761 m$$

Ques:- July 2022

Find out the earliest time on AM 25th March 1992, so that a ship of maximum draft 6.5 mtr can sail out, keeping an UKC of 1.5 mtr, while passing over shoal (depth marked 4.2m on chart) at West Port (#2905)

Soln:-

Draft : 6.5 mtr.
Minm UKC : 1.5 mtr
Depth required : 8.0 mtr.
Lowest depth : 4.2 mtr
H.O.T req : 3.8 mtr.

By secondary port, calcn time & height at West Port
↓
By using graph, find out earliest time on AM when H.O.T is 3.8 mtr.

Ques:- Dec 2020

A vessel is scheduled to pass under high tension cables in OOSTENDE (ATTI NO. 1564) at 1200 hrs on 4th Feb 1992. The charted depth under the cable is 6.20m and their height above MHWS is shown as 20.40m.

The vessel's draft is expected to be 8.5m even keel and the highest point of ship is 28.5 cm above the keel. Determine her UKC and overhead clearance

Soln:- H.O.T at 1200 hrs on 4th Feb 1992 : 3.373 m (calcn by SHM method)

For U.K.C :-	For overhead clearance :-
C.D : 6.20m	Actual height of cable = Charted height + MHWS − HOT
H.O.T : 3.373m	= 20.40 + 6.1 − 3.373
9.573m	= 23.127 m
Draft : 8.5m	Airdraft of vessel = 28.5 − 8.5
UKC : 1.073m	= 20m
	Clearance below cable = 23.127 − 20
	= 3.127m

25/04/2025

Ques: Dec 2020 at 1230 hours on 20th Feb 1992

H.C	M_2	S_2	K_1	O_1
A1	044	011	308	118
g	034	088	005	178
p.T/24	29×12.5 = 2.5	30×12.5 = 15	15.0×12.5 = 187.5	13.9×12.5 = 173.75
(A1+g) − p.T/24 = θ	75.5	84	125.5	122.25
sin θ	0.968	0.995		
cos θ	0.250	0.105	−0.581	−0.534
Ft = Fl	1.21	1.27	0.89	1.26
H	1.80	0.53	0.06	0.08
(H×Ft) sin θ	2.108	0.670		
(H×Ft) cos θ	0.545	0.071	−0.031	−0.054
R sin r : R cos r	2.778	0.616		
r : R (see quadrant)	77.497	2.845		
2r : R^2 & 3r : R^3	154.994	8.094	232.491	23.028
f4 : F4 & f6 : F6	327	0.036	279	0.013
d4 : D4 & d6 : D6	121.994	0.291	151.491	0.299
D4 cos d4	−0.154			
D6 cos d6	−0.263			

0.531

Port	OOSTENDE
ATT NO.	1564
Date	20 Feb, 1992
Time zone	

Mean level	
Z0	2.69
Seasonal correction	−0.1
M.L	2.59

$H.O.T = M.L + \Sigma H.Ft \cos\theta + D4 \cos d4 + D6 \cos d6$

$= 2.59 + 0.531 - 0.154 - 0.263$

$= 2.704\,m$

For UKC:

C.D: 6.20m
H.O.T: 2.704m
8.904m
Draft: 8.5m
UKC: 0.404m

For overhead clearance:

Actual height of cable = charted height + MHWS − HOT
= 20.40 + 5.0 − 2.804 = 22.596m

Air draft of vessel = 28.5 − 8.5 = 20.0m

Clearence below cable = 22.596 − 20
= 2.596m

JAN 2025
OCT 2023
JUNE 2022

Calculate by simple Harmonic short method, the height of tide at Port Adelaide (Outer Harbour) on 20th Feb 1992 at 0930 L.T / 0000 HRS G.M.T

PORT	ADELAIDE (OUTER HARBOUR)	MEAN LEVEL	
ATT NO.	6160	Z_0	1.59
DATE	20 Feb, 1992	Seasonal correction	-0.033
TIME	0930 L.T	M.L	1.557

H.C	M_2	S_2	K_1	O_1
A_1	044	011	308	118
g	105	176	050	024
p.T/24	29 x 9.5 = 275.5	30 x 9.5 = 285	15 x 9.5 = 142.5	13.9 x 9.5 = 132.05
$(A_1+g) - p.T/24 = \theta$	-126.5	-98	215.5	9.95
$\sin\theta$	-0.804	-0.990	X	X
$\cos\theta$	-0.595	-0.139	-0.814	0.985
$F_t = F_1$	1.21	1.27	0.89	1.26
H	0.50	0.49	0.25	0.16
$(H \times F_t)\sin\theta$	-0.486	-0.616	X	X
$(H \times F_t)\cos\theta$	-0.360	-0.086	-0.181	0.199
$R\sin\gamma : R\cos\gamma$	-1.102	-0.446		
$\gamma : R$ (also see quadrant)	67.966 + 180 = 247.966	1.189		
$2\gamma : R^2$ & $3\gamma : R^3$	135.932	1.414	23.898	1.681
$f_4 : F_4$ & $f_6 : F_6$	0	0	0	0
$d_4 : D_4$ & $d_6 : D_6$	135.932	0	23.898	0
$D_4 \cos d_4$	0			
$D_6 \cos d_6$	0			

$$H.O.T = \Sigma H.Ft \cos\theta + M.L + D_4 \cos d_4 + D_6 \cos d_6$$

$$= 1.557 + (-0.428) + 0 + 0$$

$$= 1.129\,m$$

Q.2 Tropical Revolving Storm (TRS)

(Page No 27 to 48)

Notes by: Anupam Singh Rajput

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01/05/2025

Q.2. Tropical Revolving Storm (TRS)

Ques 1) State the conditions favourable for the formation of a Tropical Revolving Storm (19 times) (OR), State the factor affecting movement of TRS? (4-times)

Ans:- The conditions favourable for the formation of TRS are as follows:-

(i) Warm sea surface temperature

- The sea surface temperature must be 27°C or more
- When sea surface temperature is above 27°C, the water evaporates rapidly.
- As it rises and cools, water vapour condenses into cloud and rain.
- This condensation process releases latent heat which caused more air to rise.
- This further lowers the surface pressure, intensifying the storm.

(ii) Fair amount of Coriolis Force

- For the formation of TRS, the circulation is required
- Hence, the formation can take place, where Coriolis force is available.
- That is why, within a belt of 5 degree latitude of both sides of equator no cyclone forms.
- Usually forms/develop at latitude between 5° and 20° of both sides.

(iii) Low pressure area surrounded by areas of High pressure area

- In low pressure, the air is rising upward.
- As air rises, it create space near the surfaces.
- Air always moves from high pressure to low pressure.
- So, surrounding high pressure area push air towards the low-pressure center.
- Due to the Earth's rotation (coriolis force), the moving air starts spinning which is the favourable condition for the formation of TRS.

(iv) Pre-existing near surface disturbance.

- A weather disturbance like a tropical wave or low pressure system is necessary to kickstart the development.
- It is like a spark that is required to start a fire.

(V) Weak prevailing winds

- If the prevailing wind are strong, the air would not rise vertically.
- It would be carried off horizontally, thereby not allowing a TRS to form.
- It happens during change of season in mid April - mid June & from Oct to Dec.

(vi) High humidity
- A TRS needs lots of moisture in the air, this is called humidity.
- The more moisture there is, the more heat gets released.
- This makes the air lighter and rise faster, which makes the storm stronger.

Ques 2) What are the warning signs of an approaching Tropical Revolving storm and the weather associated with it. (12-times)

(OR),

What type of weather is associated with 'EYE' and 'EYE WALL' of a TRS.

Ans:- The warning signs of an approaching TRS are as follows:-

(i) Swell
- Swell are the waves generated by a distant TRS.
- They have a long wave length and appear in a quick succession.
- From the eye-wall region, they emerge radially in all directions and reach the coast hundreds of miles away.

(ii) Rapid fall in atmospheric pressure.
- This is one of the earliest signs
- The atmospheric pressure falls steadily.
- A sudden and continuos drop in barometric pressure indicates, there is a TRS in the vicinity.

(iii) Clouds
- Cirrus clouds moving outward from the storm center.
- Thickening of clouds from cirrus to altostratus to nimbostratus.
- These clouds brings heavy continuos rain with squally gale force wind.

(iv) Change in sea temperature & Humidity.
- Sea surface temperature increases.
- Humidity becomes very high.
- Air becomes heavier.

(v) Weather Reports and warning.
- Storm warning bulletins issued by Meteorological department for good guidance for mariners.
- Pay attention to any mention of low pressure areas developing into depressions.

01/05/2025

The weather associated with Eye and Eye wall of a TRS are as follows:-

WEATHER FACTOR	EYE	EYE WALL
Atmospheric Pressure	• The lowest atmospheric pressure in a TRS occurs in the eye	• Extremely low and rapidly falling as you approach the eye wall
	• 15 to 20 Hpa fall of pressure is expected	• Pressure gradient is high
	• In extreme cases, center pressure is as low as 920 Hpa.	• Barometer reading can drop below 950 hpa in strong cyclones.
Clouds	• Sky may be partly or fully clear, in well-developed storms.	• Towering anvil shape cumulonimbus clouds gives torrential rain
	• Directly above eye, a small circular patch of blue sky may be seen.	• Nimbostratus cloud will give heavy continuous rain.
	• Eye is surrounded by towering cumulonimbus cloud, forming a stadium appearance, if viewed from inside	• Cloud base is low. It may extend nearly to sea level due to moisture content.
Winds	• Light winds or complete calm.	• Strongest wind of the entire storm.
	• Often less than 10 knots.	• Can go upto 100-140 knots
		• Wind is cyclonic (anticlockwise in NH & clockwise in SH)
		• Wind is gusty, shifting and cause extreme structural & sea impact
Temperature	Slight increase of temperature due to adiabatic heating of subsiding air.	Comparatively lesser temperature due to rain.
Visiblity	Generally good visiblity.	Under the nimbostratus clouds, visiblity becomes poor due to rain.

Ques 3) With respect to a TRS, explain:

(i) Tropical depression

Ans:- • A tropical depression is the initial organized low-pressure system that can intensify into a tropical storm, Cyclone or Hurricane depending on ocean and atmospheric condition.

• It is the first stage in the development of a potential tropical storm.

• The maximum sustained wind within a tropical depression are 34 knots or less.

- The atmospheric pressure is mildly low, usually 1000-1007 hpa.
- Moderate to heavy rainfall.
- Moderate to high swell.

(ii) Track

Ans:- The area over which storm area has already passed.
- It is the horizontal movement of the storm's center over time.
- It is influenced by atmospheric circulation, coriolis effect and steering wind

(iii) Path

Ans: It is the movement pattern of the storm as it travels across the ocean or over land.
- It is the direction in which storm is moving.
- It is influenced by wind system, coriolis force and pressure system.

(iv) Trough

Ans:- Trough is a long, narrow area of relatively low atmospheric pressure (extending from a central low-pressure region.)
- It is a dashed or solid line shown on weather chart which represents a depression.
- Troughs are associated with weather system like fronts and clouds.
- They can bring cloud, rain, thundershowers & changes in wind direction.

(v) Vertex

Ans:- It is the westernmost point reached by the storm center before recurring.
- It is the furthest westerly longitude the storm center will travel during its trajectory.
- The term "vertex" should not be confused with vortex which refers to center calm area of the storm.

* Vortex or eye

It is the center calm of the storm

05/06/2025

* Right Hand semicircle (RHSC)

Ans:- The half of the storm center that lies to the right hand side of the observer who faces along the path of the storm.

* Left Hand semicircle (LHSC)

Ans:- The half of the storm center that lies to the left hand side of the observer who faces along the path of the storm.

(vi) Dangerous Semi-Circle

Ans:- Right Hand semi-Circle (RHSC) in Northern Hemisphere and Left Hand semi-circle (LHSC) in southern Hemisphere is Dangerous semi-circle.

(vii) Navigable Semi-Circle

Ans:- Left Hand semi-Circle (LHSC) in Northern Hemisphere and Right Hand semi-circle (RHSC) in Southern Hemisphere is Navigable semi-circle.

(viii) Dangerous Quadrant

Ans:
- The advance quadrant of RHSC in NH & LHSC in SH is dangerous quadrant.
- When existence of the TRS in the vicinity has been confirmed, evasive action has to be taken to keep the vessel out of this quadrant.

(ix) Navigable quadrant

Ans:- The advance quadrant of LHSC in NH & RHSC in SH is navigable quadrant.

(x) Vertical wind shear

Ans:-
- It refers to change in wind speed or direction with the height in atmosphere.
- It means winds at different altitudes are blowing at different speed or in different directions.
- High wind shear disorganize the convection and weakens or destroy the storm.

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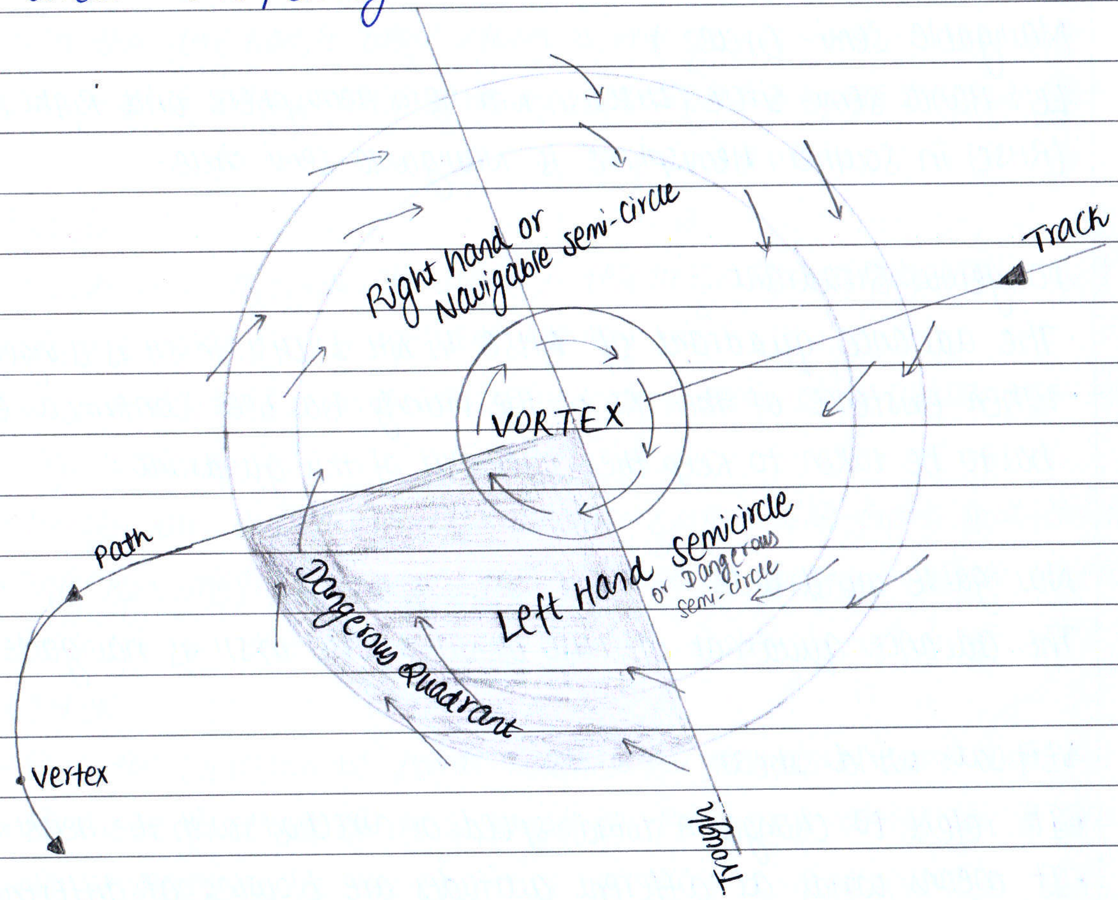
(xi) Characteristic Path

Ans:-
- It is the predicted or average path that a TRS usually follows based on regional climatology.
- It is based on typical storm behaviour in a region.
- It help forecast the likely movement of the TRS.

(xii) Alternate Path.

Ans:-
- It is a secondary, possible deviation in the TRS track that the storm might take due to changing atmospheric condition.
- It represents a variation from the expected/forecast path.
- It helps mariner to prepare for rapid course alteration, if storm changes direction unexpectedly.



Ques 4) What is TRS? With suitable sketch describe its structure, formation, development and decay. (3 times)

(OR),

With suitable diagram, Explain the structure of TRS? (4-times)

(OR),

Draw a cross section of TRS showing areas of clouds and precipitations (2-times)

(OR),

Explain well developed TRS structure with diagram

Ans:-
- A Tropical revolving storm (TRS) is a rapidly-rotating storm characterized by low pressure centre, strong winds and a spiral arrangement of thunderstorms
- These tropical cyclones take birth in the warm oceanic region and move towards the continents.
- TRS tends to move in anti-clockwise in Northern Hemisphere and clockwise in Southern Hemisphere.
- TRS are a great danger to shipping regardless of where they are encountered and require a special study.
- Whenever a vessel is in an area where TRS are likely to be encountered, careful watch should be kept for the warning signs of an approaching TRS and take early evasive action.

Structure of TRS:

(i) Eye or vortex
- Both horizontal and vertical wise, it is the innermost portion of the matured cyclone.
- It is a diameter of 10-30 km.
- This area is calm with little cloud and low rain because the centrifugal force keeps the cloud mass away.
- The temperature inside the eye may be about 5°c higher than the surrounding

(ii) Eye wall or inner ring area
- The diameter is 30-50 km.
- This area has maximum wind speed which can go upto 100-140 knots.
- Terrible thunder, continuos lightning, heavy continuos rain from thick dark

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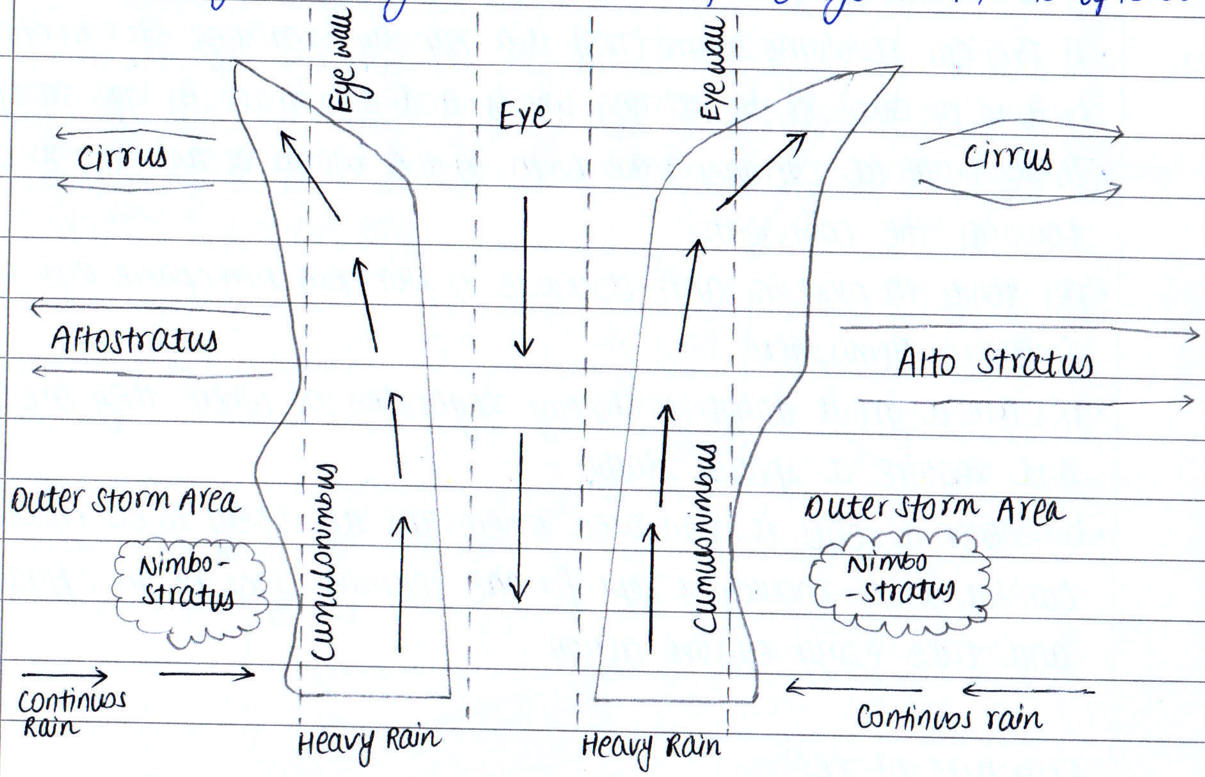
Nimbostratus & Cumulonimbus cloud.
- Voilet wind and squally weather with tidal waves and storm surges

(iii) Outer ring area/ Outer storm area
- The diameter is 50-200 Km
- In this area, strength of wind speed decreases rapidly.
- There will be increase in pressure.
- Intensity of rainfall will decrease.
- Eye and eye wall region is the core of the cyclone. That is upto 50 Km.



Formation of TRS:
- TRS forms in pre-existing near surface disturbed area of ocean.
- The sea surface temperature must be 27°C or more.
- The formation can take place, where coriolis force is available.
- Usually forms/develop at latitude between 5° and 20° of both sides.
- There will be rapid fall of pressure in the central region.
- There will be weak prevailing winds.
- A TRS needs lots of moisture in air, that is High humidity.

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Development of TRS:

Immature stage: The fall of pressure in the central region continues very rapidly. The cloud and rain get organized in a spiral band.

Matured stage: At this stage, fall in pressure and increase in wind speed are stopped. The circulation expand outwards with high wind speed extending more to the right side i.e. Dangerous semi-circle.

Decay of TRS:

The TRS starts decaying due to the:

- Lack of moisture
- When enters the land: Due to the roughness of the land, the frictional drag retards the wind speed.
- The system also decays when it moves over a cold ocean surface where the sea surface temperature is less than 26°c.
- This happens when TRS moves northwards to higher latitudes.

Ques 5) Explain with a suitable sketch the movement of a tropical revolving storm in the Northern and Southern Hemisphere (4 times)

(OR),

Explain with the help of suitable sketches the most probable path of a cyclone in the North and South Hemisphere (2 times)

(OR),

Describe with a neat sketch, typical path of a TRS in Southern Hemisphere. Why does TRS not always follow such a track? (4 times)

Ans:- A Tropical revolving storm (TRS) moves along a curved path due to prevailing wind and coriolis effect.

Northern Hemisphere	Southern Hemisphere
• Originates in latitude between 5 & 20 Deg North	• Originates in latitude between 5 & 20 Deg South.
• Initially travel between Westward and Northwestward, guided by Trade winds at speed of about 12 knots.	• Initially travel between Westward and Southwestward, guided by Trade winds at speed of about 12 knots.

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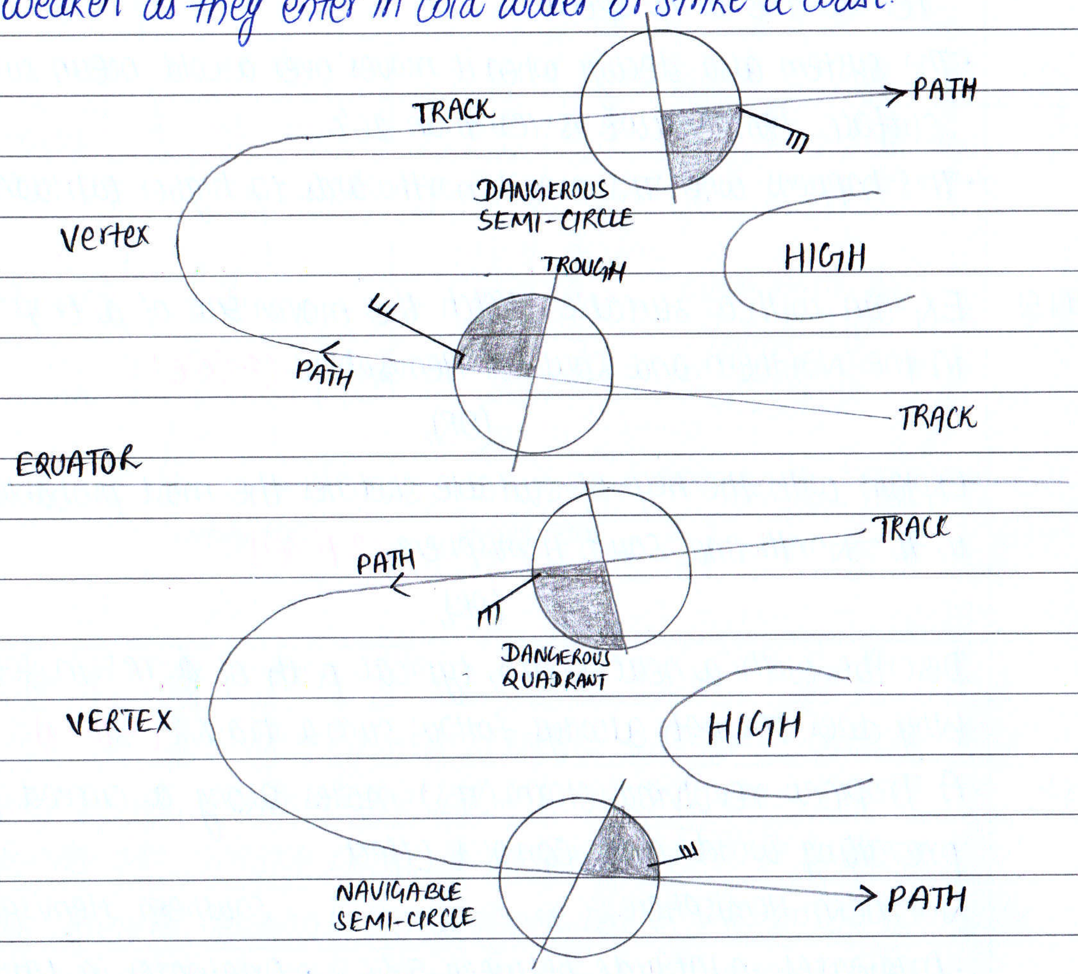
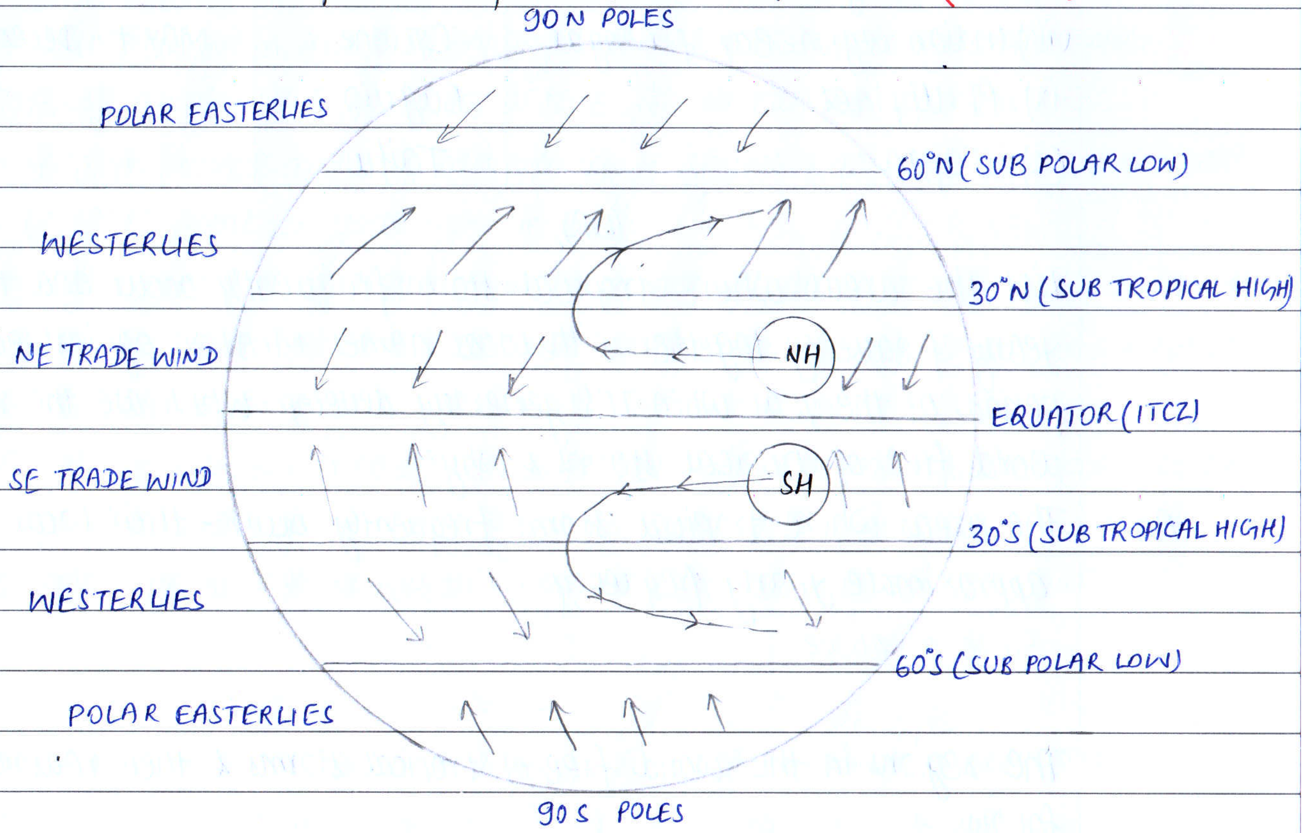
• As it moves poleward, it get influenced by westerlies & they curve away from the Equator	• As it moves poleward, it get influenced by westerlies & they curve away from the Equator.
• It curve to N and then recurve to NE.	• It curve to S and then recurve to SE.

- After recurving, the speed of travel increases to about 15-20 kts.
- Sometimes, a TRS does not curve or recurve at all, but continues on its original path, crosses the coast and dissipates quickly thereafter due to friction and lack of moisture.
- In a day, it can cover a distance of about 300 KM.
- There is a tendency to move in areas of warm water.
- They weaken as they enter in cold water or strike a coast.



Ques 6) Draw the isobaric pattern of a well developed TRS (2 times)

Ans:-



The isobaric pattern associated with a well developed TRS are :-

a) Low pressure is surrounded by high pressure

b) Pressure gradient is very high

c) Isobars are closed shape.

d) Wind speed is very high

e) Wind coverage is low

f) In Northern Hemisphere, the wind direction is anticlockwise and In southern Hemisphere, the wind direction is clockwise

g) Formation of various clouds and which leads to precipitations.

Ques 7) Give the names of the TRS in different parts of the world (3 times)

Ans:-

(i) North Altantic (Western side)	Hurricane	June to November
(ii) North Pacific (Western Side)	Typhoons	June to November
(iii) North Pacific (Eastern Side)	Hurricane	June to November
(iv) South Pacific (Western Side)	Hurricane	December to April
(v) South Indian ocean (Eastern Side)	Willy Willy	December to April
(vi) South Indian ocean (Western Side)	Cyclone	December to April

vii) Indian region- Arabian sea	cyclone	May, October & November
viii) Indian region- Bay of Bengal	Cyclone	May to December
ix) Philippines	Baguio	
(x) Japan	Taifu	

(OR),

List the areas where tropical storm frequently occur and their approximate yearly frequency together with local names. Mention against each area the period of the year when TRS generally develop. Which are the regions in the world free of tropical storms & why?

Ans:- The areas where tropical storm frequently occur - their local names - approximate yearly frequency

Same as above

The regions in the world free of tropical storms & their reasons are as follows:-

(a) Equatorial Region

- 0° to 5° N/S
- Reason: Coriolis force is too weak to initiate cyclone rotation

(b) Polar Region

- Above 60°N & 60°S
- Reason: sea surface temperature are too cold to sustain storm formation

(c) South Atlantic Ocean

Reason: High wind shear
Cooler water
Lack of pre-existing disturbances

(d) South-east Pacific Ocean

Reason: Cold ocean currents
Strong vertical wind shear

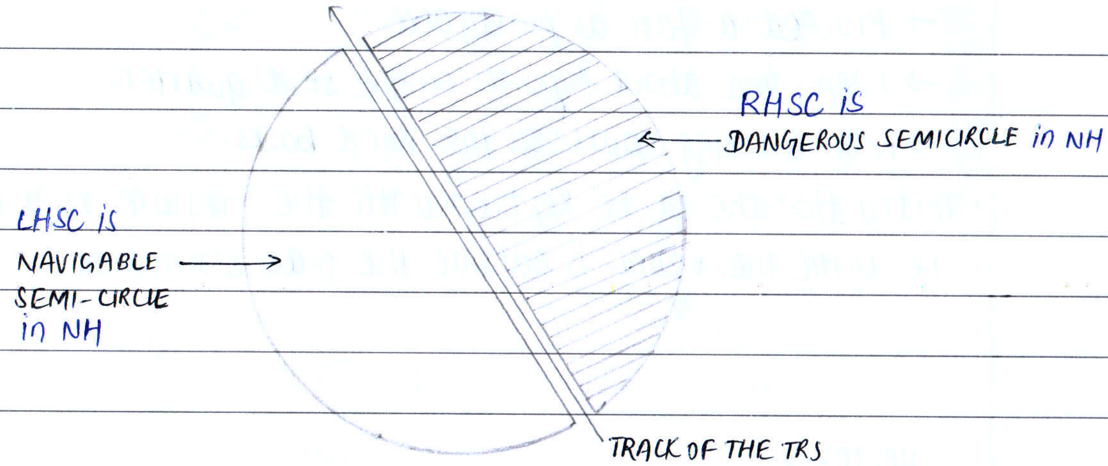
Ques 8) Avoiding actions in NH:

a) With the diagram, explain avoiding action for TRS in Northern Hemisphere (7 times)

Ans:- STEP 1: OBTAIN THE BEARING OF THE STORM CENTRE

- Face the wind, and according to Buys Ballot's law, the storm center will lie 8-12 point on your right in NH.
- If the pressure has fallen 5 mb below normal, allow 12 points as it means that either the vessel is in the outer fringes of a well developed TRS, or a new TRS is forming in vicinity.
- If the pressure has fallen 20 mb or more below normal, allow 8 points as it means that the vessel is near the eye of a well developed TRS.

STEP 2: IDENTIFY IN WHICH SEMI-CIRCLE VESSEL LIES



For a stationary observers, if the wind veers, vessel is in RHSC and, if the wind backs, vessel is in LHSC.

So, we can say, in NH,

If the wind veers, vessel is in Dangerous semi-circle &

If the wind backs, vessel is in Navigable semi-circle.

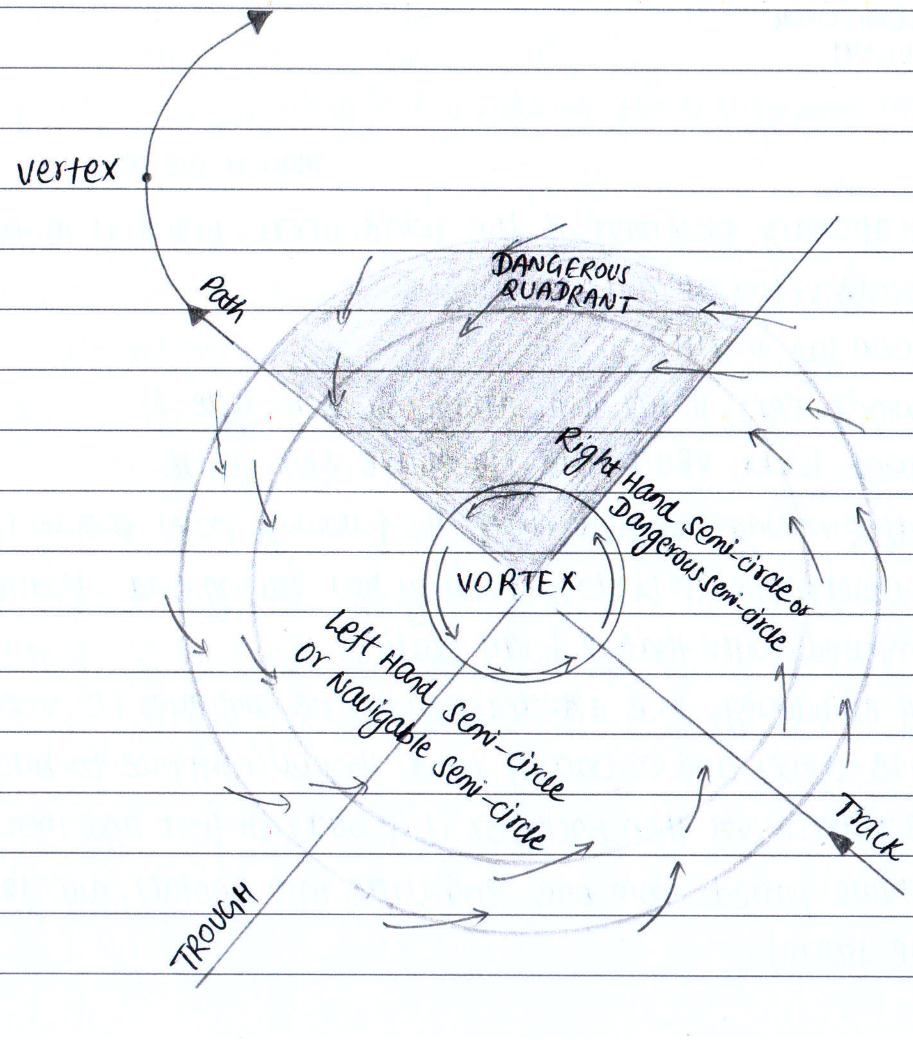
While determining the semi-circle, the following point should be noted:

- Wind observation to be logged every hour during bad weather, and should be compared with that 2 hours earlier.
- Veering or backing, once detected, should be continuos i.e. veering wind should continue to veer and a backing wind should continue to back. (If the wind veers at first and then backs, or if it backs at first and then veers, the vessel must have passed from one semi-circle into another, due to change of path of the storm)

- During the two hour interval, while veering or backing of wind is being decided, the observer must be stationary.
- If a vessel was overtaking a TRS, or, if approaching a stationary TRS from its rear, the wind would veer in LHSC and back in the RHSC.

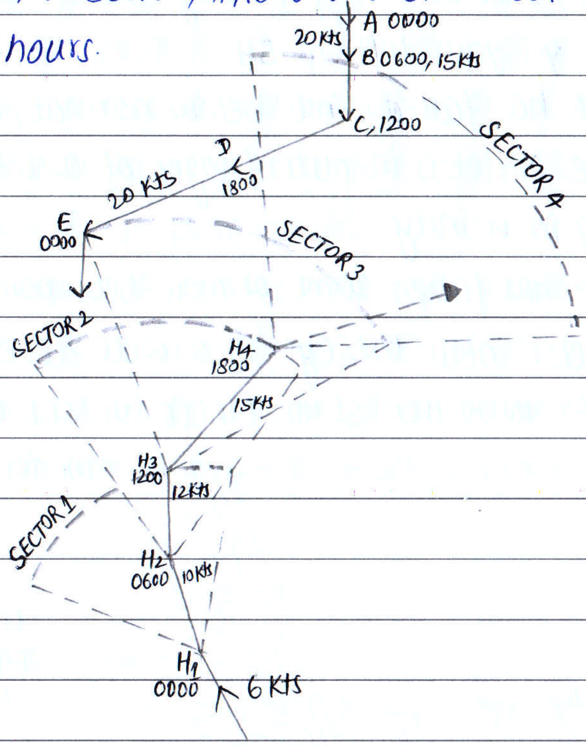
STEP 3: TAKE AVOIDING ACTION

- Any avoiding action should aim to keep the vessel well out of eye/eye-wall.
- If a vessel is in Dangerous semi-circle/Dangerous quadrant (RHSC)
  - → Proceed as fast as practicable
  - → Keep wind 1-4 points on the stbd bow, 1 points for slow vessels.
  - → Keep altering course as the wind veers.
- If a vessel is in Navigable semi-circle/Navigable quadrant (LHSC)
  - → Proceed as fast as practicable
  - → Keep wind about 4 points on the stbd quarter.
  - → Keep altering course as the wind backs.
- This action should be kept up until the pressure rises back to normal i.e. until the vessel is outside the outer storm area.



Ques 8·b) Explain your actions in avoiding a TRS in Northern Hemisphere when it is near the point of re-curvature with the help of safety sector method.

Ans:-
- From the reported position of the center of storm, lay off its track and the distance it is expected to progress in 24 hours.
- From the reported center, lay off two lines 40° on either side of the track.
- With the centre of the storm as the centre & estimated progress in 24hrs as a radius, cut an arc on two lines on either side of the track.
- This will form a sector, into which storm centre is expected to move within the next 24 hours.



Avoiding action (provided if there is sufficient sea room) :-
- Proceed at maximum safe speed to get the ship outside of this sector as early as possible.
- If ship find herself at or near the point of curvature of the storm:
  In such cases all the efforts must be made to avoid crossing ahead of the storm, and to stay clear of the area into which the storm may turn after re-curving.
- In above diagram, at 1200, with ship at C, the storm is reported at H_3, now moving NE
- Sector 3 is drawn. From the plot, it is evident that if ship continues her 'Sly course, she will be in dangerous proximity of storm.
- Therefore, a bold alteration of course is made & speed is increased.

Ques 9) Avoiding actions in SH:

State your actions to avoid getting closer to the eye of TRS if you were in southern Hemisphere (5 times)

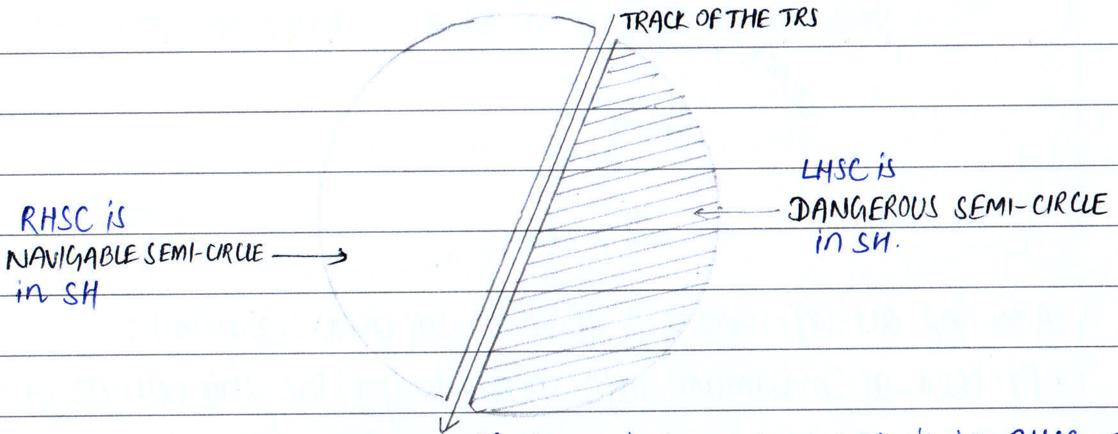
(OR),

Describe the practical rules for avoiding eye of a TRS in the southern Hemisphere. Support your answer with neat sketches (4 times)

Ans:- STEP 1: OBTAIN THE BEARING OF THE STORM CENTRE

- Face the wind, and according to Buys Ballot's law, the storm centre will lie 8-12 point on your left in SH.
- If the pressure has fallen 5mb below normal, allow 12 points as it means that either the vessel is in outerfringes of a well developed TRS, or a new TRS is forming in vicinity.
- If the pressure has fallen 20mb or more below normal, allow 8 points as it means that the vessel is near the eye of a well developed TRS

STEP 2: IDENTIFY IN WHICH SEMI-CIRCLE VESSEL LIES



For a stationary observer, if the wind veers, vessel is in RHSC and if the wind backs, vessel is in LHSC.

So, we can say, in SH,

If the wind veers, vessel is in Navigable semi-circle &

If the wind backs, vessel is in Dangerous semi-circle.

While determining the semi-circle, the following point should be noted:

- Wind observation to be logged every hour during bad weather, and should be compared with that 2 hours earlier.
- Veering & backing, once detected should be continuos i.e. veering wind should continue to veer and a backing wind should continue to back.

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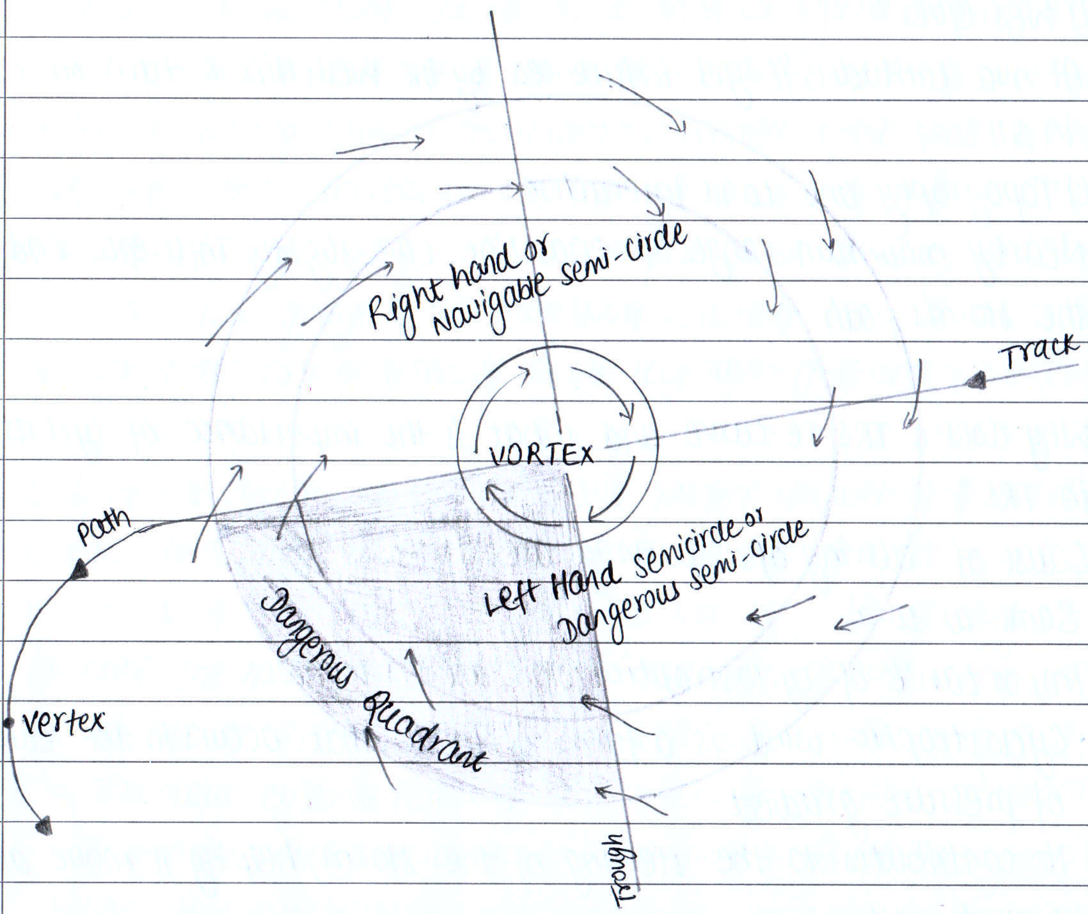
- During the two hour interval, while veering or backing of wind is being decided, the observer must be stationary.
- If a vessel was overtaking a TRS or if approaching a stationary TRS from its rear, the wind would veer in LHSC and back in the RHSC.

STEP 3: TAKE AVOIDING ACTION

- Any avoiding action should aim to keep the vessel out of eye/eye wall.
- If a vessel is in Dangerous semi-circle/Dangerous quadrant (LHSC)
  - → Proceed as fast as practicable
  - → Keep wind 1-4 points on the port bow, 1 points for slow vessels.
  - → Keep altering course as the wind backs.
- If a vessel is in Navigable semi-circle/Navigable quadrant (RHSC)
  - → Proceed as fast as practicable.
  - → Keep wind about 4 points on the port quarter.
  - → Keep altering course as the wind veers.
- This action should be kept up until the pressure rises back to normal i.e. until the vessel is outside the outer storm area.



Ques 10.a) What are the causes for curving and re-curving of TRS? (2-times)

Ans:- • When the TRS reach higher latitudes, they change the direction.

• As it moves poleward, it get influenced by westerlies & they curve away from the Equator.

• In Northern Hemisphere, it curve to N and then recurve to NE, and In Southern Hemisphere, it curve to S and then recurve to SE.

Causes of curving and Re-curving of TRS are as follows:

(a) Coriolis force
As TRS moves away from the Equator, Coriolis force increases, causing it to curve poleward towards higher latitudes

(b) Steering winds
The movement of TRS is guided by trade winds. Changes in these wind leads to curving or re-curving.

(c) Sub-tropical High-Pressure belt
The sub-tropical ridge steers the TRS westward. When the TRS reaches the western edge of the ridge, it curves poleward & eastward - this is re-curvature.

(d) Westerlies.
At mid-latitudes, it get influenced by the westerlies & turn NE in NH & SE in SH.

(e) Topography and Land Interaction.
Nearby mountain ranges or coastline can slightly influence and modify the storm's path.

b) Why does a TRS re-curve and what is the importance of cyclostrophic wind in TRS?

Ans:- Cause of curving & re-curving are:-
Same as 10.a.

Importance of cyclostrophic wind are as follows:

• Cyclostrophic wind is a form of wind that occurs in the curved path of pressure gradient.

• It contributes to the steering of the storm, helping it move along its curved path.

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- The cyclostrophic wind, along with other forces like the coriolis force and pressure gradients, contributes to the overall circulation pattern of the TRS.
- The cyclostrophic wind influences the distribution of moisture, heat, and momentum within the storm.

10.c) Why does the speed of TRS increase after re-curving? (2-times)

Ans:- The speed of a Tropical Revolving storm (TRS) increases after recurving due to the influence of the westerlies.

Explanation:

- TRS curve N'ly in Northern Hemisphere & S'ly in southern Hemisphere
- Then it re-curve NE'ly in Northern Hemisphere & SE'ly in southern Hemisphere.
- The TRS curve & re-curve towards oceanic high situated at around 30 deg North & south of Equator.
- As we know,
  - → there is high at 30°N & low at 60°N.
  - → As wind blow from High to low
  - → Wind blows from 30°N to 60°N is know as westerlies (They are named Westerlies because they are going from West to East)
- After recurving due to the effect of westerlies, the speed of the tropical revolving storm increases.
- As westerlies are going in direction from west to east, and after recurving, TRS are also going in direction North Easterly. which adds to the speed of Tropical Revolving storm.

Ques 11) State the regulation given in SOLAS regarding reporting a TRS & list the information which must be included in such a report (4-times)

(OR),

Describe the message required to be sent as per SOLAS (2-times)

Ans:- SOLAS CHAPTER V, REGULATION 32

2. Tropical cyclones (storms)

Information is to be tramitted whenever the master has good reason to believe that a tropical cyclone is developing or exists in the neighbourhood.

As much as practicable, following information should include in the message:
- A statement that a tropical cyclone has been encountered.
- Time, date (UTC) and position of the ship when observation was taken.
- Corrected barometric pressure (state the unit)
- Barometric tendancy (the change in barometric pressure during the past three hours)
- True wind direction.
- State of the sea
- Swell (slight, moderate, heavy) and true direction from which it comes.
- Period or length of swell (short, average, long)
- True course & speed of ship.

Subsequent observations
- When a master has reported a TRS or other dangerous storm, it is desirable but not obligatory, that further observation be made and transmitted hourly, if practicable, but in any case not more than 3 hours, as long as the ship remains under the influence of storm.
- Wind of Beaufort Force 10 or above for which no storm warning has been recieved, it is to deal with storm other than TRS.
- When such storm is encountered, the message should contain similiar information but excluding the details concerning sea and swell.

Ques 12) Describe the following in respect to Tropical Revolving Storm (TRS):
a) Why ITCZ cannot be termed as an Equitorial Front or Inter-Tropical Front (3 times)

Ans:- The ITCZ is not an equatorial front because it's primarily a zone of convergence where the trade winds of the Northern and Southern Hemisphere meet, whereas, Front is a boundary seperating distint air masses.

Explanation:

ITCZ as a Convergence Zone

The ITCZ is a belt of clouds and rainfall that encircles the globe near the Equator, where the trade wind converge. This convergence is driven by rising air in the equatorial region due to intense solar heating.

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Fronts as Boundaries:

Fronts are boundaries between different air masses with distinct temperature and moisture characteristics. A cold front is a boundary where cold air is displacing warmer air, while a warm front is a boundary where warm air is displacing cooler air.

b) What is the reason for fewer occurrences of T.R.S formation in South Atlantic and eastern part of South Pacific?

Ans:- The reason for fewer occurrences of T.R.S formation in South Atlantic and eastern part of South pacific are as follows:-

(i) Cooler sea surface Temperature

The Benguela current in the Atlantic and the peru current in the Pacific bring cold water equatorward, reducing the warmth needed for TRS formation.

(ii) Strong wind shear

Vertical wind shear (that is change in wind speed and direction with altitude) is consistently strong in these region, disrupting the organised convection and rotation needed for TRS formation.

(iii) Lack of pre-existing disturbance

Pre-existing low pressure system are often necessary for TRS to develop, and these are less common in South Atlantic and eastern South Pacific.

c) Why do TRS usually form on the western extremities of the ocean?

Ans:- The reason why TRS usually form on the Western Extremities of the Ocean are as follows:-

(i) Warmer Sea Surface Temperature

- Western part of tropical ocean (like western Pacific, Western Indian Ocean) usually have higher sea surface temperature due to ocean current & solar heating.
- Warm water provides the latent heat energy required for TRS development.

(ii) Ocean current and Heat accumulation.

- In most ocean, warm equatorial current flow westward, carrying heat towards the western side.
- Like in pacific, North/South Equatorial current push warm water westward.

(iii) High humidity and strong convection

- Warmer water lead to more evaporation, resulting in high humidity and intense convection - essential for cyclone formation.
- This leads to stronger vertical cloud development and storm intensification.

(iv) Lower wind shear

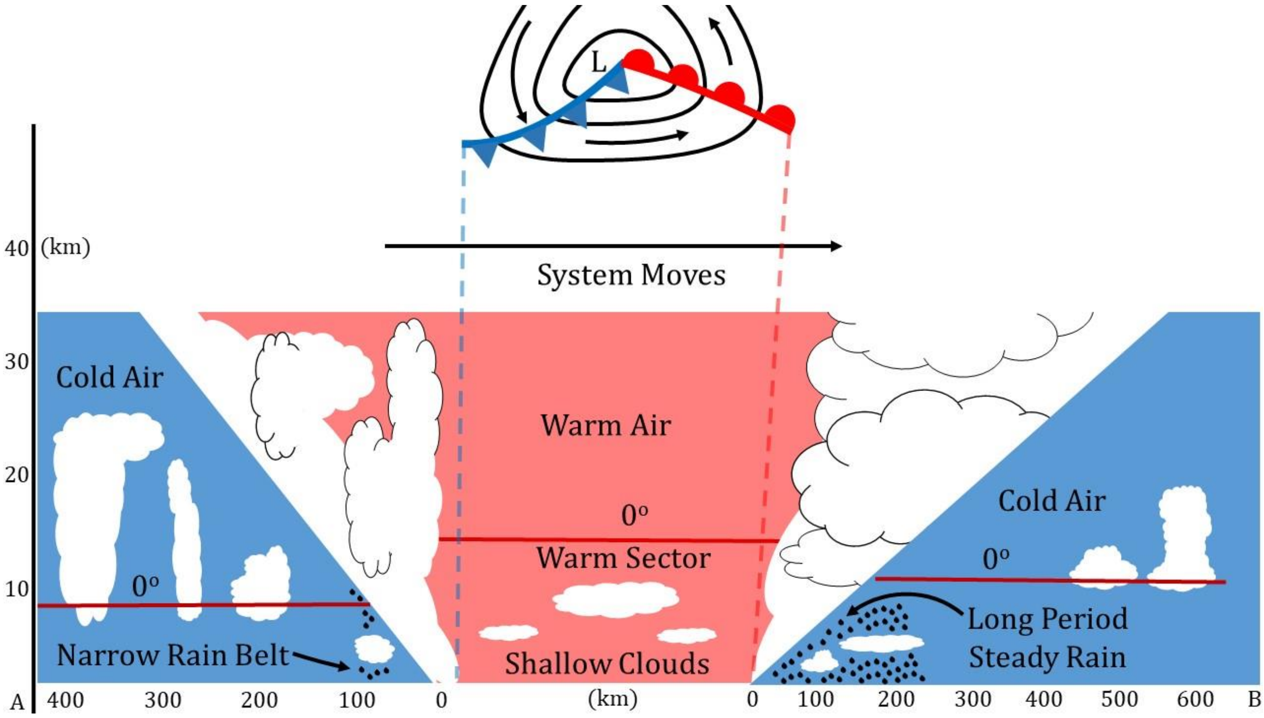
- Western part of ocean often have weaker vertical wind shear, which is essential for TRS to develop and maintain structure.
- High wind shear destroys cyclone organization.

(v) Presence of low-level disturbances

- The ITCZ is usually more active in western tropical oceans.
- This increase the chance of pre-existing low pressure disturbances, which can develop into TRS.

Q.3 Climatology/ Frontal / Non Frontal depressions

(Page No 50 to 91)



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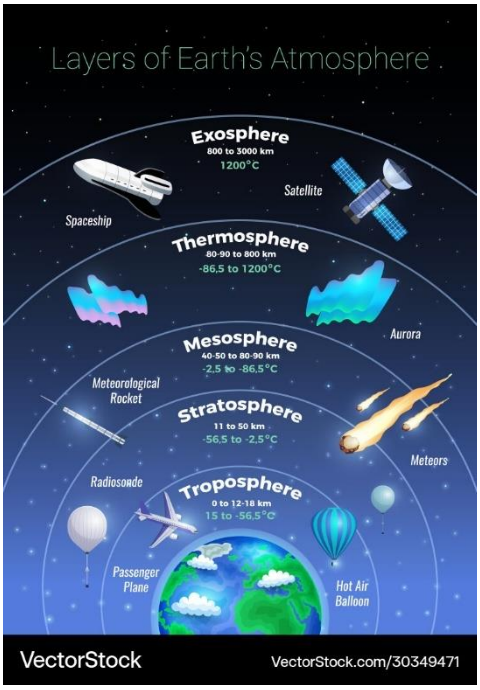
Atmosphere

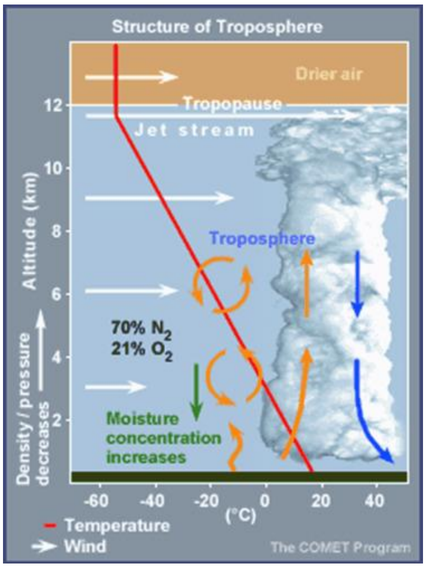
Troposphere :



- It extends from sea level to about 9 km. in the polar region and to about 16 km. in the equatorial region.
- Most of the air mass and water vapour lies in this region.
- **Temperature decreases with height at about 0.6° C / 100m**. (**Lapse rate**). Variations in this value are common.
- Sometimes due to local influences
  - **thin layers are formed in which temperature may remain constant** (**Isothermal layer**), or
  - **through which the temperature may actually increase with height** (**Temperature inversion**).
- Normal weather phenomena, clouds and storms occur in this region.

Composition of gases in Troposphere

- Composition of main gases present in this region, expressed as %age of the total volume, are approximately as follows :

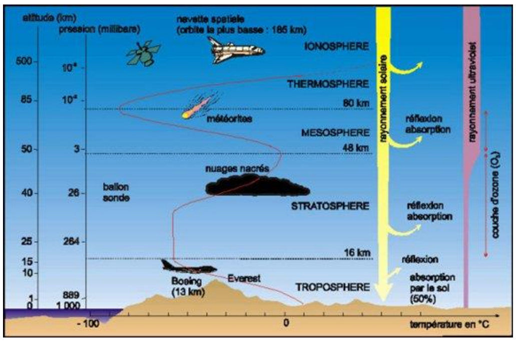


- Nitrogen --- 78.09%
- Oxygen --- 20.95%
- Argon --- 0.93%
- Carbon dioxide --- 0.03%

- It helps in supporting plant and animal life on Earth, but it has very little bearing on meteorological processes and properties.
- In addition to the above composition, the air contains substantial amount of water vapour, which varies considerably depending on the temperature of air and the amount of evaporation and condensation taking place.

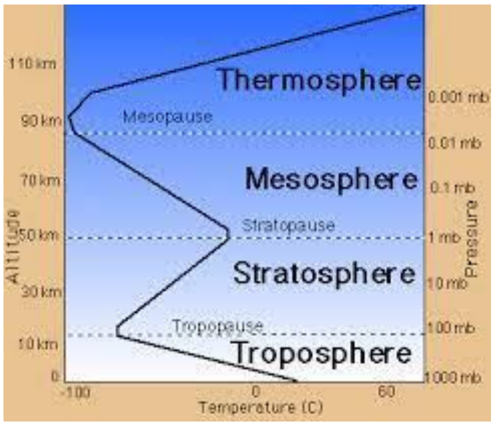
- The amount of water vapour plays a vital role in determining the meteorological processes.

- Density of atmosphere reduces with height, but the rate of decrease is more at lower level as compared to that at higher level.



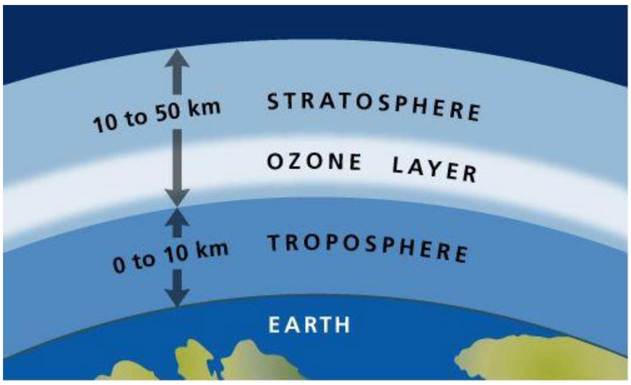
- Nearly half the mass of the atmosphere lies below 5 km. and nearly two-thirds lies below 9 km., with no definite upper limit.
- It has been observed that **meteors entering the atmosphere at a height of 130-160 km. turn white hot due to friction with air**. This shows that air is present well above this limit.

<u>Tropopause</u> :



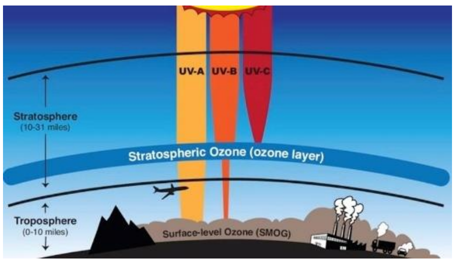
- This is a thin **layer separating the Troposphere from Stratosphere**.
- This is so called because **<u>at this level the fall of temperature with height abruptly stops.</u>**

<u>Stratosphere :</u>



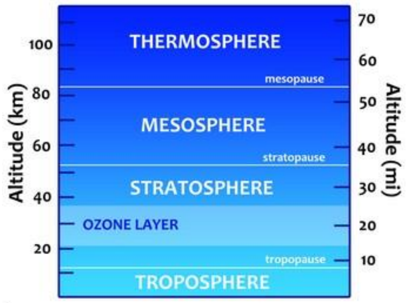
- It extends from **above the Tropopause to about 50 km. above the sea level.**
- The **temperature remains steady with increase in height and even increases slightly with height in the upper part.**

- At **about 20 to 40 km. above sea level there is a thin layer of ozone, which absorbs the ultra-violet radiation of the sunlight and thus prevents damage to all forms of life.**



Stratopause :

➢ This is a region of about 5 km. which **separates the Stratosphere from the Ionosphere above it.**



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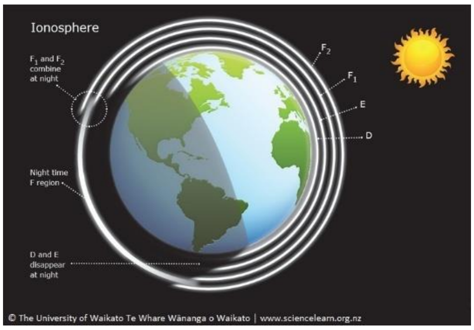
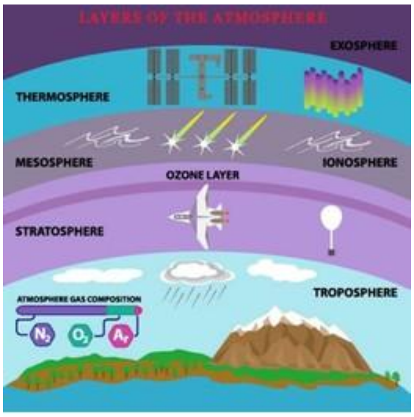
Ionosphere :



➢ It is **sub-divided into Mesosphere or the D-layer**, and

➢ the **Thermosphere or the E & F layers, above the D-layer**.

➢ This is an **electrically conducting region**, which **helps in reflecting the radio signals back to the Earth and thus helps in propagating the signals to very large distances.**



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➢ The **optical phenomenon Aurora occurs within this region**.

Diurnal variation of Temperature

Factors governing the variation of temperature

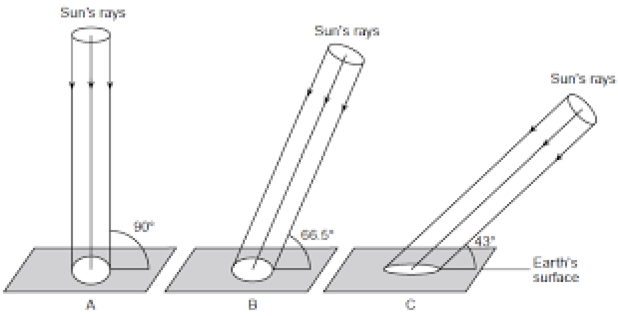
➢ Altitude of the Sun
➢ Length of the Day
➢ High Latitude of the Observer
➢ Cloud Cover & Water Vapour
➢ Dust & Other Pollutants
➢ Ocean Currents
➢ Pressure Distribution

Altitude of Sun :

- **When the Sun is at a low altitude**

➢ the **insolation** (Solar Radiation) arrives at an acute angle to the Earth's surface.

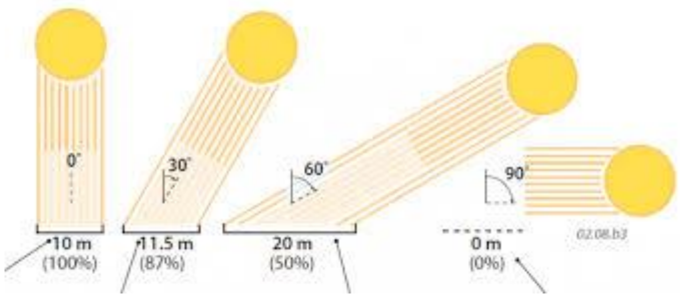
- Much of it is reflected back to space as short wave radiation, without affecting the surrounding air.
- Some of the insolation, which is absorbed by the Earth, is spread over a large surface area.



- Thus, the **temperature of the Earth does not increase much**.

- **<u>When the Sun is at a high altitude</u>**

  - The insolation (Solar Radiation) reaches the Earth **practically at right angles**.



  - Much of it is absorbed and re-radiated later on as long waves, which heat the surrounding air.
  - Also, the **insolation is concentrated over a small surface area** and so the **<u>temperature of the Earth increases</u>**.

<u>Length of day</u> :

- This will determine the amount of insolation received by the Earth's surface and the consequent heating of the air above it.
- The length is based on the declination of the Sun and the latitude of the observer as follows :

- If **both declination and latitude are of same names i.e. both are North or South, then the length of the day is longer than night.**

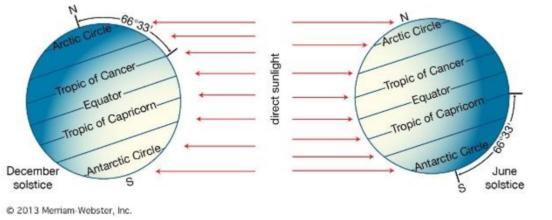
- Furthermore, the length of the day will increase if the values of declination and / or latitude increase.

- If **both are of opposite names i.e. one is North and the other is South, then the length of the day is shorter than night**.

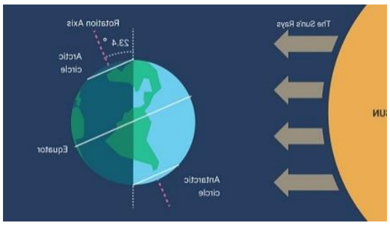
- Furthermore, the length of the day will decrease if the values of declination and / or latitude increase.

High latitude of observer :

- As declination of the Sun is maximum 23.5°, its altitude during the day will always be low for any observer in higher latitudes.



- So, all the insolation will be received at an acute angle.



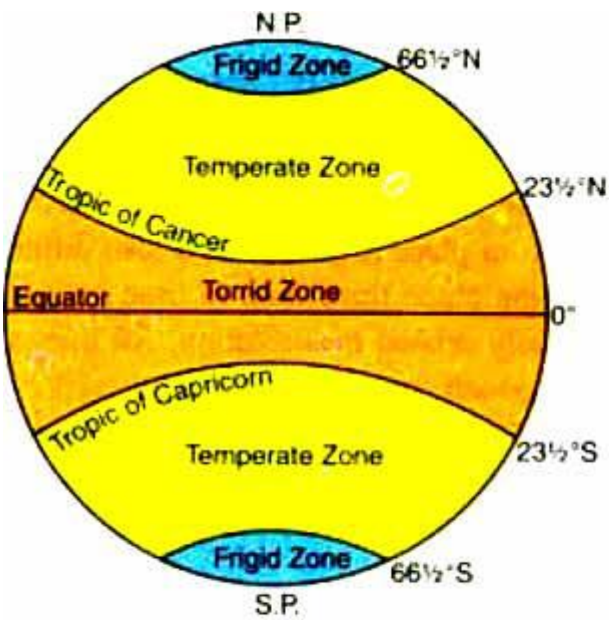
- Hence the heating of the air will be less, as explained above, even though the length of the day may be long.

- **Cloud cover and water vapour** will affect the heating of air as explained in the previous Sub-sub-sub-topic.
- **Dust and other pollutants** will absorb part of the insolation and thus reduce the heating of the Earth's surface and the air above it.
- **Ocean currents** close to the coast will affect the temperature of air in coastal regions.
- **Pressure distribution** and the resulting wind systems will change the air temperature of a region by bringing in warm or cold air mass from the neighbouring regions.

Temperature zones

- Due to the inclination of the Earth's axis the declination of the Sun changes from 23½°N (Tropic of Cancer) to 23½°S (Tropic of Capricorn). Hence during the year maximum heat is received within this region.

- From 23½°N to 66½°N (Arctic circle) and from 23½°S to 66½°S (Antarctic circle) the Sun's rays reach the Earth at an inclination to the surface and hence the amount of heat received is comparatively less.
- The Polar regions above 66½°N and S receive very little sunlight and heat.
- Due to the above reasons the Earth is divided into the following temperature zones :



- **Torrid zone** : From 23½°N to 23½°S.
- **Temperate zone** : From 23½°N to 66½°N and from 23½°S to 66½°S.
- **Frigid zone** : Above 66½°N and S.
- **Lines joining places** having the **same temperature are called <u>Isotherms</u>**.

<u>Diurnal variation of air temperature</u>

- After sunrise the amount of insolation received by the Earth keeps on increasing with the increase in altitude of the Sun, as explained above.
- This continues till noon after which the insolation received by the Earth starts reducing till sunset due to decrease in the Sun's altitude.
- As the temperature of the Earth's surface starts increasing during the day it also starts **re-radiating heat (terrestrial radiation)** and this amount keeps on increasing as the temperature of the Earth's surface keeps increasing.
- Before noon the insolation is much more than the terrestrial radiation. Hence the temperature of the Earth and the air in contact with it keeps increasing.
- Around noon the insolation reaches its maximum value and then it starts reducing but it is still more than the terrestrial radiation and hence the temperature of the Earth and the air in contact with it continues to increase.
- After meridian passage of the Sun the gap between the insolation and terrestrial radiation keeps reducing and around 1400 hr. they become equal.
- Subsequently the terrestrial radiation becomes more than the insolation and so the temperature of the Earth and the air in contact with it starts reducing.

- **Hence the maximum air temperature is experienced at 1400 hr. to 1500 hr.**

- After sunset there is no insolation, however the terrestrial radiation continues during the night, but with a reducing rate, due to reduction in the temperature of the Earth's surface.
- Hence the temperature of the Earth and the air in contact with it continuously reduces during the night.

- **Soon after sunrise** the insolation starts increasing and equals the terrestrial radiation i.e. the **temperature of the Earth and the air in contact with it would have reached its minimum value.**
- After this the air temperature will again start increasing.

- The above analysis is based on clear sky without pollution or water vapour. Presence of these ingredients would considerably alter the above data.

Diurnal variation of range of air temperature over land and sea

- **Over land, variation of temperature** may be **as high as 20°C**
- While **over sea it may be only 1°C**.

The reasons are as follows:

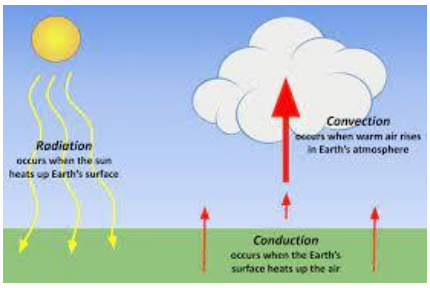
a) Specific heat, b) Conduction, c) Convection, d) Radiation, e) Evaporation

a) Specific Heat

- It is the **amount of heat required to raise the temperature of unit mass of a substance by unit degree.**
- **Specific heat of land is low** as **compared to that of sea**.
- During the day, even though the amount of insolation received by the land and sea are the same, the temperature of land increases considerably more than that of sea.
- Hence **the air above land is hotter than over sea**.
- **During the night** the land re-radiates heat faster than sea. Hence the land and the air above it cools more than sea.

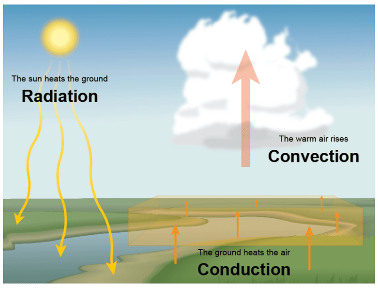
b) <u>**Conduction**</u>

- **Land** is a **poor conductor of heat as compared to sea**.
- The **insolation received by land during the day** remains **concentrated in the upper few centimetres only**,
- While the **same insolation received by sea spreads over a large expanse**.
- Hence **during the day, the temperature of air above land increases faster and more than that over sea.**



- For the same reason **at night, due to terrestrial radiation, the temperature over land falls faster than over sea.**

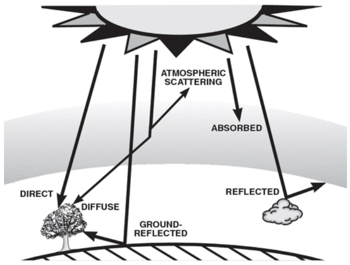
c) **Convection**



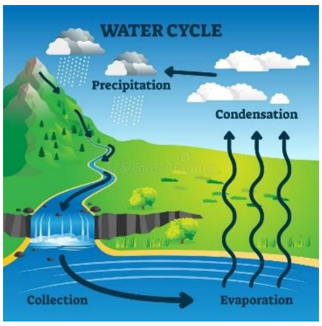
- Convection currents in the sea help to spread the heat to deep waters and the surface remains comparatively cool.
- Hence the air temperature above it also remains less.
- There is no such thing on land.

d) **Radiation**

- Radiation penetrates deep into the sea whereas it cannot go deep into land.
- Hence the land surface can heat the air above it to a higher temperature than sea.



e) **Evaporation**



- Evaporation of water is continuously taking place at sea whereas it is practically negligible on land.
- Latent heat required for it is derived from the sea surface, which helps to cool it and thus reduce the temperature of air above it.

Relative Humidity and Dew Point

Humidity

- **Evaporation** is the escape of water vapour from the surface of water.
- This goes on continuously and it increases with the increase in the temperature of water.
- Considering that three-fourth of the Earth's surface is covered with water, large quantity of water vapour is formed in the lower levels of the atmosphere.
- Quantity of water vapour present in the atmosphere is called **Humidity.**

Absolute Humidity

- Actual mass of water vapour contained in a parcel of air is called **Absolute Humidity (gm./m^3)**

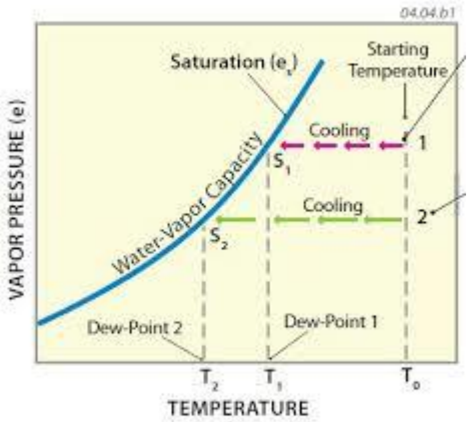
Relative Humidity

- The ratio of the actual amount of water vapour contained in a given mass of air, to the maximum amount of water vapour it can hold at that temperature, is called **Relative Humidity (RH)**.
- It is expressed as %age of the maximum water vapour it can hold.

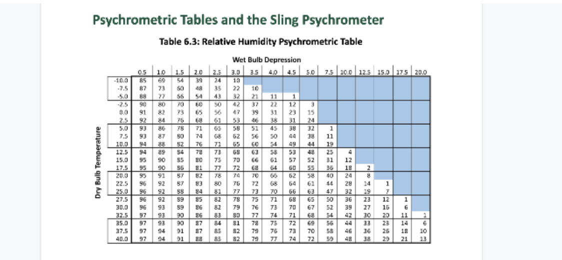
$$RH = \frac{\text{Present quantity of water vapour}}{\text{Maximum quantity of water vapour}} \times 100$$

- Capacity of air to hold water vapour increases with the increase in temperature of air.
- If the temperature of a given mass of air is increased but there is no change in the amount of water vapour in it, then its RH would have decreased.
- **Hence the RH of an air mass is inversely proportional to its temperature.**
- This also implies that diurnal variation of temperature will cause a Diurnal variation of RH.
- When a given mass of air at a given temperature is holding maximum amount of water vapour, then the air is said to be **Saturated** or its **RH is 100%.**

<u>**Dew Point --- Measurement and its significance**</u>



- Consider a mass of air at a certain temperature and having some RH.
- If it is cooled, then gradually it will reach a state of saturation.
- The temperature at which it reaches this state is called **Dew Point** of that mass of air.
- Hence the **Dew point of a given sample of air depends on its initial temperature and RH.**
- Hygrometer or Psychrometer is used to obtain wet and dry bulb thermometer readings.



Psychrometric Tables and the Sling Psychrometer

Table 6.3: Relative Humidity Psychrometric Table

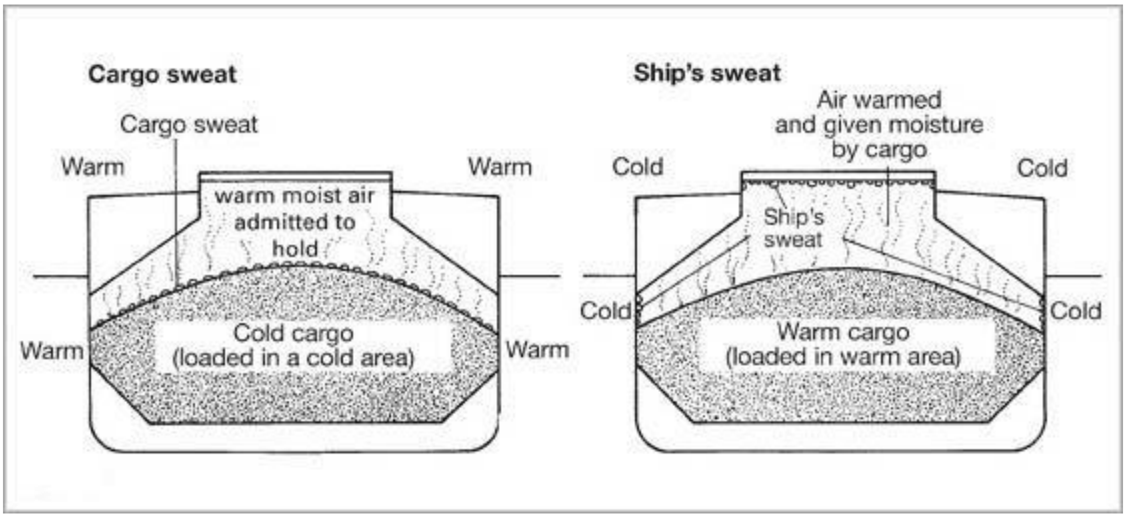
Dry Bulb Temperature	Wet Bulb Depression 0.5	1.0	1.5	2.0	2.5	3.0	3.5	4.0	4.5	5.0	7.5	10.0	12.5	15.0	17.5	20.0
-10.0	85	69	54	39	24	10										
-7.5	87	73	60	48	35	22	10									
-5.0	88	77	66	54	43	32	21	11	1							
-2.5	90	80	70	60	50	42	37	22	12	3						
0.0	91	82	73	65	56	47	39	31	23	15						
2.5	92	84	76	68	61	53	46	38	31	24						
5.0	93	86	78	71	65	58	51	45	38	32	1					
7.5	93	87	80	74	68	62	56	50	44	38	11					
10.0	94	88	82	76	71	65	60	54	49	44	19					
12.5	94	89	84	78	73	68	63	58	53	48	25	4				
15.0	95	90	85	80	75	70	66	61	57	52	31	12				
17.5	95	90	86	81	77	72	68	64	60	55	36	18	2			
20.0	95	91	87	82	78	74	70	66	62	58	40	24	8			
22.5	96	92	87	83	80	76	72	68	64	61	44	28	14	1		
25.0	96	92	88	84	81	77	73	70	66	63	47	32	19	7		
27.5	96	92	89	85	82	78	75	71	68	65	50	36	23	12	1	
30.0	96	93	89	86	82	79	76	73	70	67	52	39	27	16	6	
32.5	97	93	90	86	83	80	77	74	71	68	54	42	30	20	11	1
35.0	97	93	90	87	84	81	78	75	72	69	56	44	33	23	14	6
37.5	97	94	91	87	85	82	79	76	73	70	58	46	36	26	18	10
40.0	97	94	91	88	85	82	79	77	74	72	59	48	38	29	21	13

- Enter the meteorological tables with the dry bulb reading and the difference of wet and dry bulb readings to obtain the values of Dew point and RH.

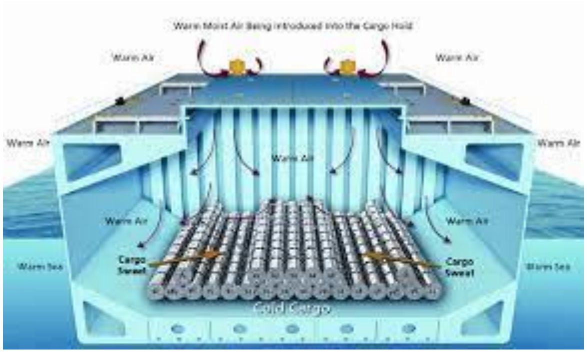
- By knowing these values ventilation of the cargo holds may be restricted or allowed to prevent damage to the cargo, as follows :

<u>**Cargo Sweat**</u>

- If a ship is carrying cargo from cold region to warm region then the temperature of outside air will be more than the temperature of the cargo and the air inside the cargo hold.



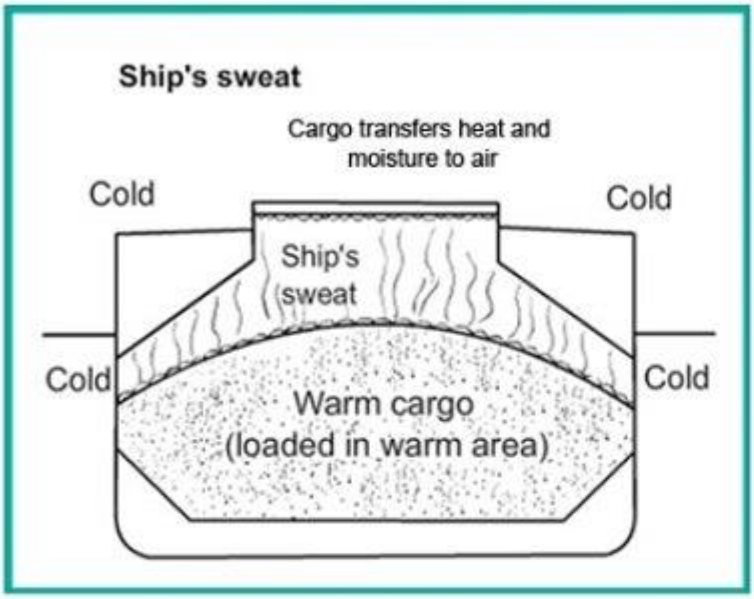
- If ventilation is carried out and the warm air from outside is allowed to enter the hold then this air will be cooled by coming in contact with cold cargo.
- If this cooling continues beyond the dew point of the incoming air then water vapour will condense on the cold cargo, called **Cargo Sweat**.



- To prevent this cargo sweat **Restrict ventilation when the temperature inside the cargo hold is less than the Dew point of the outside air.**
- If such restriction may damage the cargo inside the hold then de-humidifiers should be used on ventilators so that much of the water vapour in the incoming air is removed.

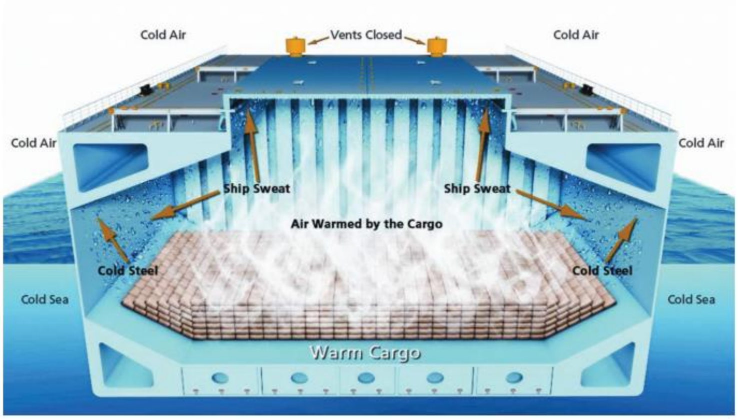
<u>Ship Sweat</u>

- If a ship is carrying cargo from warm region to cold region then the temperature of outside air will be less than the temperature of the cargo and the air inside the cargo hold.



- If ventilation is not permitted then the warm air inside the hold will be cooled by conduction due to contact with the shipside steel, which is cooled by contact with the cold water outside the ship.

- If this cooling continues beyond the dew point of the warm air then water vapour will condense on the shipside steel, called **Ship Sweat**.



- To prevent this ship sweat **allow ventilation when the temperature inside the cargo hold is more than the Dew point of the outside air.**

Lapse Rate

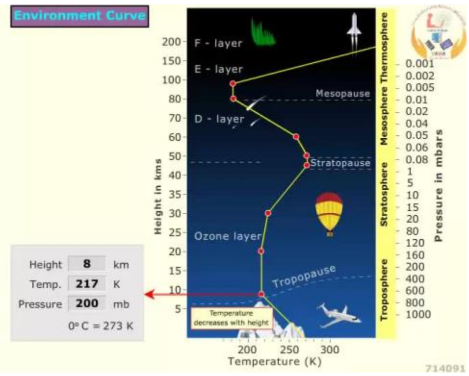
- The variation in environmental lapse rates throughout the Earth's atmosphere is of critical importance in meteorology.

- This is particularly more in case of tropopause.
- The atmospheric temperature varies with the height.
- Air temperature readings at different heights can be received from instruments carried by various means such as radiosondes, rockets, etc.

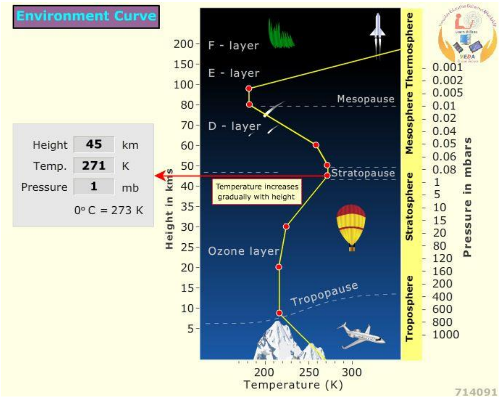
Environment Lapse Rate (ELR)

- The ELR is the **rate of decrease of temperature** with height in the environment.
- It is obtained from the environment curve.
- The rate is not constant and varies with the amount of solar radiation reaching the earth's surface.
- The larger the amount of solar radiation reaching the surface, the higher is the surface temperatures and the greater the ELR.
- The average ELR is between $38°F \sim 39°F$ per mile but it may vary considerably.
- The **ELR is said to be positive when temperature decreases with height in the environment**.
- It is **Zero when temperature is constant with height (isothermal)** and
- **ELR is negative** when **temperature increases with height**.

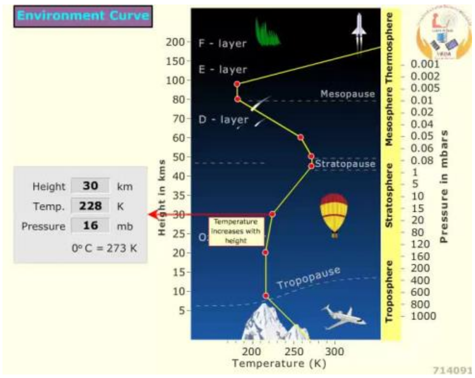
<u>Environment Curve</u>



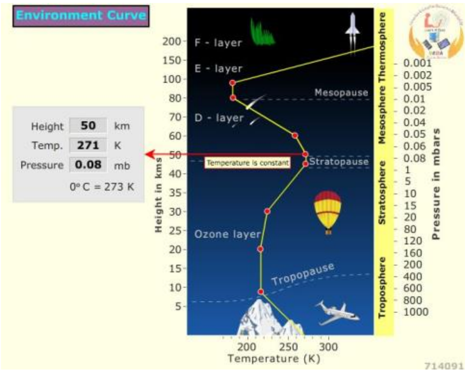
- **Radiosondes are used** by meteorologist **to measure the environmental lapse rate and compare it to** the **predicted adiabatic lapse rate to forecast the likelihood that air will raise.**
- **Charts of the environmental lapse rate** are **known as thermodynamic diagrams**.



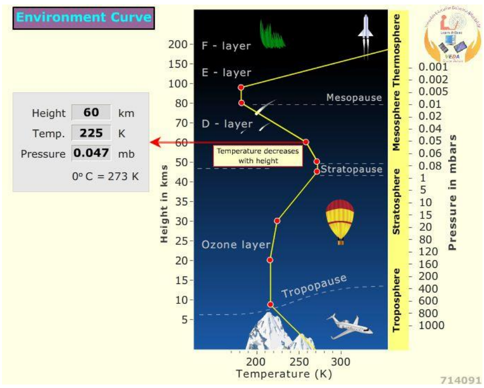
- The graph obtained by plotting and joining these readings shows the variation of temperature with height in air which is static.
- This graph is called the **<u>environment curve</u>**.



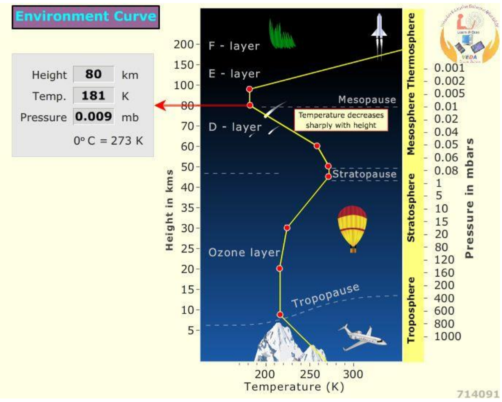
- The **curve** will **usually show a general fall of temperature with height in the environment.**
- It will **also show that the change of temperature varies throughout the height of the atmosphere.**



- At some levels the variation of temperature per mile may be greater than at other levels.
- At some levels, the temperature may even increase with height.
- In other words, the **temperature lapse rate is not constant for all levels of the atmosphere.**

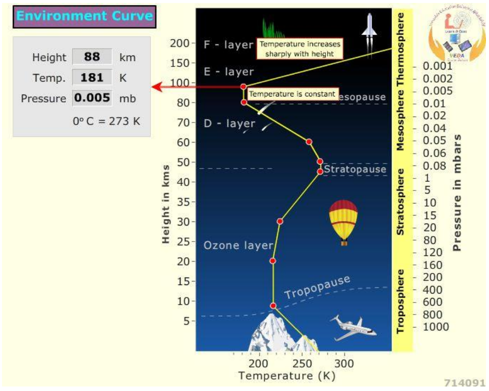


Explore the interactive below to study the variation in pressure and temperature with height within different layers of the atmosphere.



➢ The **temperatures** here are **given in the Kelvin scale**.

➢ The **Kelvin scale is an absolute, thermodynamic temperature scale using as its null point absolute zero (0 K),** the temperature at which all thermal motion ceases.



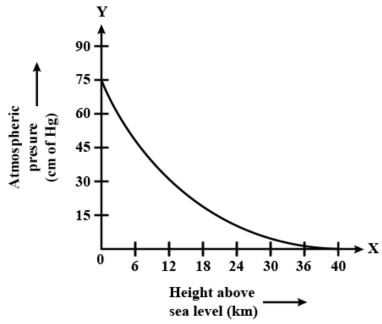
Variation of atmospheric pressure with height

➢ Atmospheric pressure decreases as height increases.

➢ The graph of the lapse rate of atmospheric pressure against height above sea level is a curve.

➢ The average lapse rate is about 115 mb per km height in the lower levels of the atmosphere (up to 5 km height).

➢ At higher levels, the lapse rate is higher.

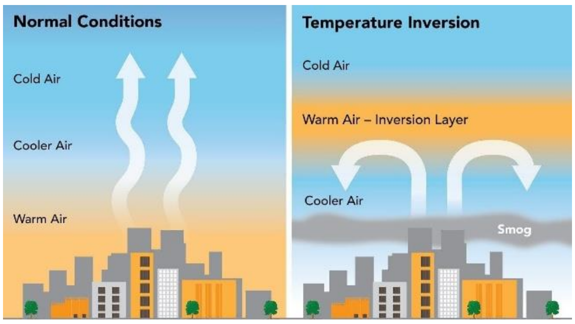


➢ Instruments that measure height above sea level, called **altimeters**, work on the predictable lapse rate of atmospheric pressure.

Variation of temperature with height

➢ In the troposphere, the temperature of air normally falls steadily as height increases.

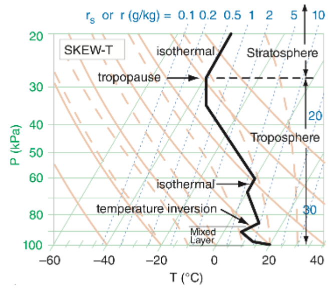
➢ Sometimes, local influences cause the temperature of air to:



(a) Increase with height instead of falling. This is called a ***temperature inversion.***

OR

(b) Remain constant with height. The air is then said to be an ***isothermal layer***.



However, both above conditions, (a) and (b), are temporary and will return to normal subsequently.

Adiabatic lapse rate of temperature

- Adiabatic change of temperature of a parcel of air is the change in its temperature due to increase or decrease of its volume, without any exchange of heat from the surroundings.
- If the volume is increased, the temperature of the parcel would decrease and vice-versa.
- This is due to a law in physics.
- If a parcel of air is made to rise in the atmosphere, its volume would increase in accordance with the rarer air at that height.
- This expansion causes the parcel of air to cool, though no exchange of heat has taken place with the surrounding air.
- This cooling is hence adiabatic.

Wet and dry air

- Any parcel or **sample of air that is fully saturated** is called **wet air or saturated air.**
- Any sample of air that is not fully saturated is called dry air.

Adiabatic changes

DALR (Dry Adiabatic Lapse Rate)

- It has been observed that the temperature of a dry parcel of air, which is made to rise, falls at a steady rate of $10°C$ for every km of ascent i.e., the adiabatic lapse rate of a dry parcel of air, or
- **Dry Adiabatic Lapse Rate (DALR)** is $10°C$ **per km**.

SALR (Saturated Adiabatic Lapse Rate)

- The temperature of a saturated parcel of air, which is made to rise, falls at a rate of approximately $5°C$ per km of ascent i.e.,

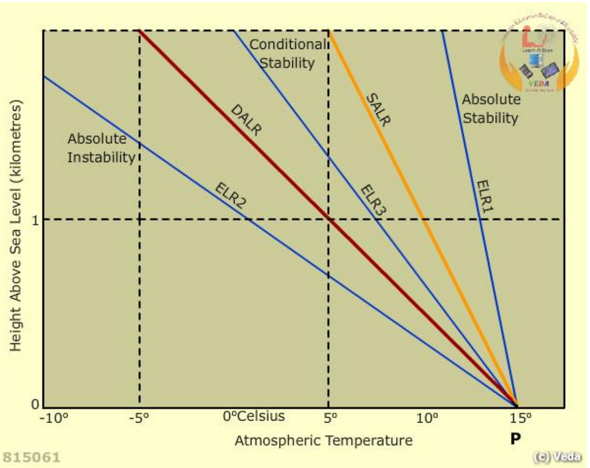
- The adiabatic lapse rate of a saturated parcel of air, or **Saturated Adiabatic Lapse Rate (SALR), is about 5°C per km.**
- **SALR is less than DALR** because, as the saturated air is cooled, its capacity to hold water vapour decreases and the excess moisture condenses into water droplets.
- This **condensation releases latent heat** that **warms up the parcel of air**.
- The temperature of the rising parcel of saturated air, therefore, falls only by about 5°C per km instead of 10°C.
- SALR is slightly variable – less at the equator and more at the poles.

- When we require an average value of the adiabatic lapse rate of any parcel of rising air, and we do not know its exact moisture content, **an average value of 6.5°C per km height would give a reasonably approximate result.**

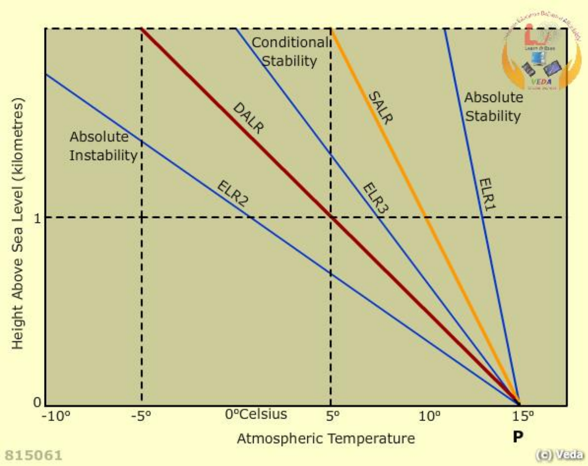
Stability of air

- A ship may be unstable, a person may be mentally unstable, but air? Yes, air also can be unstable!
- **Equilibrium of air** is its tendency to return to its original position, when slightly displaced by an external force.
- In the accompanying diagram, consider a point P at sea level, having an atmospheric temperature of 15°C.
- If a parcel of air at P is made to rise slightly by some disturbance, its temperature would fall by 10°C per km height (DALR)
- If the parcel is dry, and by about 5°C per km height (SALR) if it is saturated, shown by the DALR and SALR lines.

Absolute stability



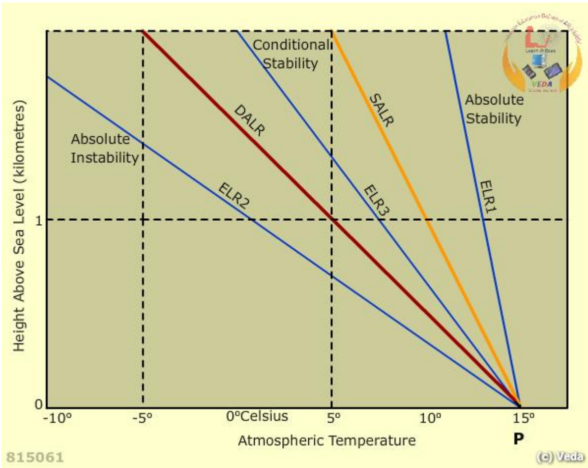
- If the surroundings (environment) are such that the **actual lapse rate existent** is **less than DALR and SALR**, **absolute stability is said to exist (see ELR (1) in figure).**
- i.e., if dry, the temperature of parcel at 1 km height is 5°C



- if wet, the temperature of parcel at 1 km height is 10°C
- Present temperature of surrounding air at 1 km height, as per ELR (1) in figure, is more than 10°C.
- The parcel of air is thus colder and hence denser than the surrounding air at that level and it would hence try to return below to its original position.
- Since this happens regardless of whether the parcel is originally saturated or not, this condition is referred to as **absolute stability**.

Absolute Instability

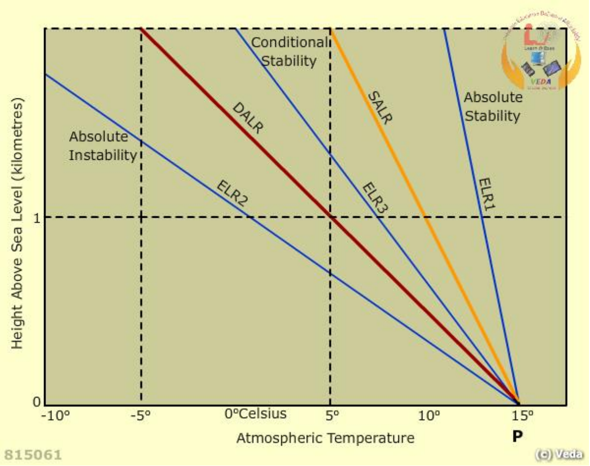
- If the environment is such that the **actual lapse existent is more than SALR and DALR, absolute instability is said to exist** (see ELR (2) in figure).
- i.e., if dry, the temperature of parcel at 1 km height is 5°C
- if wet, the temperature of parcel at 1 km height is 10°C
- Present temperature of surrounding air at 1 km height as per ELR (2) in figure, is less than 5°C.
- The parcel of air is thus warmer and hence less dense than the surrounding air at the same level and would thus try to continue upwards in the direction of the original disturbance.



- Since this happens regardless of whether the parcel is originally saturated or not, this condition is referred to as **absolute instability**.

Conditional Stability

- If the environment is such that the **actual lapse rate existent is less than DALR but more than SALR, conditional stability is said to exist (see ELR (3) in figure).**
- i.e., **if dry, the temperature of parcel at 1 km height is 5°C**
- if **wet, the temperature of parcel at 1 km height is 10°C**
- **Present temperature of surrounding air at 1 km height as per ELR (3) in figure, is between 5°C and 10°C.**



- This means that **if the parcel of air is dry**, **it is colder (and hence denser) than the surrounding air at the same level**, and **would try to return below to its original position** i.e., **stable equilibrium**.

- **If the parcel of air is saturated**, **it is warmer (and hence less dense) than the surrounding air at the same level**, and **would try to continue upwards, in the direction of the original disturbance** i.e., **unstable equilibrium.**
- Because **stability or instability, in this case, depends on whether the parcel is dry or saturated, this condition is referred to as <u>conditional stability.</u>**

<u>Neutral equilibrium of air</u>

- If the ELR coincides with DALR when the parcel of air is dry or with SALR when the parcel is saturated, then the parcel of air which is displaced upwards, is at the same temperature as that of the surrounding air at the same level and would have no tendency to return to its original position or to continue to move upwards in the line of original disturbance.
- This condition is called **<u>indifferent or neutral equilibrium</u>**.

Diurnal variation of pressure

- Pressure is the **force /unit area**.
- In case of atmosphere **the pressure will be the total mass of air, upto the top of the atmosphere, standing over a unit area of Earth's surface**.
- This has been estimated to be **about 1 kg. / cm^2**.
- Instead of air if we consider a heavier material like mercury then a **column of 750 mm. of mercury will exert the same pressure as the total column of air**.
- This **column is called a Bar** and for **measurement purposes it is divided into 1000 Millibars.**
- Under the **SI system of units, the pressure is measured in Pascals which is same as Newton/m^2.**

1 Millibar = 100 Pascals, **1 Bar = 1000 Millibars** = **100000 Pascals** =

1 Kg./cm^2 = **100 KN/m^2**

Semi-diurnal variation of atmospheric pressure

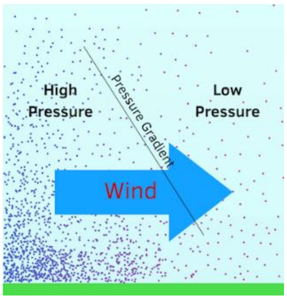
- Owing to many causes, which are not fully understood by man, atmospheric pressure changes with the time of the day.
- It has been observed that it is **highest at about 1000 and 2200 hours** and
- **lowest at about 0400 and 1600 hours Local Mean Time**.
- Since **this happens twice a day**, it is **called semi-diurnal variation of atmospheric pressure.**

Semi-diurnal range of atmospheric pressure

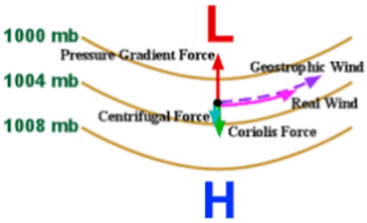
- The **difference between** the **maximum and minimum values** is called the **semi-diurnal range of atmospheric pressure**.
- The **average semi-diurnal range is more in the tropics than in middle latitudes**.
- In **tropical regions it is about 3 mb (i.e., up to $\pm$ 1.5 mb from normal)** and
- In UK (**lat $51°$ N)** it is **about 0.8 mb** (**i.e., up to $\pm$ 0.4 mb from normal**).
- In **high latitudes**, **it is negligible and frequently masked by fronts and frontal depressions.**
- The rate of change of pressure at a given place is called **Pressure or Barometric tendency.**

- It is usually measured for a period of 3 hours to enable the meteorologist to prepare his weather predictions.
- **Lines drawn on the chart joining places having the same barometric tendency** are called **Isallobars.**

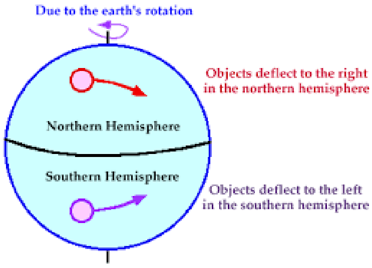
Geostrophic wind



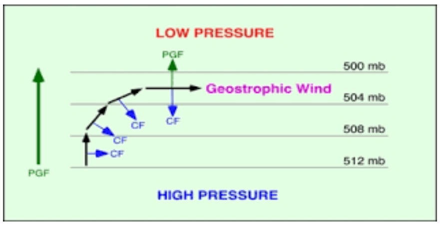
- By simple logic wind would blow from high-pressure area to low-pressure area or from isobar of higher value towards isobar of lower value at a velocity or force called the **Gradient force** of wind.



- This force is directly related to the pressure gradient in the region or inversely related to the distance between the isobars, and acts at right angles to the isobars.
- Due to rotation of the Earth the **Coriolis or Geostrophic force** is created which **acts at right-angles to the direction of motion of the wind and deflects it to the right in the Northern hemisphere and to the left in the Southern hemisphere.**

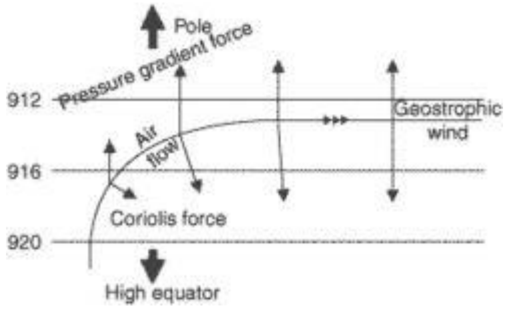


- In a Northern hemisphere consider that isobars are running parallel to each other.
- The wind will blow at right angles to the isobars towards the low pressure according to the Gradient force.
- At the same time Coriolis force will act at right angles to the direction of wind and deflect it to the right.

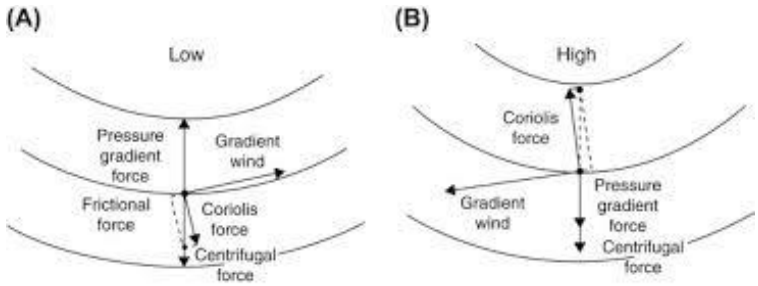


- The resultant wind will blow at some angle between the two forces.
- As the direction of wind changes, the direction of Coriolis force will also change, while the direction of the Gradient force will remain the same.
- Hence the resultant wind will continuously change direction to the right and follow a curved path.

- At some point the two forces will become opposite to each other and wind will blow parallel to the isobars towards the right of the original direction. This is called **Geostrophic wind.**

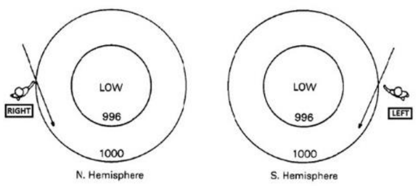


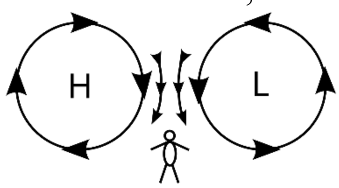
- Exactly the same effect will occur in the Southern hemisphere except that the final direction of wind will be to the left of the original direction.
- **Geostrophic force is minimum at Equator** and **increases with the latitude of the observer and reaches maximum at the poles**.
- **Within few degrees of the Equator this force is negligible** and so the **wind practically blows across the isobars in accordance with the Gradient force.**
- The above analysis is based on the assumption that the isobars are parallel.
- However even if these are curved, the net result of the wind direction remains the same.
- So, in the Northern hemisphere if isobars are in concentric circles with the low pressure in the centre, the Geostrophic wind will circulate in an anti-clockwise direction and cut inwards across the isobars and spiral towards the centre.
- Similarly, if the high pressure is in the centre then the Geostrophic wind will circulate in a clockwise direction and cut outwards across the isobars and spiral away from the centre.



- Exactly opposite will happen in the Southern hemisphere.

- **Buys Ballot's law** is derived from the above principles.
- It states that in the Northern hemisphere if the observer faces the wind, the low pressure will lie to his right, and vice-versa in the Southern hemisphere.

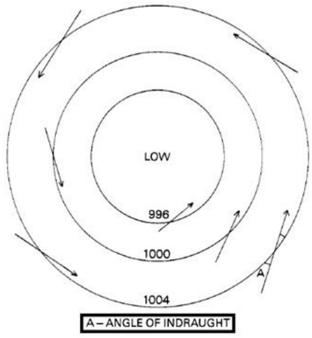




- This law is not applicable close to the Equator as due to absence of the Geostrophic force the wind blows across the isobars.

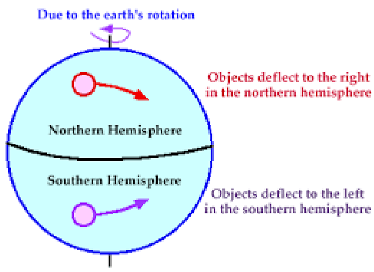
Frictional force

- The Geostrophic wind may be deflected slightly due to friction offered by land or sea over which it is blowing.
- In addition, this force also counters the Geostrophic force and reduces its value to about two-thirds over sea and to about one-half over land.
- At more than 600m. above sea level this force is normally not present.
- The resultant wind direction will be inclined at an angle to the isobars depending on the quantum of the above forces.
- This inclination is called **In-draft**.
- It has been observed that **over land the In-draft is about 30° towards the low pressure, and over sea it is about 10°.**
- At high levels the wind blows practically parallel to the isobars due to absence of the frictional force.



Angle of indraught.

- If there was no Coriolis Force, the Global wind belts at the surface would blow strictly in the North- South direction.
- Due to the rotation of the Earth, any movement of the air in the Northern Hemisphere is deflected towards Right and in the Southern Hemisphere is deflected to the Left.
- This apparent deflection is called the **Coriolis Force**.
- The amount of the deflection the air makes depends on a speed at which the air is moving and its latitude.



- Thereby slowly moving winds will be deflected only a small amount, while Stronger winds will be deflected more.
- Likewise winds blowing closer to the Poles will be deflected more than the winds at the same speed close to the Equator.
- The **CORIOLIS FORCE is ZERO at the Equator**.

RECAP

- Pressure Gradient causes the air parcels to accelerate across the Isobars from areas of High Pressure towards the areas of Low Pressure.

- The Coriolis effect then deflects air parcel to the right in the Northern Hemisphere and to the LEFT in the Southern Hemisphere.
- As the wind gains speed, the Coriolis effect increases in magnitude until it balances the Pressure Gradient Force.
- The result is an unaccelerated Horizontal wind blowing parallel to the Isobars that is called the Geostrophic Wind.

Trade winds and Westerlies

Trade Winds

- Trade winds roughly cover almost the entire area tween $30°N$ and $30°S$ latitudes on both sides of the equator.
- The trade winds are a result of a pressure gradient from the sub tropical belt of high pressure to the equatorial belt of low pressure.
- In the northern hemisphere, the wind moving towards the equator is deflected by the earth's rotation to flow south-westward.
- Thus, the prevailing wind there is from the north east, and it has been named as the **North East Trades**.
- In the southern hemisphere, deflection of the wind is towards the left, this causes the **South East Trades**.
- The trade winds are considered to be steady and persistent in direction.
- They bring heavy rainfall to the eastern coasts of continents lying within the tropics because they blow on-shore.
- On the western coasts of continents, these trade winds do not bring any rainfall as they are off-shore winds or winds blowing just parallel to the shores.
- So the western areas within the tropics suffer from aridity.
- This explains the great deserts of the Sahara, Kalahari, Atacama and the Australian deserts, all lying on the western margins of the land masses within the tropical latitudes.

Westerlies

- The Westerlies or the prevailing westerly winds blow between $35°$ and $60°$ north and south latitudes
- From the sub-tropical high pressure belts towards the sub polar low pressure belts.
- In the Northern Hemisphere, the **Westerlies generally blow from the south west to the north east,** and

- In the **southern hemisphere from the North West to the south east.**
- Westerlies are not as constant in strength and direction as the trade winds.
- They are rather stormy and variable though the main direction remains from west to east.
- They are **also known as anti-trade winds**, because **their movement is in the opposite direction from that of the trade winds.**
- In the northern hemisphere, land masses cause considerable disruption in the westerly winds.
- But in the southern hemisphere, between 40°S and 60°S, the Westerlies gain great strength and persistence because of the vast expanse of oceans in their belt.
- This made the mariners of old call them the **roaring forties**, the **furious fifties** and the **screaming sixties**.
- In olden days, sailing vessels had to face great danger while sailing in the opposite direction in the face of the prevailing westerly winds.

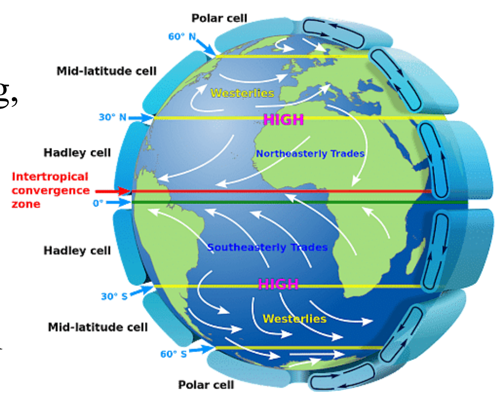
Polar, Ferrel and Hadley Cells

Polar Winds

- The winds blowing in the Arctic and the Antarctic latitudes are known as the **polar winds**.
- They have been **termed the polar easterlies, as they blow from the polar high pressure centers towards the sub polar low pressure belts.**
- These **winds are extremely cold as they blow from the landmass capped with ice**.
- Southern hemisphere has more regular polar winds than the northern hemisphere.

Hadley Cells

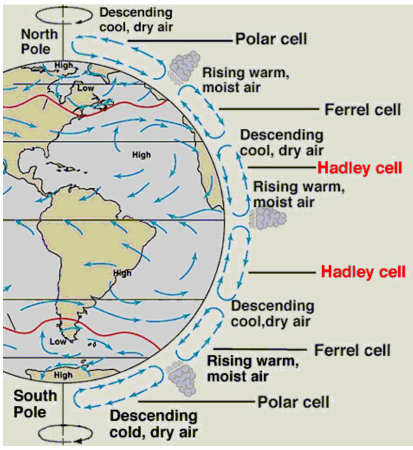
- **Hadley Cell** is closer to the Equator, consists of winds, converging and rising, at the Equator and then diverging North and South of the equator as it reaches the upper Troposphere.
- The wind then sinks at 30° latitude (North or South) as they converge with the Winds in the Ferrel Cell.



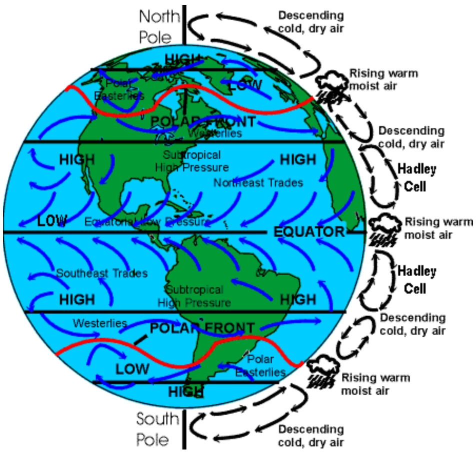
- They hit the surface and diverge back to the Equator, to complete the cell.

This provides the Equator-ward wind component of the Trade Winds.

Ferrel Cells



- Ferrel Cells, as winds sinking at 30° North & South Latitudes and then travelling Pole ward as they hit the ground and diverge with the winds from Hadley Cell.
- This provides the **Pole-ward component of the Mid-latitude Westerlies.**
- This wind **travels towards the Poles, until they converge with winds in Polar Cell at 60° Latitude.**
- This wind then rise up and spread out equator-ward to complete the cell.

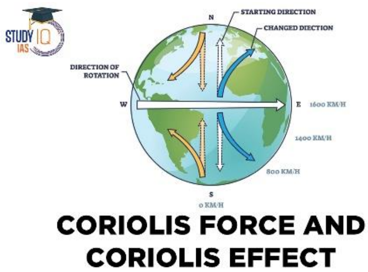


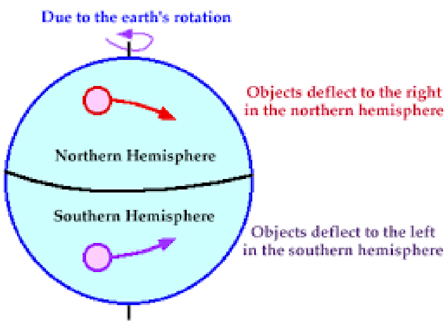
Polar Cells

- Polar Cells has winds rising up at 60° Latitude and spreading out Pole ward as they reach upper Troposphere.
- The winds sink down at Poles and then diverge towards the Equator, until they reach 60° Latitude where they rise up again to complete the cell.
- They provide the Equator-ward component of the Polar Easterlies.

CORIOLIS Force and its effect

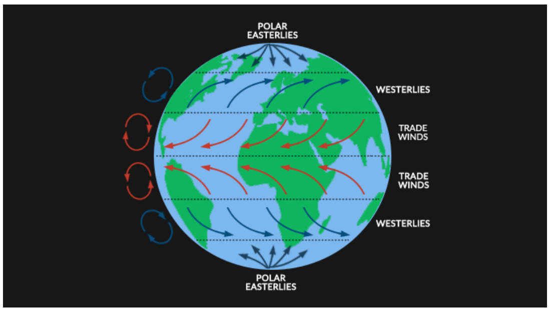
- If there was no Coriolis Force, the global wind formed at the surface, will strictly blow in the North- Soth direction.





- Due to the rotation of the Earth, any movement of the air in the Northern Hemisphere is deflected towards Right and in the Southern Hemisphere is deflected to the Left

- This apparent deflection is called the **<u>Coriolosis Force</u>**.
- The amount of the deflection the air makes depends on a speed at which the air is moving and its latitude.
- Thereby slowly moving winds will be deflected only a small amount.
- While Stronger winds will be deflected more.

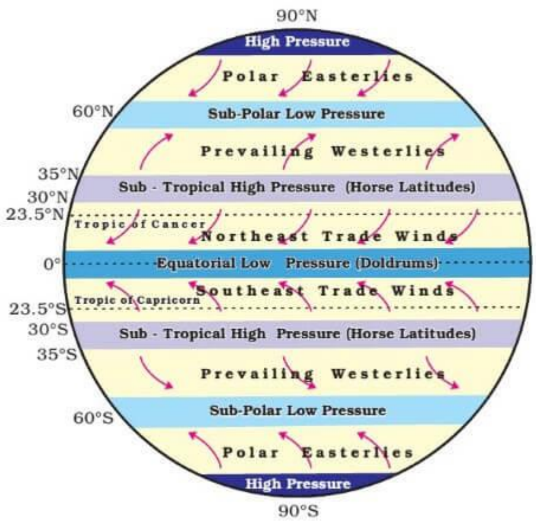


- Likewise winds blowing closer to the Poles will be deflected more than the winds at the same speed close to the Equator.
- The **CORIOLIS FORCE is ZERO at the Equator**.

<u>Major Pressure Belts and Wind System</u>

<u>WESTERLY BELT</u>:

- On the Pole-ward side of the Sub Tropical High Pressure Belts, are the regions where the mobile depressions and anticyclones of the temperature Zones are found.
- As this pressure system moves generally from a Westerly direction, they cause considerable variations in the wind direction and fall at any given place.
- On the whole, there is a **predominance of Westerly Winds**.

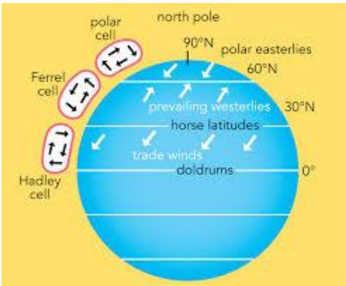


Major Pressure Belts and Wind System

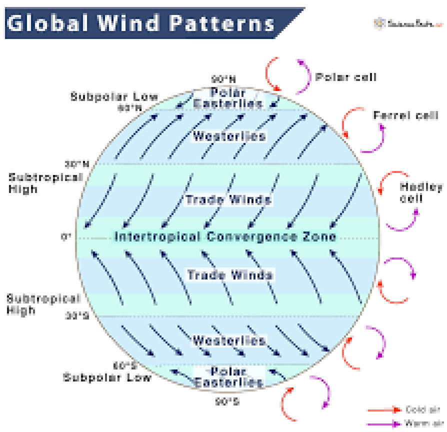
- In the Southern Hemisphere these winds often reach gale force and they are known as the **<u>Roaring Forties</u>**

<u>Sub Tropical Anticyclone Belt</u>

- These are belts of Light and variable winds. Fine clear weather marks the central regions of the Sub tropical High Pressure Belts.
- They are mainly located 30 deg to 35 deg North and South are referred to as Horse Latitudes.



<u>**Trade Wind Belts**</u>



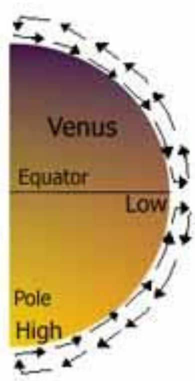
- This is the belt of winds which exists between the Sub tropical Anticyclone and the ITCZ
- The **Notrh East Trade winds** are in the **Northern Hemisphere** and the **South East Trade winds are there in the Southern Hemisphere.**
- The general tend of trade winds as shown by the Vector.
- Mean winds and the mean position of the ITCZ are illustrated below for January and July.
- Note that the typical North East Trades evident in other areas are absent in the North Indian Ocean.
- In July, the particular feature of the area are the MONSOONS.
- The wind direction and speed with an air trade wind belt varies, the average strength is force Four, with the general tendency to increase in strength during the Winter season.
- The common cloud is Cumulus with vertical development and showers.
- Occasionally Trade winds may be absent. Their place can be taken by Tropical Storms.

<u>**Doldrums Belt**</u>

- This is the Zone of Light and variable winds which form a narrow belt between the Equator and about Latitudes 12° Noth which varies with Longitude and the season.
- The doldrums are generally known for Light and variable winds.
- But storm, Heavy Rain and Thunderstorms are also experienced.

Global Winds

- At the most fundamental level, the global winds are set in motion by differential heating of Earth's surface by sunlight, i.e. the tropics are warm and polar areas cold.
- This differential heating gives rise to pressure differences and, consequently, to the pressure gradient force that compels air to move.
- Ultimately, as we saw earlier, the moving air redistributes heat from areas of surplus to areas of deficit.



- Remember the vertical motion of air at High and Low pressure centers described in the previous section,

1. If Earth did not rotate, what would the global atmospheric circulation be like?
2. What is the Hadley Cell?
3. Low pressure systems are the ITCZ, polar fronts, and subpolar Lows. At what latitude are they located and what are their characteristics?
4. High pressure systems are the subtropical Highs (horse latitudes), and polar Highs. At what latitude are they located and what are their characteristics?
5. Based on your knowledge of sky conditions for High and Low pressure, at what latitude do you think the subtropical deserts are located? The tropical rainforests?

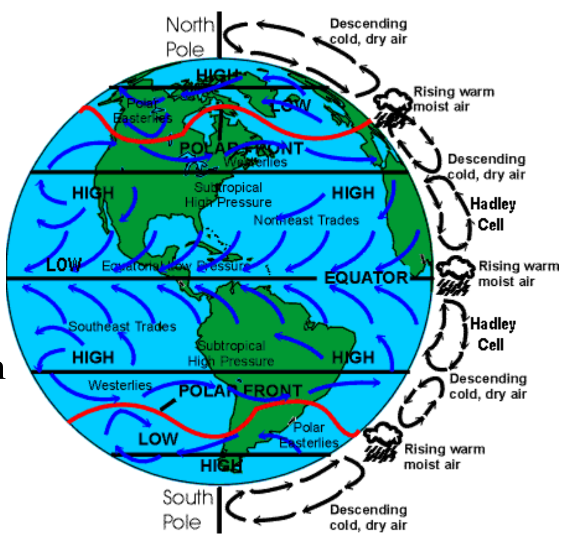
BOX 1

- At the **equator**, the warm surface causes **low pressure** and rising air.
- At the **poles**, cold air produces **high pressure** and sinking air.
- If Earth did not rotate, this would describe the global circulation.
- Air would rise at the equator, flow at high altitude to the Poles, then sink and return to the equator along the surface forming two gigantic circulation cells.
- On planets like Venus, with negligible Coriolis force due to very slow rotation this is, in fact, what happens.

Global Pressure

- On Earth, however, Coriolis makes the situation more complicated.
- Air rises near the Equator, but rather than flowing all the way to the poles, Coriolis deflection produces sinking air at about 30° north and south latitudes as shown on the right side of the diagram below.
- This vertical motion in the tropics is so well defined that it has a name:
- The **Hadley Cell**. Rising air in the Hadley cell along the equator produces deep clouds, thunderstorms, and rain in a band of low pressure called the **Intertropical Convergence Zone** (ITCZ).
- Sinking air near 30° latitude causes high pressure areas called the **subtropical highs**.
- The highs produce clear skies and calm winds in a latitude band sometimes called the **Horse Latitudes,** which lie just north of the Hawaiian Islands and dominate Hawaiian weather.

- Coriolis makes the air flow at higher latitudes even more complicated, but in general air flows out of the subtropical highs poleward along the surface then rises again at the **Polar Front,** which wobbles between 50° and 70° latitude.
- At the polar front, air rises, producing cloudy skies in a band of bad weather sometimes called the **Subpolar Low**.
- At the highest latitudes, circulation is similar to the Hadley cell, except much smaller.
- Air sinks over the poles, where **Polar High** pressure, clear skies, and cold air dominate, then flows equatorward and rises again at the Polar Front.



- These large circulation cells produce global pressure bands in latitude zones as shown in the accompanying diagram as **HIGH** (30° latitude and the poles) and **LOW** (equator and 50-70° latitude).
- The surface pressure bands not only determine the climate at their location, but also drive the vast global surface winds.

- Studying the diagram will help you, not only in this class, but in understanding the weather wherever you travel in the world.

Global Winds

- The diagram above shows two idealized views of air motion, the vertical cross-section shown on the right and the horizontal winds drawn over the image of Earth.
- Look at the very center near the word "Equator."
- Notice high pressure is to the north and low pressure is at the equator itself.
- Remember the rules regarding air motion in relation to pressure differences.
- Imagine standing on the high pressure area in the northern hemisphere looking equatorward and holding out your right arm.
- The PGF sets air in motion from you toward the equatorial low.
- The moving air is then deflected in the direction your arm points, to the right, by Coriolis.
- That motion forms the **northeast trade winds** as shown in the diagram.
- Now do the same for the southern hemisphere.
- Imagine standing on the high in the South Pacific, and looking north toward the equator, holding out your left arm this time.
- Air is deflected by Coriolis to the left, in the direction your arm is pointing, forming the **southeast trade winds**.
- The trade winds, so-named because of their dependability for sailing ships, are usually very reliable and cover nearly one half of Earth's surface.
- Trade wind weather is generally dry and sunny because of the subtropical High pressure influence.
- Areas near the equator lie in a low pressure zone (remember the ITCZ from the Global Pressure section above?) where winds are generally light or calm, a condition that mariners term the **doldrums**.
- (This is a good place to note how winds are named: **winds are named for the direction they come <u>from</u>**. So, northeast trade winds come from the northeast, westerly winds come from the west, sea breezes come from the sea, valley breezes come from the valley, and so on.)
- Now apply the same reasoning to the winds between the subtropical highs and the polar front, or subpolar lows.

- Air flows from high to low pressure and Coriolis deflection produces **westerly** winds in both the northern and southern hemispheres between about 30° and 60° latitude.
- Westerly winds tend to shift direction much more than the trades and also tend to be more blustery.
- In the southern hemisphere, they blow with such ferocity that mariners named these latitudes the **Roaring Forties**, **Furious Fifties**, and **Screaming Sixties**.
- The highest average wind speed, in fact, occurs off the coast of Antarctica near 60° S latitude at over 60 kilometers (37 miles) per hour. That's the *average* wind speed.
- Cold **Polar Easterlies** cover the highest latitudes for the same reason easterly trade winds prevail in the tropics.
- Finally, one should note that the diagram shows a very idealized version of the global winds.
- Heating and cooling of land surfaces causes much variation, such as seasonal monsoons in tropical Asia.
- Nonetheless, it generally holds true, especially over the oceans.
- For the purposes of testing and your own long-term understanding of the weather in other parts of the world, memorizing the yellow global wind and pressure belt diagram will be quite helpful.

Sub tropical oceanic highs

- You have studied the forces that cause wind over the oceans.
- The movement of wind varies.
- The wind blowing over the polar regions, the tropics and in the temperate regions all have their own distinctive characteristics.
- In places the winds blow permanently in a particular direction throughout the year.
- These are known as **permanent winds**.
- They are also called as the **planetary or prevailing winds**.
- Certain winds blow in one direction in one season and in the opposite direction in another. They are known as **periodic winds**.
- There are **some local winds** too, **caused by local factors in different parts of the world**. Let us study these in detail.
- The planetary wind system includes the High & Low Pressure Belt.
- Winds tend to blow from High Pressure Centres to Low Pressure Centres.

- Land masses cause considerable disruption of the winds, particularly in the Northern Hemisphere.

Trade Winds

- The **Trade Winds** and the **Westerlies** are the **main planetary winds of the world.**
- **Trade winds** roughly **cover the entire area between 30 deg North & 30 Deg South latitudes on both sides of the equator**.
- The **Trade winds area** are a **result of the Pressure Gradient from the Subtropical belt of High Pressure to the Equatorial Belt of Low Pressure**.
- In the **Northern Hemisphere**, the **wind moving towards the Equator, is deflected by the earth's rotation to flow south westward**.
- Thus the **prevailing wind there is from the North-East, and it has been named as the North-Easterly Trade Winds.**

- In the **Southern Hemisphere**, the **deflection of the wind is towards the left, this cases the South Easterly Trade Winds**.

Westerlies

- The **Westerlies** are the **prevailing westerly wind blow between 35 deg North/ South and 60 Deg North/ South latitudes from the Sub-tropical High Pressure belts towards the Sub-Polar Low Pressure Belts**.
- In the Northern Hemisphere, the Westerlies generally blow from the South West to the North East, and in the Southern Hemisphere from the North West to the South East.

Periodic and Local Winds

Fohn wind effect:

- Wind from sea having high Relative Humidity (RH) strikes a mountain and starts ascending it.
- The temperature of the rising air will decrease at DALR and its RH will increase.
- Once the air mass becomes saturated the temperature will decrease at SALR, which is less than the DALR.
- This will cause rain on the windward side of the mountain.

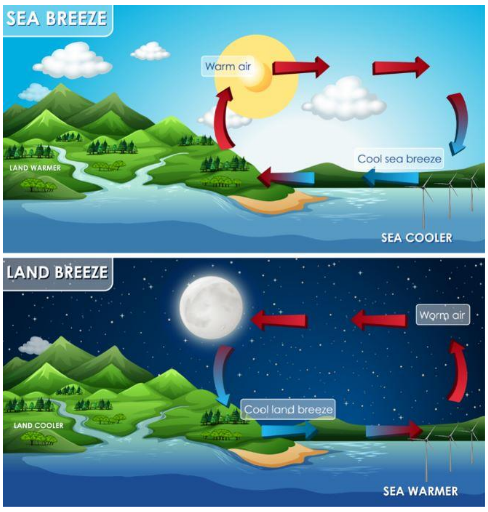
- On top of the mountain the temperature of air will be very low, and it will be saturated.
- When the air mass descends on the leeward side of the mountain the temperature will rise and the air will become unsaturated.
- As it descends further the temperature will increase at DALR and the RH will continuously decrease.
- Hence near the ground level the air **on the leeward side of the mountain will be drier and will be at a higher temperature than on the windward side.**
- Also, **rain will be experienced on the windward side and not on the leeward side.**

Land and sea breeze:

- Due to low specific heat of land as compared to water, it gets heated during the day and cools during the night, faster than sea.
- Hence there is always considerable difference in temperature of air over land and sea.

Sea Breeze

- During day the air mass over land is very hot so it becomes lighter than the surrounding air and hence rises, thus creating a low pressure over land.
- As the air mass over sea is not as hot so there is a high pressure over the sea.
- Distance between the high and low pressures is not much i.e. the pressure gradient is high.
- Hence winds blow directly across the isobars, which run parallel to the coast, from sea towards land. This is called **Sea breeze**.
- It normally **sets at about 1000 hr. with force of about 3 to 4 and dies down by sunset.**

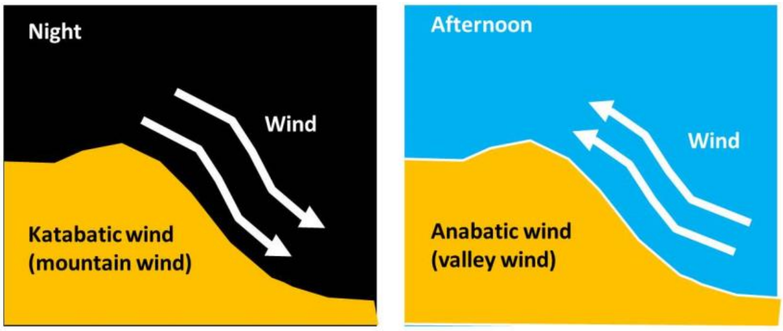


Land Breeze

- At night temperatures and pressures over land and sea are reversed and so **winds blow across the isobars, which run parallel to the coast, from land to sea, called Land breeze**.
- It normally **sets in about 2 hours after sunset and lasts till sunrise**.
- Sea breeze is much stronger than land breeze.
- These are normally experienced upto about 20 miles inland from the coast and are prominent along high, dry, rocky or desert coastline.

Katabatic wind:

- On clear nights the land becomes colder than sea.
- If there is a high mountain close to the sea, then the cold air on top of the mountain being heavier tends to flow down the slope by gravity and blows across the sea with force 7 or more.
- This wind is not based on pressure conditions and hence cannot be predicted.
- These are experienced in Adriatic Sea, off Greenland and Norway.



The mountain cools down, the air becomes heavier so it descends.

The sun warms the mountain, the aire is lighter and ascends

Anabatic wind:

- During day air in the valley becomes warm due to contact with land surface while the air over land at higher altitude is relatively cold.
- This causes the air to blow gently up the slope of land with little force.

Tornado:

- This is a violent whirl of wind of about 100m. diameter having cyclonic winds of 150 knots at its centre.
- It appears like a huge dark funnel shaped cloud with its base in the sky and tapering down to the ground.
- It mainly occurs in Middle West and Central plains of USA. It occurs when the Maritime Polar air from NW overruns the Maritime Tropical air from Gulf of Mexico.

Waterspouts:

- This is usually formed when a Tornado travels to sea from land. It is similar in appearance to a Tornado but not as violent.
- It usually lasts from 10 to 30 minutes.

Nor'wester:

- These are thunderstorms experienced in the State of Bengal at the head of the Bay of Bengal, from March to May and they cease once the SW monsoon sets in.
- They occur in the afternoon around sunset time particularly after a hot day, and last for 3 to 4 hours only.
- They approach from NW direction and hence this name is given.
- They move slowly over land but once at sea they pick up speed.

Elephantas:

These are squalls, blowing in from South or East, experienced on the West coast of India in September towards the end of SW monsoon.

Etesian:

This is summer winds blowing from Northerly direction in the Aegean Sea and Eastern Mediterranean.

Gregale:

This is NEly wind blowing in Western and Central Mediterranean in winter, off the coasts of Malta and Sicily.

Harmattan:

This is Easterly wind blowing on the West coast of Africa from November to March. Coming from the Sahara desert it is dry and brings lot of dust and sand.

Khamsin: This is a Southerly wind blowing in Egypt and Red sea from February to June. It is hot, dry and dusty.

Levanter: This is Easterly wind blowing in Straits of Gibraltar which brings cloud, haze and fog.

Bora: This is Katabatic wind blowing down the mountain on coast of Adriatic in winter.

Mistral: This is Katabatic wind blowing from North to NW direction down the mountain slope into the Rhone valley.

Norther: This is Northerly gale occurring in winter in Chile, Gulf of Mexico and Western Caribbean.

Pampero: This is a strong squall occurring from June to September in Rio-de-La Plata at the passage of a cold front when the wind backs suddenly from North to South or SW. It is accompanied with rain, thunder and lightning.

Sirocco: This is hot and dry wind coming from the deserts of South Africa into the Mediterranean.

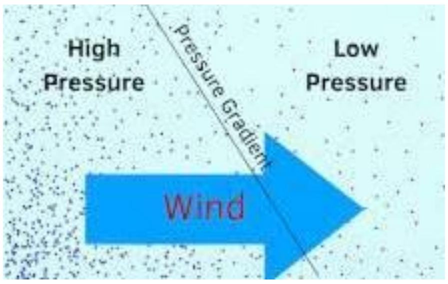
Shamal: This is usually a NWly wind in the Persian Gulf and Gulf of Oman. It can be a normal wind or gale associated with depression. In some areas it even blows from West or SW direction. It brings lot of dust and fine sand, which reduces visibility considerably. During summer the wind force may be upto 7 but in winter it may go upto 9.

Southerly Buster: This is a Southerly wind occurring on the SE coast of Australia, mainly in summer season, from behind a cold front.

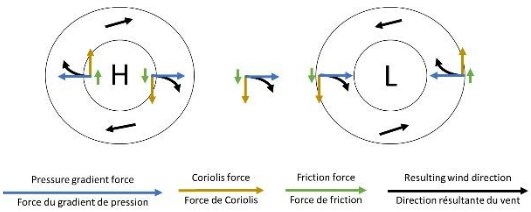
Sumatra: This is SW squalls occurring between May and October in Malacca Straits and West coast of Malaya. These are accompanied with thunderstorm.

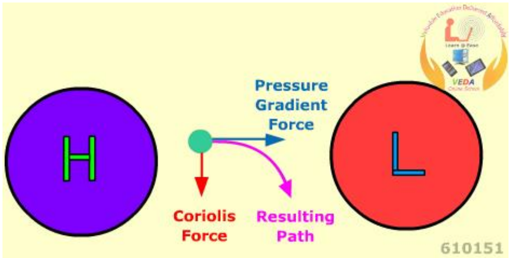
Gradient and cyclostrophic winds

Pressure Gradient Force



- Wind is movement of air in the atmosphere caused by differences in atmospheric pressure between two localities.
- The atmosphere tries to achieve uniform pressure by transferring air, from one region of high pressure (excess air) to another region of low pressure (deficient air), in the form of wind.
- However, wind does not blow directly from high to low pressure.

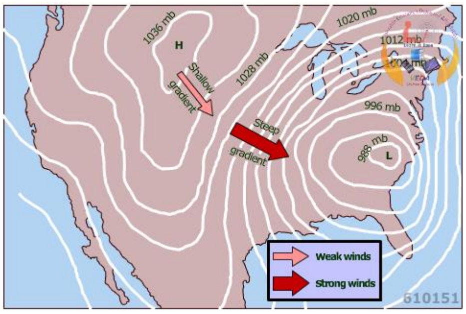




- Due to the pressure gradient, geostrophic force and frictional force, wind tends to blow in a circular manner around regions of high or low pressure.

Pressure Gradient

- The change in pressure measured across a unit distance is called a pressure gradient.
- It results in a net force directed from high pressure to low pressure, the 'pressure gradient force', which triggers the initial movement of air.



- In the case of severe depressions, the **angle of in-draft** is greatly **affected by a third force called Cyclostropic force** and is explained later on under Tropical Revolving Storms.

Cyclostrophic force causing the Gradient wind

- As stated above, the winds circulate around a low pressure like in a Tropical Revolving Storm (TRS).
- This creates the **centrifugal force**, also called the **Cyclostrophic force**, which **acts radially outwards opposite to the Gradient force** and thus reduces its value to some extent.
- In effect it causes a reduction in the angle of in-draft because the other forces stated in the previous Sub-sub-sub-topic are not affected.
- As the winds come closer to the centre of the storm, its force increases, which also increases the Cyclostrophic force.
- Hence closer to the centre where this force is maximum, the winds blow practically parallel to the isobars. This is called **Gradient wind**.
- **Cyclostrophic winds** are characterized by a **balance between the pressure gradient force and the centrifugal force**, **primarily occurring in small-scale**, curved wind flows like tornadoes or dust devils, **where the Coriolis force is negligible**.

- **What is Cyclostrophic Wind?**

Cyclostrophic wind is a **type of wind circulation that results from a balance between the local atmospheric pressure gradient and the centrifugal force**.

- **Where does it occur?**

It's most prominent in small-scale, high-speed, curved wind flows, such as:

- Tornadoes
- Waterspouts
- Dust devils
- Other small atmospheric circulations

- **Why is the Coriolis force negligible?**

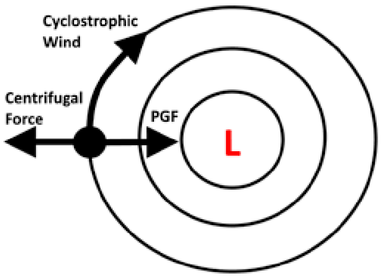
In these small-scale systems, the curvature of the airflow is so great that the centrifugal force (the force that pulls objects away from the center of a curve) becomes the dominant force, outweighing the Coriolis force.

- ❖ **How does it differ from other wind types?**

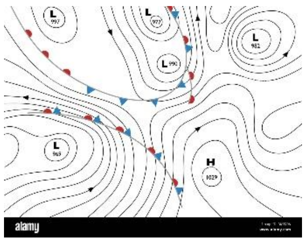
Unlike larger-scale cyclonic systems (like hurricanes), cyclostrophic winds can rotate in either a clockwise or counterclockwise direction, depending on the specific conditions.

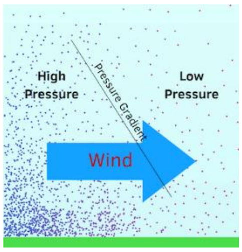
- **Example:**

- ➢ Imagine a tornado;
- ➢ The air is swirling rapidly around a low-pressure center.
- ➢ The centrifugal force, due to the rapid rotation, is balanced by the pressure gradient force (the force that pushes air from high to low pressure), resulting in a cyclostrophic wind flow.



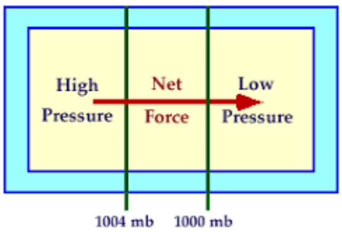
A line drawn on the weather map, connecting points of equal pressure, is called the ISOBAR.

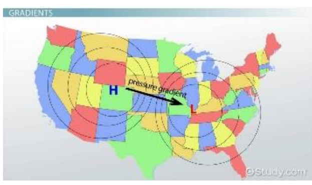




The change in pressure measured across a unit distance is called a Pressure Gradient.

This gradient results in a net force that is directed from High Pressure to Low Pressure. This force is called a Pressure Gradient Force.





This force triggers the initial movement of the air.

Doldrums

- The **equatorial region** is **relatively warmer**, **causing a low pressure area known as the doldrums** (also **known as the equatorial low**).
- It is a **belt of light converging winds and rising air**.
- Sailing vessels tended to drift a lot due to less or no wind movement at all.
- The doldrums, a term originally used by sailors, is called the **Inter-tropical Convergence Zone (ITCZ)**

General wind and Pressure System

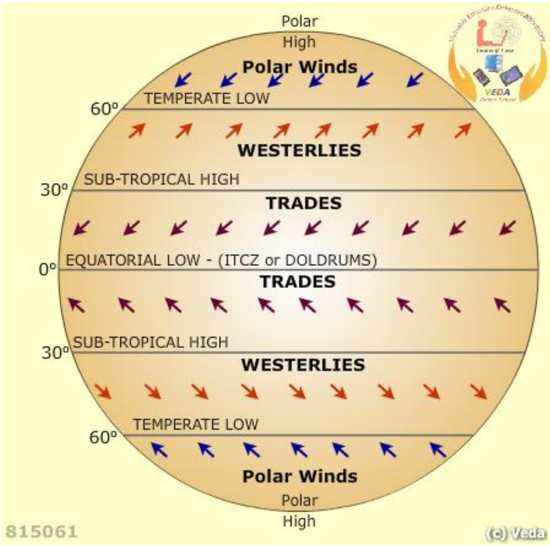
The general pressure and wind systems which would exist if the entire surface of the Earth is only water –

- There would be a permanent low pressure area over the equator (**equatorial low**) and at 60° N & S (**Temperate latitude low**).
- There would be permanent high pressure area at 30° N & S (**sub- tropical high**) and at also the poles (**polar high**).
- Wind would blow from area of high pressure (HP) to area of low pressure (LP) being deflected to its right in the northern hemisphere and left in the southern hemisphere, as shown in the accompanying figure.
- **Because the winds converge at the equator, that area is called the Inter-tropical convergence zone (ITCZ).**
- The converging air would ascend, with little or no horizontal movement.
- Sailing vessels used to be stuck for long periods for lack of wind to propel them.
- **Hence this area is also called 'Doldrums'** meaning **area of inactivity or stagnation.**

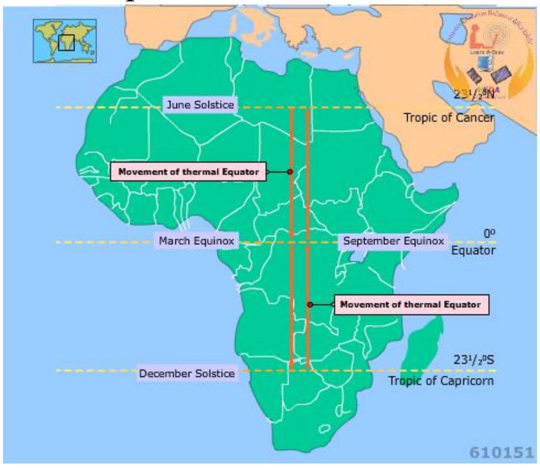
ITCZ (Inter-tropical Convergence Zone)

- Inter-tropical Convergence Zone (ITCZ) is also known by sailors as the **Doldrums** or the **Calms** because of its monotonous, windless weather.
- It is a low-pressure area where the NE and SE trade winds converge.
- It encircles Earth near the thermal equator, though its specific position varies seasonally.

- It is characterised by convective activity, which often generates vigorous thunderstorms over large areas.
- It is most active over continental land masses by day and relatively less active over the oceans.
- It plays an important role in the global circulation system and is also known as the **Equatorial Convergence Zone** or **Intertropical Front**.



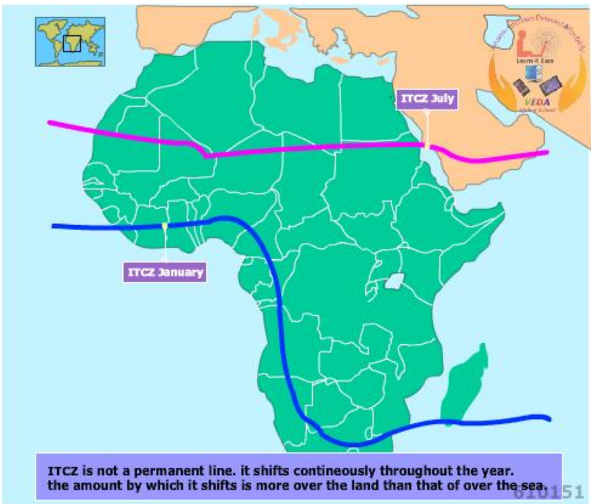
- **Thermal Equator,** also known as **Heat Equator,** is a belt encircling the Earth, defined by the set of locations having the highest mean annual temperature at each longitude around the Earth.
- It is not identical to the geographic Equator.
- Chennai, India, at 13° N 080° E is considered to lie on the thermal equator.



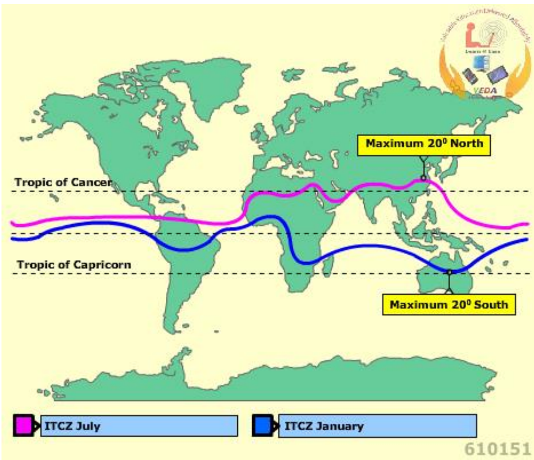
- The movement of the thermal equator causes the prevailing pressure and wind pattern to move to the north and south as shown in the image.
- It is important to understand the cause and impact of the ITCZ.
- Let's take a look at the trade winds and air masses over Africa.
- North-east trade winds originate from the tropical continental air mass.
- South-west trade winds originate from the tropical maritime air mass.

- The tropical maritime air mass originates in the Atlantic Ocean in the vicinity of the Gulf of Guinea.
- Since it is originated in tropical latitudes, it is very warm with high relative humidity. This causes unstable weather in the region.

- The tropical continental air mass originates in the large land mass in low latitudes, such as the Sahara Desert.
- Since it originated in tropical latitudes it is very warm and its relative humidity is low. This causes stable weather in the region.
- When these two air masses meet, moist air is forced upward.



- The rising air is cooled adiabatically causing water vapour to condense, resulting in a band of heavy precipitation around the world.



- As the ITCZ moves north it carries the tropical maritime air mass winds over the land.
- This will bring wet weather.
- Because of the influence of tropical continental winds, places north of the ITCZ will be experiencing hot dry weather.
- Thunderstorms are common phenomena beneath the ITCZ.
- Because of ITCZ's nature of changing location, rainfall is affected in many countries near the equator, resulting in the wet and dry seasons of the tropics.

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Q.4 Ice/ Atmosphere

(Page No 93 to 104)

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Q.4) Ice/ Atmosphere

1) Explain the purpose, duties and responsibilities of International Ice Patrol? (7 times)

(OR),

Describe the function of International Ice Patrol. (7 times)

The International Ice Patrol is an organization operated by the U.S. Coast Guard, established in 1914 after the tragic sinking of RMS Titanic in 1912.
It monitors the presence and movement of icebergs in the North Atlantic Ocean, especially around the Grand Banks of Newfoundland.
The International Ice Patrol (IIP) is recognized under Chapter V/Regulation 6 of SOLAS titled, "Ice Patrol Service".

Purpose of International Ice Patrol Services:

- In general, to contribute to Safety of Life at sea, Safety of Navigation and Protection of the Marine Environment.
- To monitor the extent of the Iceberg danger near the Grand Banks of Newfoundland.
- To provide Limits of All Known Ice (LAKI) to the maritime community.

Duties and responsibilities of International Ice Patrol Services:

- Surveillance of Icebergs by regular aircraft reconnaissance (survey to gain information) and satellite monitoring to detect icebergs drifting near the Grand Banks of Newfoundland.
- Collect data on sea surface temperature, ocean currents, and weather to predict iceberg drift.
- Provide daily North Atlantic Ice Charts showing iceberg danger zones.
- These are broadcasted to ships via radio, NAVTEX, and satellite systems.
- Helps mariners plan safe routes around ice-prone areas during iceberg season (typically Feb–Aug).

Necessity of the Ice Patrol Services

- The cold Labrador Current, carries some Ice Bergs south to the vicinity of the Grand Banks of Newfoundland and into the great circle shipping lanes between Europe and major ports of the East coast of USA and Canada.
- In this area, the Labrador current, meets the warm Gulf Stream and the temperature difference between the two air masses is about 20°C, which results in Dense Fog.
- The combination of Icebergs, fog, severe storms, fishing vessels and busy transatlantic shipping lanes makes this area most vulnerable for navigation.
- While sailing through this area, ships try to make their voyage as short and as economical as possible (Optimum Routeing).
- Therefore, ships in the vicinity of the "Limits of All Known Ice" (LAKI), normally will pass just to south of this boundary.
- For vessels crossing the North Atlantic Ocean , the farther south the Ice Limits are, the farther the ship must travel to avoid the icebergs.

2.a) Explain the formation of sea ice (5 times)

(OR),

Explain with block diagram the various stages in the development of sea ice. (2 times)

(OR),

Explain with help of a suitable diagram the sequential formation of sea ice. (2 times)

Formation of Ice is a complex process. The fresh water and sea water freeze in dissimilar manner.

Formation of Sea Ice

➢ With Salt present in water, it delays the lowering of temperature of the water to below its normal freezing point.

➢ The higher the salinity the greater will be the effect on the freezing of water, i.e it takes longer time to freeze.

➢ As the surface water cools, it becomes more dense and sinks, being replaced by warmer, less dense water from below which in turn, is cooled. This is continued and called Convection.

➢The formation of Ice at Ocean/ Sea thus take sometime to form than does the lake ice in similar conditions.

Stages in the Development of Sea Ice:

(i) Frazil Ice

- Tiny needle-like ice crystals suspended in supercooled water.
- Occurs when sea surface temperature drops below -1.8°C.
- Appears as slushy water.

(ii) Grease Ice

- As frazil crystals accumulate, they form a greasy, soupy layer.
- Looks oily or slick, hence the name.
- Still not solid – flows with water movement.

(iii) Pancake Ice

- Grease ice begins to consolidate into round, flat disks.
- Disks collide and form raised edges.
- Common in turbulent seas.

(iv) Nilas

- A thin, elastic, new sheet of ice formed from freezing of grease ice.
- Dark, flexible, and up to 10 cm thick.
- Can bend without breaking.

(v) Young Ice

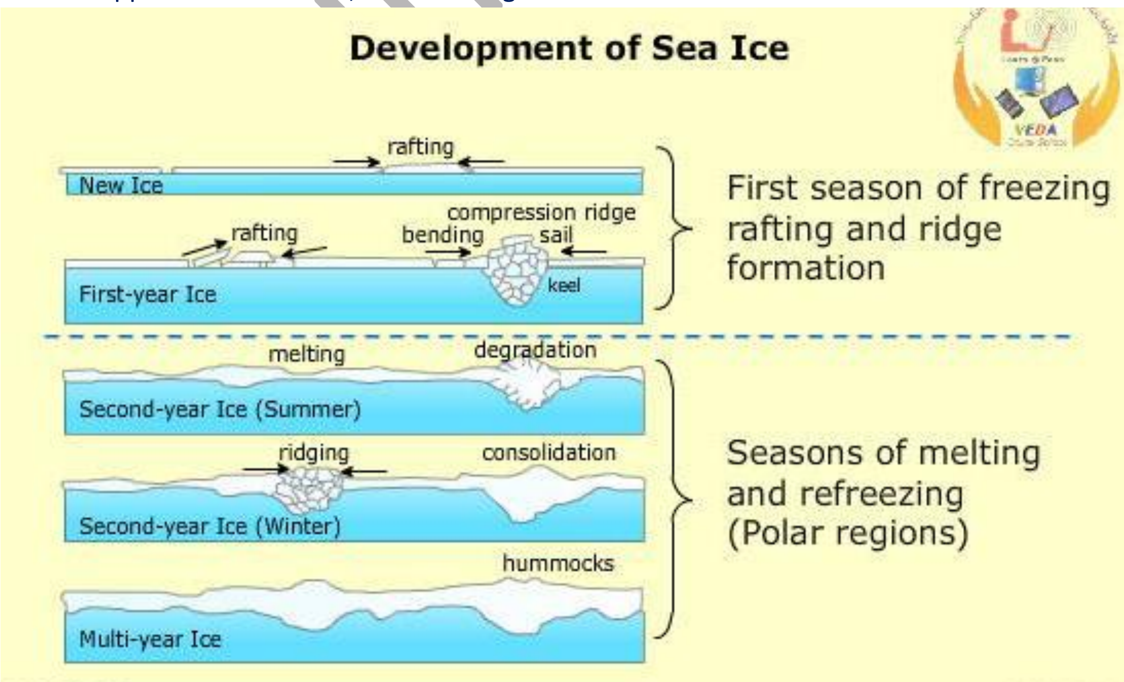
- Transitional stage between nilas and first-year ice.
- Thickness: 10–30 cm.
- Begins to stiffen, with surface ridging possible.

(vi) First-Year Ice

- Ice that has grown through a single winter.
- Thickness: 30 cm to 2 m.
- Harder and less saline than newly formed ice.

(vii) Multiyear Ice

- Survives one or more summer melt seasons.
- Thicker, more compact, and less saline than first-year ice.
- Appears bluish-white, and is stronger.



b) Describe the factors on which the movement of sea ice is dependent upon. (2 times)

Main Factors Influencing Sea Ice Movement:

(i) Wind (Primary Driving Force)

- Wind is the most important factor, accounting for up to 70–80% of sea ice drift.
- Acts on the surface of the ice, pushing it in the wind direction, slightly deflected due to Coriolis effect.
- Stronger wind = faster ice drift.

(ii) Ocean Currents

- Subsurface currents like the Labrador Current, Beaufort Gyre, and East Greenland Current influence the direction and speed of sea ice.
- Sea ice drifts slightly slower than the underlying current.

(iii) Coriolis Effect

- Due to Earth's rotation, ice movement is deflected:
- To the right in the Northern Hemisphere
- To the left in the Southern Hemisphere
- Causes ice to move at an angle (typically 20°–40°) to the wind direction.

(iv) Ice Type and Concentration

- Multiyear ice or thick ice moves slower due to its mass.
- Thin or new ice moves faster and responds more quickly to wind and currents.
- Dense ice packs move as a unit, while loose ice responds more individually.

(v) Geographical Constraints

- Coastlines, islands, and shallow areas (shoals, sandbars) block or redirect ice flow.
- Ice can pile up (ridging or rafting) near obstacles.

(vi) Temperature & Melting

- Melting reduces ice strength, making it more fragile and mobile.
- Brine drainage also affects ice buoyancy and motion.

c) State the limitations of radar as a means of detecting ice. (2 times)

Limitation of RADAR as a means of detecting ice:

(i) Difficulty in Differentiation: Standard marine radar cannot reliably distinguish between different types of ice, such as old ice and first-year ice.

(ii) Sea Clutter: Sea clutter, caused by reflections from waves, can mask the return signals from smaller ice features, making them difficult to detect, especially in close proximity to the vessel.

(iii) Growlers: Small pieces of ice, like growlers, are particularly difficult for radar to detect due to their small size and low radar cross-section.

(iv) Weather Conditions: Heavy precipitation, such as snow or rain, can interfere with radar signals, reducing detection range and making it harder to identify ice.

(v) Ice Thickness and Meltwater: Thick ice or ice with meltwater on the surface can reflect radar signals in a way that makes it difficult to distinguish from open water.

(vi) Limited Range and Resolution: Radar has a limited range, and the resolution may not be sufficient to detect very small ice features at greater distances.

d) Explain the precautions to be taken when navigating in or near an area affected by sea ice. (3 times)

Precautions to be taken when navigating in or near an area affected by sea ice:

(i) Route Planning and Ice Information

- Use updated ice charts from authorities like the International Ice Patrol (IIP) or national ice services.
- Use ice routing services and plan the safest and most ice-free route.
- Avoid routes through high-concentration or multiyear ice, especially if vessel is not ice-class.

(ii) Use of Navigational Aids

- Use radar, ice radar, and satellite images to detect icebergs and ice edges.
- Keep radar gain and clutter settings properly adjusted.
- Use visual lookouts during daylight hours, especially during fog or snow.

(iii) Slow Down Speed

- Reduce speed in ice-infested areas to minimize impact in case of collision with ice.
- Slower speeds allow better maneuverability and reaction time.

(iv) Maintain Effective Lookout

- Post extra lookouts (including from bridge wings or crow's nest).
- Use binoculars and infrared/thermal cameras (if available) during low visibility.

(v) Avoid Ice Pressure Zones

- Avoid areas where ice is compressed by wind or current—risk of hull being trapped or damaged.
- Watch for ridging or rafting zones.

(vi) Avoid Close-Quarter Manoeuvring

- Avoid sudden helm or engine movements in ice.
- Do not attempt to turn sharply or back into ice unless specifically trained and equipped.

(vii) Prepare and Protect Equipment

- Ensure all deck machinery (anchors, winches, rudder) is free of ice and functional.
- Cover air intakes and other vulnerable machinery to prevent ice blockage.

(viii) Monitor Weather & Ice Forecasts Continuously

- Continuously monitor updates via:
- NAVTEX
- SafetyNet (Inmarsat-C)
- HF/MF/VHF broadcasts
- Ice patrol websites

(ix) Be Prepared for Emergency

- Keep lifesaving appliances ice-free and ready.
- Have an emergency plan in case the vessel gets beset (trapped) in ice.

e) Describe the signs which may indicate proximity of ice on clear days and nights

(OR),

Explain signs of approaching Ice bergs and actions will you take on seeing these signs.

Signs of Ice on Clear Days & Nights

(i) Blinking (Ice Blink)

- White glare on the underside of clouds caused by sunlight reflecting off sea ice.
- Appears as a bright patch on the horizon.
- Seen above ice fields even when ice is not directly visible.

(ii) Sudden Drop in Air or Sea Temperature

- Indicates approach to colder ice-covered waters.
- Rapid drop in sea surface temperature (SST) is especially significant.

(iii) Change in Sea Surface Appearance

- Ice-infested waters often appear:
    - Greener, duller, or glassy.
    - Less wave activity or smoother surface due to ice dampening.

(iv) Floating Fragments of Ice

- Presence of growlers, bergy bits, or small ice floes.
- May be difficult to detect by radar, so visual lookout is essential.

(v) Wildlife Indications

- Birds, seals, or penguins can indicate nearby ice fields or icebergs.
- Marine life often follows ice edges.

(vi) Other Ships Altering Course

- Observing other vessels taking avoidance actions or slowing down may indicate ice presence.

<u>Actions to Take on Seeing These Signs</u>

(i) Reduce Speed: Slow down immediately to give more time to maneuvere and reduce collision impact risk.

(ii) Post Extra Lookouts: Use binoculars, night vision (if available), and assign extra watchkeepers on bridge wings or monkey island.

(iii) Alter Course: If ice is sighted ahead, alter course well in advance. Give wide berth (at least 1-2 NM) to any sighted iceberg or icefield.

(iv) Use Radar Carefully: Tune radar settings to detect small targets (use short range, high gain, low clutter).

(v) Monitor Sea Surface Temperature: Keep logging SST using engine room sensors or sea water intake thermometers. Sudden temperature drops indicate ice nearby.

(vi) Inform Engine Room: Put engine room on standby in case rapid maneuvering is needed.

(vii) Report Ice to Authorities: If uncharted ice is found, report to the International Ice Patrol, nearby vessels, or relevant NAVAREA.

(viii) Follow Routing Advice: If in North Atlantic, follow IIP-recommended iceberg limits and ice avoidance routes. Avoid night navigation in iceberg zones if possible.

3) What do you understand by Fast Ice & Pack Ice? Explain with help of a sketch the different manners in which river water (fresh water) and sea water (salt water) freeze as air temperature falls. (6 times)

Fast-Ice: Fast ice is a sea ice which remains stationary, being attached to the shore, rock, shoals, icebergs or other obstruction. It does not move with winds or currents.

Pack Ice: Pack ice is a floating sea ice that is not attached to any land or fixed object. It moves freely under the influence of wind, currents, and tides.

The process by which river water (fresh water) and sea water (salt water) freeze as air temperature falls:

<u>Formation of Sea Ice</u>

Same as Ques 2.b

<u>Formation of Ice in Fresh water</u>

➢ The loss of heat from a body of fresh water takes place mainly from the surface exposed to the air.

➢ As the surface water cools, it becomes dense and sinks and is displaced by warmer less dense water from below setting in Convectional Currents.

➢ The warm water having come on top, will be cooled and continuing the process of overturning, i.e setting up the of the convection till the entire body of water attains a temperature of 4°C.

➢ The maximum density of fresh water occurs at 4°C, and the upturning will be ceased and

➢ Thus if further cooled, the cooling of water below 4°C, causes an increase in its volume and consequently decreases in density and so the convection stops.

➢ Once the stable condition is achieved, cooling of surface water leads to a rapid drop in temperature and formation of ice begins when temperature falls to 0°C.

➢ The thin layer of Fresh water staying on top can then be rapidly cooled down to the Freezing Point and the Ice forms on the surface, while the underlying water may still be close to 4°C.

4.a) What is an iceberg and how it forms?

- Iceberg is a large mass of floating ice, having a height of at least 5 metres above sea level.
- It could be of glacier or ice-shelf origin, and which may be afloat or aground.
- Sizes of icebergs are small, medium, large and very large.
- May be described as tabular, domed, pinnacled, wedged, dry-docked or blocky.

Formation of an Iceberg:

(i) Snow Accumulation

- In cold polar regions, snow falls continuously over many years.
- The snow gradually compresses into firm (compact snow) and then into glacial ice under its own weight.

(ii) Glacier Formation

- Over time, this compressed ice forms a glacier, which slowly moves downhill due to gravity.
- The glacier flows from land into the sea or toward an ice shelf edge.

(iii) Calving

- When a glacier or an ice shelf reaches the ocean, large chunks of ice break off from the edge.
- This process is called calving.
- The broken-off chunk becomes an iceberg and begins to float in the sea.

(iv) Drifting

- After calving, the iceberg floats (since ice is less dense than seawater) and drifts with currents and wind.
- About 90% of an iceberg is underwater, only 10% is visible above sea level.

b) Write down different types of icebergs found at sea

(i) Tabular Iceberg: A flat-topped iceberg whose horizontal dimension is much greater than the vertical dimension. Most show horizontal banding of snow layers.

(ii) Domed Iceberg: An iceberg which is smooth and rounded on top.

(iii) Pinnacled Iceberg: An iceberg with a central spire, or pyramid, with one or more spires.

(iv) Wedged Iceberg: An iceberg which is rather flat on top and with steep vertical sides on one end, sloping to lesser sides on the other end.

(v) Drydocked Iceberg: An iceberg which is eroded such that a U-shaped slot is formed near or at water level, with twin columns or pinnacles. This is also referred to as a twinned iceberg.

(vi) Blocky Iceberg: A flat-topped iceberg with steep vertical sides, usually a fragment of a tabular berg.

(vii) Glacier berg: An irregularly shaped iceberg.

(viii) Iceberg Tongue: A major accumulation of icebergs projecting from the coast, held in place by grounding and joined together by fast ice.

(ix) Sloping iceberg: An iceberg which is rather flat on top and with steep vertical sides on one end, sloping to lesser sides on the other end.

(x) Weathered iceberg: An iceberg that shows marked signs of deterioration from the effects of atmosphere and ocean.

c) Explain the formation of icebergs from floating glaciers, ice shelf and characteristics of each.

(OR),

Define an iceberg. Describe the icebergs of Arctic and Antartic

Icebergs from Floating Glaciers (Tidewater Glaciers)

Formation Process:

- Snow falls in highland polar regions and compacts into ice over time.
- This forms glaciers that flow slowly downhill under gravity.
- When a glacier reaches the coast, it may extend over the sea, becoming a floating glacier
- Eventually, due to stress and buoyancy, chunks of ice break off the edge—this is calving.
- The calved ice floats away as an iceberg.

Characteristics of Icebergs from Glaciers:

- Usually irregular in shape (domed, jagged, pinnacled).
- Contain many cracks and crevasses.
- Often smaller than icebergs from ice shelves.
- Seen in Greenland, Alaska, Arctic etc.

Icebergs from Ice Shelves

Formation Process:

- In Antarctica, continental glaciers flow outward and form huge floating platforms over the sea called ice shelves.
- These shelves are hundreds of meters thick and extend far into the sea.
- Due to internal pressure, wind, and tides, large flat sheets of ice break off (calve) from the ice shelf edge.
- These become massive, tabular icebergs.

Characteristics of Icebergs from Ice Shelves:

- Very large and flat-topped (tabular).
- Often hundreds of kilometers wide and long.
- Have steep sides and may rise high above the sea.
- Common around Antarctica.

5) Describe the Ice bergs of Arctic region and usual path they take. Describe the life span of Arctic region Icebergs. (5 times)

Icebergs of the Arctic Region:

- Origin: Arctic icebergs are primarily calved from glaciers along the coast of Greenland.
- Major sources: Jakobshavn Glacier (West Greenland), Scoresby Sound (East Greenland)
- These glaciers flow into deep fjords and release large chunks of freshwater ice into the sea, forming icebergs.

Usual Path of Arctic Icebergs

(i) West Greenland Current: Icebergs drift south along the coast of Greenland via the cold West Greenland Current.

(ii) Labrador Current: They enter the Labrador Sea and are carried further south by the Labrador Current. This current brings them into the North Atlantic Ocean.

(iii) Grand Banks of Newfoundland: Many icebergs reach the Grand Banks, off the coast of Newfoundland, which is the southernmost limit of Arctic icebergs. This is the same region where the Titanic disaster occurred in 1912.

Greenland → Baffin Bay → Davis Strait → Labrador Sea → Newfoundland (Grand Banks)

Life Span of Arctic Icebergs

- From calving to melting: About 1 to 3 years.
- In open sea (post-calving): Most last several months, depending on:
  - Size
  - Water temperature
  - Wave action
  - Air temperature

6) Discuss with the aid of suitable sketches the normal season and probable movement of North Atlantic Icebergs from birth/origin to decay. (8 times)

(OR),

How do icebergs of the northern hemisphere form and decay? (2 times)

(I) Origin of Icebergs of the North Atlantic Region:

- Origin: Arctic icebergs are primarily calved from glaciers along the coast of Greenland.
- Major sources: Jakobshavn Glacier (West Greenland), Scoresby Sound (East Greenland)
- These glaciers flow into deep fjords and release large chunks of freshwater ice into the sea, forming icebergs.

(II) Normal season of Icebergs of the North Atlantic Region:

Season	Activity Level
Winter (Dec-Feb)	Minimal calving
Spring (Mar-May)	Start of increased calving and iceberg movement
Summer (June-July)	Peak iceberg movement and southern drift
Late Summer-Autumn (Aug-Oct)	Iceberg continue to melt and decay in warmer waters

(III) Probable movement of Icebergs of the North Atlantic Region:

(i) West Greenland Current: Icebergs drift south along the coast of Greenland via the cold West Greenland Current.

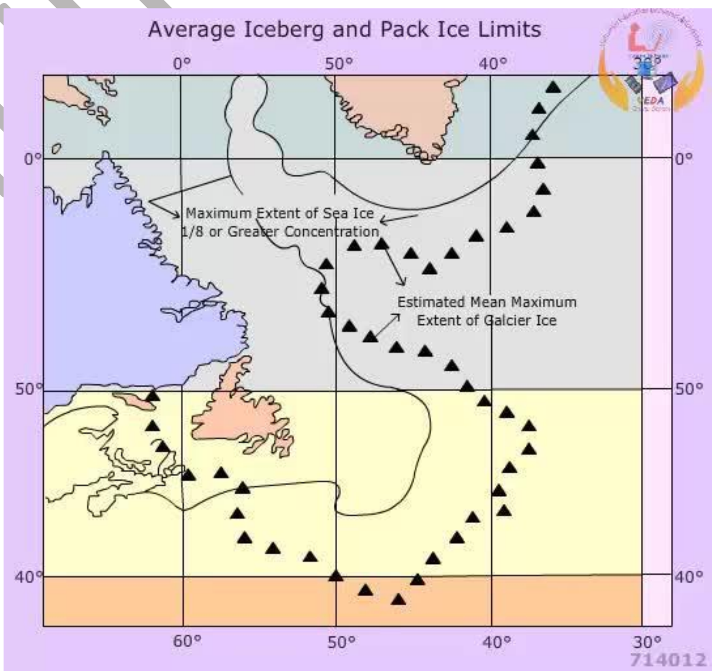
(ii) Labrador Current: They enter the Labrador Sea and are carried further south by the Labrador Current. This current brings them into the North Atlantic Ocean.

(iii) Grand Banks of Newfoundland: Many icebergs reach the Grand Banks, off the coast of Newfoundland, which is the southernmost limit of Arctic icebergs. This is the same region where the Titanic disaster occurred in 1912.

Greenland → Baffin Bay → Davis Strait → Labrador Sea → Newfoundland (Grand Banks)

(IV) Decay of Icebergs of the North Atlantic Region:

- From calving to melting: About 1 to 3 years.
- In open sea (post-calving): Most last several months, depending on:
  - Size
  - Water temperature
  - Wave action
  - Air temperature
- Large icebergs may survive several months to a year, but most melt completely in the North Atlantic before autumn.



7) How is sea ice different from icebergs?

Sea ice and icebergs are both forms of ice found in the ocean, but they originate from different sources and have distinct characteristics.
Sea ice is formed from the freezing of ocean saltwater, while icebergs are chunks of freshwater glacial ice that break off from glaciers or ice shelves.

<u>Sea Ice</u>
Origin: Forms directly from the freezing of seawater at the ocean's surface.
Composition: Primarily composed of frozen saltwater, with some brine (salt water) trapped within its structure.
Formation: Forms and melts entirely within the ocean.
Thickness: Generally thinner than icebergs, typically ranging from a few centimeters to a few meters thick.
Extent: Covers vast areas of the ocean, particularly in polar regions, but its extent fluctuates with the seasons.

<u>Icebergs:</u>
Origin: Formed from glaciers or ice shelves on land. They break off (calve) from these formations and float into the ocean.
Composition: Primarily composed of freshwater ice, which is less dense than saltwater.
Formation: Formed on land and then float into the ocean.
Thickness: Can be significantly thicker than sea ice, with some icebergs being massive structures.
Extent: Individual icebergs can vary greatly in size and shape, from small growlers to massive tabular icebergs.

8.a) Describe the factors which may give rise to **ice accretion** and methods of reducing ice accretion. (8 times)

(OR),

Describe the accretion of Ice and what precaution are required to be taken to avoid ice accretion on-board?

(OR),

What is ice accretion? What are the conditions when this can occur on board? (2 times)

(OR),

Explain the three mechanisms of ice accretion on board a ship.

Ice accretion, also known as icing or glaze, refers to the process where ice accumulates on the surface of an object, typically a solid object, due to freezing precipitation or the freezing of super-cooled water droplets

<u>Factors Which May Give Rise to Ice Accretion</u>
The transit of a cold frontal system in winter will rapidly bring down the air temperature, causing the vessel's steel structure to cool.
Ice accumulates on ships due to three causes:

- Precipitation (rain, drizzle or snow) falling on very cold decks and freezing into ice called hoar frost.
- If the sea surface temperature drops below + 4° C, Water coming on deck - spray (wind force 4 and above) and/or water shipped (due to pitching or rolling in heavy sea and/or swell).
- Direct freezing water droplets in form of fog or mist falling on very cold masts, rigging and superstructure – called rime. It forms on the windward side only and can grow up to one centimetre per day.

<u>Dangers of ice accretion</u>

- Crew cannot go on deck for any work, especially for dropping or picking up anchor.
- Stability of the ship would be reduced – weight of ice above would decrease the GM and also the range of positive stability.
- If such danger is critical, vessel have to steer into lower latitudes – higher temperatures - till the ice melts off.
- Any electrical machinery on deck may not function.
- Vessel's trim may change by the head causing difficulty in steering.
- Pipelines on deck may freeze.
- Viscosity of hydraulic oil in the systems may increase.
- Castings made from cast iron could fracture.
- Icing of bridge windows could occur leading to difficulty in maintaining proper visual lookout.
- Deck scuppers may be blocked.

Preparations if Ice Accretion is expected/ Precaution required to be taken to avoid ice accretion on-board

- Take additional bunkers as an allowance for manoeuvring in heavy weather and for deviations due to ice and ice accretion.
- Maintain a large stock of de-icing salt on board.
- Change to lower sea suction and provide temporary steam pipes at the intakes.
- Cover the mooring lines, cable drums, etc., with plastic covers.
- Cover all exposed motors and control stands.
- In exceptional circumstances, and subject to the vessel's stability, reduce the ballast tank levels if there is a risk of the ballast freezing.
- Check the ballast air-pipes for clogging with ice, prior to any ballasting or de-ballasting.
- If ice accretion is rapid, then maintain steerage away from the spray.
- Keep both anchors slightly out of the hawse-pipes, so that ice formed inside the hawse-pipes can be broken by heaving the anchor.
- Cover the spurling pipes.
- Cover the fairlead openings by canvas and wooden templates.
- Keep crowbars and ice-picks ready for use.
- The crew should be appropriately clothed according to the temperature and wind conditions.
- Keep the Radars on 'stand by' if not in use.
- Switch on the bow thruster heater for about 3 hours before arrival, and turn them slowly every hour to ensure that the oil is warm.
- Check electrical insulation.
- Drain the fire lines on deck and grease their expansion joints.
- Spread de-icing salt on decks.
- Lower a length of manila rope in the scuppers to prevent icing.
- Switch on the heating coils of the emergency generator.
- Follow the manufacturer's instructions with regard to the engine cooling system. Fill it with a solution of water and antifreeze at the recommended ratio to provide protection down to at least minus 40° C.
- Maintain the outside air-circulation into the engine room at the minimum required.
- Close all doors to all spaces.
- Close the Fore Peak tank manually operated valves.
- Close all tank manholes.
- Turn on the accommodation heating and ensure that the sanitary and domestic water flow is satisfactory.

Methods of reducing ice accretion
Heating: Applying heat to surfaces using hot air, resistive heating elements, infrared radiation, or microwave heaters can melt ice or prevent its formation.
Mechanical Removal: Techniques like pneumatic systems, water jets, or ultrasonic vibrations can dislodge ice buildup.
Expulsive Methods: Using pressurized air or other means to physically expel accumulated ice.
Ice-phobic Coatings: Materials like super-hydrophobic surfaces can reduce ice adhesion and promote ice shedding.
Surface Geometry: Modifying surface shapes to minimize water droplet impact and ice accumulation.
Anti-icing Fluids: Applying fluids that prevent water droplets from freezing or delay the freezing process.
De-icing Salts: Using chemicals like sodium chloride or magnesium chloride to lower the freezing point of water and aid in ice removal.

b) What are the duties of Master when such conditions are encountered at sea? (2 times)

It is the responsibility of the master to monitor routine navigational, meteorological, and environmental data including ice data, ice charts and satellite images when navigating in colder regions or seasonal winter regions where ice formations could be possible.

Write more same points as of Precaution required to be taken to avoid ice accretion on-board from Ques 8.a

9.a) What do you understand by **"Ice Accumulation"**? (2 times)

Ice accumulation refers to the build-up of ice over time, typically caused by freezing rain, sleet, or freezing drizzle. It can also occur through the freezing of water vapour (rime ice) or the re-freezing of melted snow and ice.

Ice accumulation may occur from three causes:

- Fog, including fog formed by evaporation from a relatively warm sea surface, combined with freezing conditions;
- Freezing drizzle, rain or wet snow.
- Spray or sea water breaking over the ship when the air temperature is below the freezing point of sea water (about -2° C).

b) What precautions would you take to minimize ice accumulation on board? (3 times)

Write same points as of <u>Precaution required to be taken to avoid ice accretion on-board</u> from Ques 8.a

10) Hazards associated with ice accretion and ice accumulation (2 times)

Write same points as of <u>Dangers of ice accretion</u> from Ques 8.a

11) Explain the phenomenon of freezing spray and actions to be taken to minimize its effects

<u>Icing from Sea Water</u>

- When the air temperature is below the freezing point of sea water and the ship is in heavy seas, considerable amounts of water will freeze on to the superstructure and those parts of the hull; which are sufficiently above the waterline to escape being frequently washed by the sea.
- The amounts so frozen to surfaces exposed to the air will rapidly increase with falling air and sea temperatures; and have in extreme cases lead to the capsizing of vessels.
- Nevertheless, the dangerous conditions are those; in which strong winds are experienced in combination with air temperatures of about -2°C or below; freezing rain or snowfall increases the hazard.
- The rapidity with which iceberg accumulates increases progressively as the wind increases above force 6 and as the air temperature falls further below about -2°C.
- It also increases with decreasing sea temperatures.
- The rate of accumulation also depends on other factors; such as the ship's speed and course relative to the wind and waves, and the particular design of each vessel.

12) Information given in ice charts

Ice analysis charts: These charts indicate amounts and boundaries of each type of ice, ice-packs, ice-leads and ice-bergs, based on actual observation.

Ice prognosis charts: These charts contain the same type of information as ice analysis charts, but predicted for a specified future time, and are usually made 12 hours and 24 hours in advance.

After studying the situation shown by the ice analysis chart and taking into account various factors such as winds, currents, temperatures of air and sea, etc., the prognosis charts are made by experts.

13) What all details are promulgated in the ice report?

(OR),

What report you will file on encountering ice at Sea.

Extract from Regulation 32 of Chapter V of SOLAS 1974, entitled 'Information required in danger messages':

- Ice, derelicts and other direct dangers to navigation:
  - The kind of ice, derelict or danger observed
  - The position of the ice, derelict or danger when last observed
  - The time and date (Universal Coordinated Time) when the danger was last observed.

- Subsequent observations: Sub-freezing air temperatures associated with gale force winds causing severe ice accretion on superstructures:
  - Time and date (Universal Coordinated Time)
  - Air temperature
  - Sea temperature (if practicable)
  - Wind force and direction

<u>Examples of messages</u>

Ice
TTT ICE. LARGE BERG SIGHTED IN 4506 N, 4410 W, AT 0800 UTC. MAY 15.

Icing
TTT EXPERIENCING SEVERE ICING. 1400 UTC. MARCH 2. 69 N, 10 W. AIR TEMPERATURE 18F (-7.8C). SEA TEMPERATURE 29F (-1.7C). WIND NE. FORCE 8.

14) Write down the obligation of Ship's Master for reporting dangerous ice

Write same as Ques 13

Q.5 Ocean Currents/ Waves

(Page No 106 to 122)

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Q.5) Ocean Currents/ Waves

Ocean Currents

1) Explain main causes of ocean currents. Give example of two warm ocean currents and two cold currents and causes of these currents. (2 times)

(OR),

What are the primary factors influencing the motion of surface currents. What is the indirect effect of wind on the surface currents & how do they affect the strength of currents as well as local climate? (2 times)

(OR),

a) Explain reasons of current. (5 times) b) Identify any two major ocean currents and write short notes on them.

Main causes of ocean currents are as follows:

(i) Gravity

- Diameter at pole is lesser than the diameter at Equator, hence the gravitational pull at the Pole is more than at the Equator.
- This causes the water at Poles to subside and is replaced by the water from Equatorial region.
- This helps in creating a flow of water from Equator towards the poles on the sea surface

(ii) Coriolis force

- Due to rotation of the Earth, the movement of water will be deflected to the right in the Northern hemisphere and to the left in the Southern hemisphere.
- This force is minimum at the Equator and maximum at the Poles.
- This causes the water to flow in a circular fashion in all the oceans.
- In North Atlantic and Pacific Oceans, the currents flow in clockwise direction,
- While in South Atlantic, South Pacific and Indian Oceans currents flow in anti-clockwise direction.

(iii) Wind

- The impact of wind on sea surface and the resulting friction between water and air creates a flow of water in the direction of wind.
- This is very prominent in the Arabian sea during SW monsoon, which causes the current to flow from the SW direction, which is against the normal clockwise flow during other parts of the year.
- Similar effect takes place in the Bay of Bengal during NE monsoon when the current flows from NE direction against the normal clockwise flow during other parts of the year.
- NE and SE trade winds blowing towards the Equator cause the Equatorial current North and South of the Equator to flow in the Westerly direction.
- Similarly, Westerlies blowing in Lat. 40°N cause the North Atlantic and North Pacific currents to flow Eastward,
- While the Westerlies blowing in Lat. 40°S create the Southern Ocean current.

(iv) Pressure

- In high-pressure region, the water level will tend to fall, while in a low-pressure region, the water level will tend to rise.
- This could generate a flow of water on the sea surface from low pressure region towards high-pressure region.

(v) Precipitation

- Heavy rainfall in a particular region will increase the sea level.
- Consequently, this will generate a flow of water towards an area having no rain fall.

(vi) Density

- Density of water increases due to increase in salinity and due to high evaporation, while it reduces due to high temperature.
- Combination of all these factors can cause the water of high density to subside, which will be replaced by flow of water of less density from another region.

(vii) Coast-line

- A current flowing in a particular direction due to the above causes will change direction due to land masses or coast line in its path.

Warm and Cold Currents

Whenever a current is warmer or colder than the sea through which it flows, it is called a warm or cold current respectively.

Warm currents: When a current from equatorial regions passes through higher latitudes, it will be a warm current.
Warm currents are generally experienced along the western shores of large oceans.

Examples of warm currents:

1. The Gulf Stream,
2. The North Atlantic Drift,
3. The Norwegian Current,
4. The Brazilian Current,
5. The Kuro Shio,
6. The Alaskan current,
7. The East Australian current,
8. The Mozambique current,
9. The Agulhas current.

Cold currents: When a current from higher latitudes passes through lower altitudes, it will be a cold current.
If it came from polar regions, it will be very cold.
Cold currents are generally experienced along the eastern shores of large oceans.

Examples of cold currents:

1. East Greenland current
2. Baffin Land current (Davis current)
3. Kamchatka current.
4. The Labrador current,
5. The Portuguese and Canary currents,
6. The Falkland current,
7. The Benguela current,
8. The Oya Shio,
9. The Californian current,
10. The Humboldt current and
11. The West Australian current.

2)a) Describe the effect of wind blowing over a long coastline and how this influences the currents in the South Pacific Ocean. (2 times)

Write joint answers from Q.No.1 & 9.a

b) Describe the effect that the rotation of earth has on ocean currents. Why is the direction of the surface current in any particular area parallel to the isobars there?

- Due to rotation of the Earth, the movement of water will be deflected to the right in the Northern hemisphere and to the left in the Southern hemisphere.
- This force is minimum at the Equator and maximum at the Poles.
- Major surface currents are driven by wind, which drags on the water surface. The Coriolis effect deflects these wind-driven currents, causing them to form large, circular gyres.
- The pressure gradient force causes air to move from high to low pressure. As this air is deflected by the Coriolis force, it flows along the isobars (lines of equal pressure).
- Similarly, surface ocean currents, driven by wind, also tend to flow parallel to isobars due to the same balance of forces.

3) What are the differences between a drifts and stream current? Mention a good example of each. Name the prominent currents of South Pacific Ocean? (3 times)

Write joints answers from Q.No.4(i) & 9.a

4) Explain briefly: (i) Drift Current (ii) Upwelling Current (iii) Gradient Current (6 times)

(OR),

Explain the cause of Gradient Current. (2 times)

(OR),

Briefly explain Gradient Current and Up-welling current. Give suitable examples (4 times)

(i) Drift Current

- Drift is the direct effect of wind blowing over long stretches of ocean for long periods.
- The frictional effect of the wind, on the sea surface, causes the sea surface to move.
- However, Coriolis force deflects the drift current to the right in the northern hemisphere (left in the southern hemisphere) by about to 30° to 45°.
  Example of drift current are:
  - North and South Equatorial currents are caused by the Trade winds.
  - North Atlantic and North Pacific currents are caused by the Westerlies.
  - Southern Ocean current is caused by the Westerlies.
- The maximum strength of a drift current is only up to about 2 knots.
- If, however, there are other strengthening factors such as gradient, shape of the coast, etc., the drift current can increase two or three-fold and is then called a stream.
  Movement of a large mass of water in a definite direction is known as **stream current.** It is faster than the drift. Example: Gulf stream, Kuroshio Current

(ii) Upwelling Current

- When wind blows across the ocean surface, they can push surface water away from coastline or in open sea areas. The outflow of water from the coast is replaced by an upward/vertical movement (upwelling) of sea-water, from a depth up to about 150 metres or so.
- Since this upwelling takes place from below, the water that comes to the surface is colder than the surrounding sea-surface.
- Upwelling is a significant process that replenishes nutrients in surface waters, leading to increased biological productivity and supporting rich marine ecosystems.
- Upwelling currents are experienced along the eastern shores of oceans, in low latitudes where direct effect of wind blowing over long stretches of ocean for long periods.
  Example of upwelling current are:
  - Canary current and Benguela current of the East Atlantic.
  - Californian current and Peru (Humboldt) current of the East Pacific.

(iii) Gradient Current

- A gradient current is caused by differences in level (resulting from natural slopes or build-up by winds) or by differences in density (resulting from differences of temperature or salinity).
- The greater the salinity, the greater the density and vice versa.
- The lower the temperature, the greater the density and vice versa.
- When different water-masses lie adjacent to each other, gradient currents are set up between them because of differences in temperature and salinity.
  Example of gradient current are:
  - The surface current that flows from the Atlantic into the Mediterranean is a result of differences in level.
  - The Mediterranean Sea, being land-locked, experiences severe evaporation. Since the input by rivers and rain is very small, its level falls and a gradient current from the Atlantic flows in through the Strait of Gibraltar.
  - The northerly current along the east coast of Africa in the Arabian sea.
  - Along the east coast of India in the Bay of Bengal, during the latter part of the NE monsoon, flows against the NE winds because of a thermal gradient.
  - The gradient is formed by the cooling of the waters at the head of the Arabian Sea & Bay of Bengal by the cold NE monsoon during December and January.

5)a) Why the surface currents attain higher rates in Western side of oceans as compared to Eastern side of Ocean (2 times)

- Western ocean currents are stronger than eastern ocean currents due to a combination of the Coriolis effect, prevailing winds, and the shape of ocean basins.
- The Coriolis effect, caused by the Earth's rotation, deflects ocean currents.
- In the Northern Hemisphere, currents are deflected to the right, and in the Southern Hemisphere, they are deflected to the left.
- This, along with wind-driven surface currents, creates a westward-flowing current along the western side of ocean basins, known as western boundary currents, which are faster than the weaker eastern boundary currents.

Here's a more detailed explanation:
Wind-driven circulation: Prevailing winds, like the trade winds and westerlies, create large, circular surface currents called gyres in the major ocean basins.
Coriolis effect: The Coriolis effect causes these gyres to displace their centers westward, resulting in strong western boundary currents along the eastern coasts of continents.
Western intensification: This westward intensification of currents occurs because the Coriolis effect is stronger at higher latitudes, and the flow is channelled into a narrower band.
Steep ocean-surface slope: The transport of surface waters towards the western boundary causes the ocean surface to slope more steeply on that side, resulting in faster geostrophic flow.

b) Eastern shore of large Ocean are prone to which currents? Give some examples.

- The eastern shores of large oceans are primarily prone to cold currents.
- These currents transport cooler water from the poles or high latitudes, typically along eastern coastlines in both the northern and southern hemispheres.
- Warm currents, which transport warmer water from the tropics, are more commonly found along western coastlines.

  Examples of cold currents along eastern shores:
    - Humboldt Current (Pacific Ocean): Flows southward along the coast of South America.
    - Canary Current (Atlantic Ocean): Flows southward along the coast of Africa.
    - Benguela Current (Atlantic Ocean): Flows southward along the coast of South Africa.
    - California Current (Pacific Ocean): Flows southward along the coast of North America.
    - Kurile (Oyashio) Current (Pacific Ocean): Flows southward along the coast of Asia.
    - East Greenland Current (Atlantic Ocean): Flows southward along the coast of Greenland.

6) Describe how the weather is affected by various currents?

<u>Effects of ocean currents on climate</u>
The effects of ocean currents on climate are numerous and a few are listed below as examples:
➢ UK and northern coasts of Europe are to warmer in January than Newfoundland.
➢ The Westerlies, blowing over the former, come from over the warm North Atlantic current and carry the oceanic influence far inland, whereas the Westerlies over the latter, come from cold hinterland.
➢ Ports in Eastern Canada (latitude 55°N) are ice-bound in winter, whereas the ports in Norway (latitude 70°N), are not ice-bound.
➢ Callao (latitude about 12°S), in Peru, is about 6°C cooler than Salvador (similar latitude) in Brazil.

7) Describe the surface current circulation in the **North & South Atlantic Ocean** along with the causes of formation of these currents. (4 times)

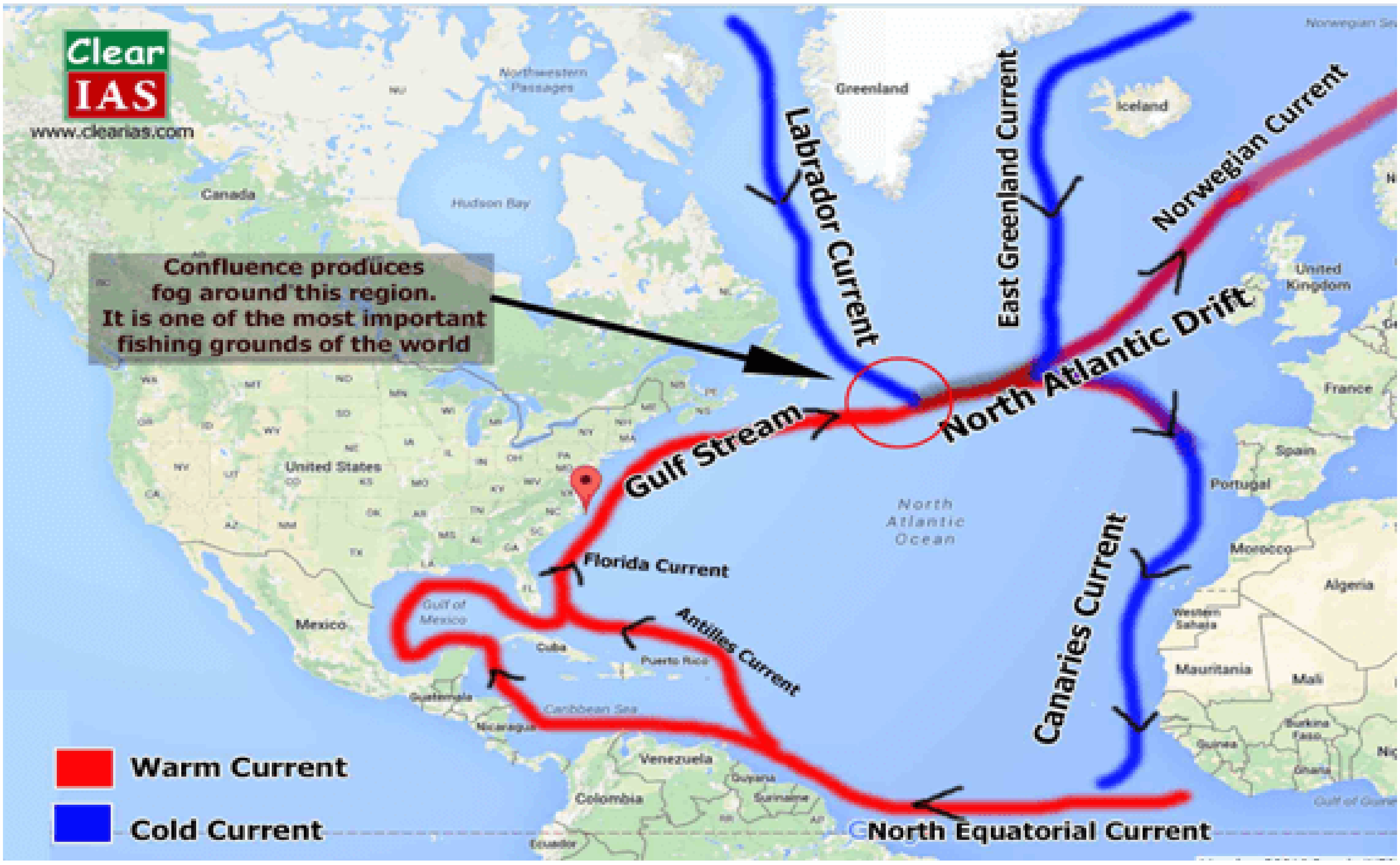
(OR),

Describe with suitable sketch the Ocean currents of North Atlantic Ocean. Identify the warm and cold currents. (3 times)

North Atlantic Ocean

Ocean currents in the North Atlantic Ocean are as follows:

Sr No	Name of Current	Warm or Cold current	Direction & Other description
1	North Equatorial Current	Warm Current	These currents originate at about 23° North and flow due WEST at an average speed of about 0.7 knots.
2	The Gulf Stream	Warm Current	These currents originate in the Gulf of Mexico and NW of Cuba and flows NE along the eastern coast of the United States and Canada.
3	**The North Atlantic Current**		The eastward moving Gulf Stream widens and changes direction to NE to form the North Atlantic Current.
3.a	Norwegian Current	Warm Current	NE Drift Current is the NE extension of the Gulf Stream, which continues to carry warm water towards northern Europe
3.b	Irminger Current	Warm Current	Part of the NE Drift current branches to form Irminger Current. Irminger current flows NW and curves to meet the East Greenland Current.
3.c	East Greenland Current	Cold Current	This current flows on the east coast of Greenland. It flows South West and South.
3.d	West Greenland Current	Cold Current	The West Greenland current continues to flow along the west coast of Greenland and through "Davis Strait" and "Baffin Bay"
3.e	Labrador Current	Cold Current	It flows from the Arctic Ocean, south along the coast of Labrador and around Newfoundland, to the Great Banks. It carries large quantity of ice with it.
4	The Canary Current	Cold Current	It flows southward along the western coast of Africa, and then westward towards the Caribbean.



South Atlantic Ocean

Ocean currents in the South Atlantic Ocean are as follows:

Sr No	Name of Current	Warm or Cold current	Direction & Other description
1	South Equatorial Current	Warm Current	It is flowing Westwards, under the influence of Trade winds. It is found South of the Equator and parallel to it, in Lat. 20°S
2	Southern Ocean Current	Warm Current	It flows Eastwards and part of it curves towards North on passing the Sothern tip of South America (Cape Horn). It continues to flow Northward as "Falkland current and meets the Brazil Current which is flowing in the opposite direction.
3	Brazil Current	Warm Current	It is also a warm current in continuation of the South Equatorial current flowing Southwards.
4	Fakland current	Cold Current	It is a cold current. It is coming from Cape Horn to meet the warm Brazilian current in Lat. 40°S where Advection fog is formed.
5	South Atlantic current	Cold Current	It flows Eastwards into the ocean. It is joined by both the above currents.
6	Agulhas current	Cold Current	It is coming from the Cape of Good Hope. It meets a part of the Southern Ocean current and flows Northwards.
7	Benguela Current	Cold Current	It meets the Agulhas current near West coast of Africa, and It flows NW wards to ultimately meet the South Equatorial current to complete an anti-clockwise circulation.

8)a) Explain with reason the flow of surface and under current in strait of Gibraltar. (5 times)

The Strait of Gibraltar is a narrow waterway connecting the Atlantic Ocean and the Mediterranean Sea. It exhibits a very important and unique two-layer flow system involving surface current flowing eastward and undercurrent flowing westward.

Here's the detailed explanation with reasons:
Flow Pattern in the Strait of Gibraltar:

1. Surface Current – Eastward (from Atlantic to Mediterranean)
   Direction: From the Atlantic Ocean into the Mediterranean Sea.
   Reason:
   - The Mediterranean Sea has high evaporation rates, especially in the eastern part (due to hot and dry climate).
   - This results in a net loss of water from the Mediterranean.
   - To compensate for this water loss, Atlantic surface water flows eastward through the Strait of Gibraltar.
   - This inflow is warmer, less salty, and less dense compared to Mediterranean water.

2. Under Current – Westward (from Mediterranean to Atlantic)
   Direction: From the Mediterranean Sea into the Atlantic Ocean, at depths below 150–200 m.
   Reason:
   - The water in the Mediterranean becomes more saline and denser due to:
     - High evaporation
     - Limited freshwater inflow
     - Restricted exchange with the open ocean
   - This dense water sinks and flows outward at depth into the Atlantic as a subsurface counter-current. Known as the Mediterranean Outflow Water (MOW).

b) Explain with sketches, the formation of Benguela Current on the West coast of Africa. (3 times)

Direction: Along the south-western coast of Africa, the Benguela Current flows northward.
It is a cold current which meets the Agulhas current near West coast of Africa, and It flows Northward to ultimately meet the South Equatorial current to complete an anti-clockwise circulation.

Formation:

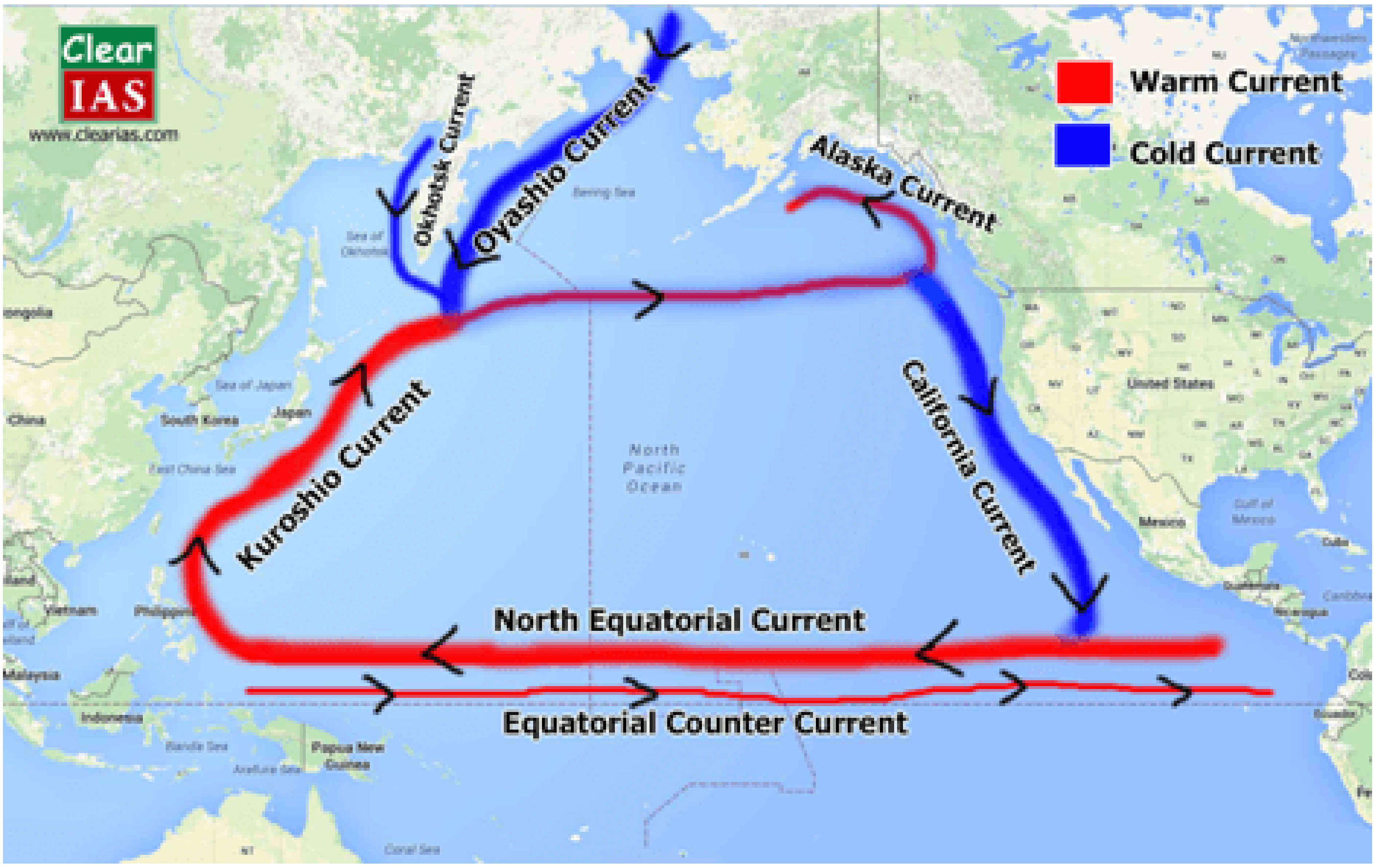
South Atlantic Gyre: The Benguela Current is part of the larger South Atlantic Gyre, a system of rotating ocean currents.
South Atlantic Current: A branch of the West Wind Drift (Antarctic Circumpolar Current) flows eastward and then northward along the coast of South Africa.
Prevailing Winds: South-easterly trade winds blow along the coast, pushing surface water away from the shore.
Upwelling: This offshore water movement causes cold, nutrient-rich water from the deep ocean to rise to the surface along the coast, forming the Benguela Current.

9.a) Describe with suitable sketch the Ocean currents of **North and South Pacific Ocean**. Also identify the warm and cold currents.

North Pacific Ocean

Ocean currents in the North Pacific Ocean are as follows:

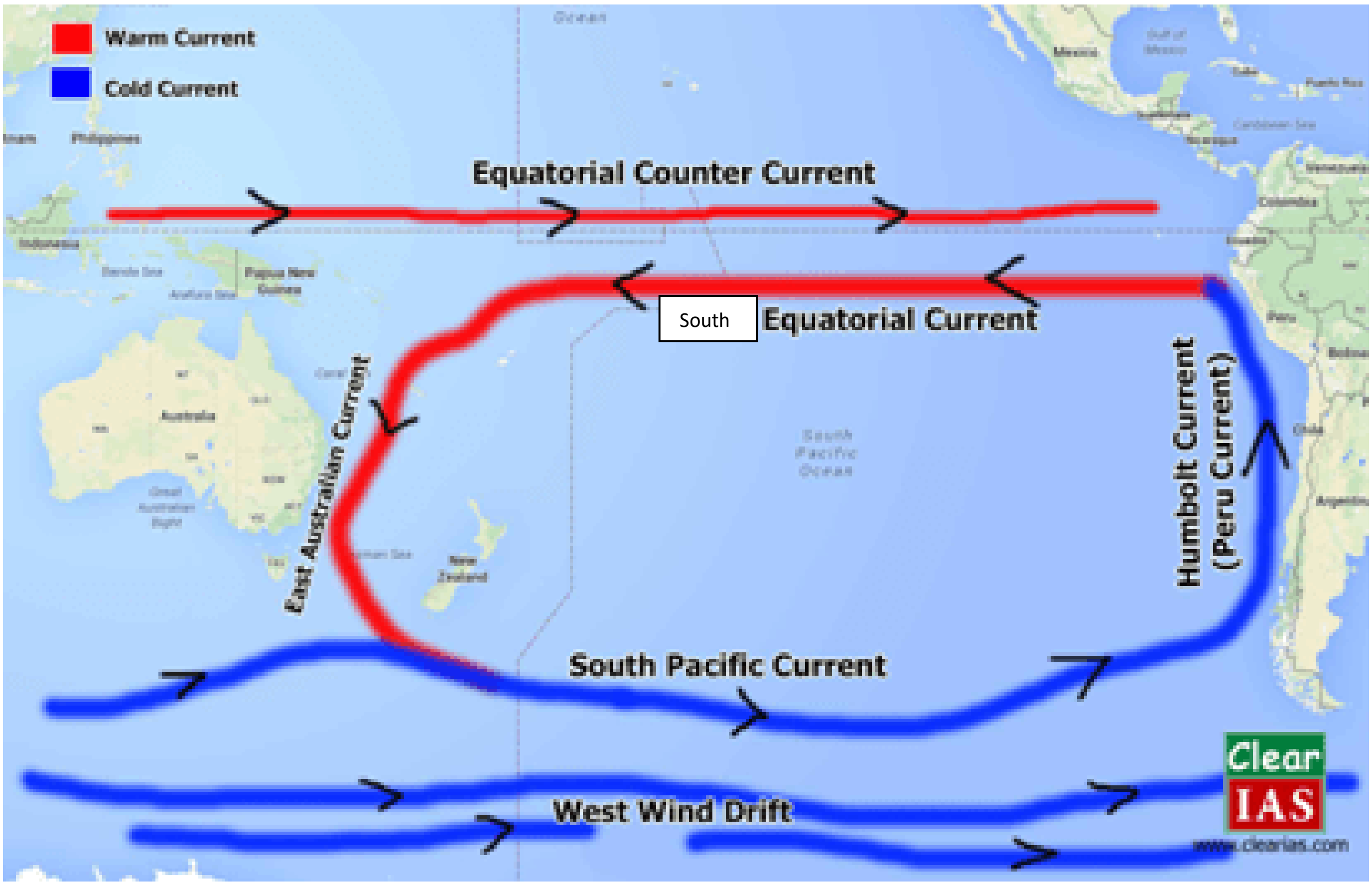
Sr No	Name of Current	Warm or Cold current	Direction & Other description
1	North Equatorial Current	Warm Current	It is flowing Westwards, under the influence of Trade winds. It is located North of the Equator and parallel to it, in Lat. 20°N.
2	Kuroshio Current	Warm Current	It is continuation of the North Equatorial current near Philippines, flowing NE wards along the coast of Taiwan and Japan.
3	Oyashio Current	Cold Current	It flows SW wards along the eastern coast of Hokkaido (Japan) and then curves eastward towards the Pacific Ocean. It meets the warm Kuroshio current, due to which Advection fog is formed on the East coast of Japan.
4	The North Pacific Current	Warm Current	It is continuation of both the above currents flowing Eastwards in Lat. 40°N.
5	Californian current	Cold Current	It is continuation of part of the North Pacific current flowing Southwards along the coast of California. It finally joins with the North Equatorial current to complete a clockwise circulation.



South Pacific Ocean

Ocean currents in the South Pacific Ocean are as follows:

Sr No	Name of Current	Warm or Cold current	Direction & Other description
1	South Equatorial Current	Warm Current	It flow westward and slowly turn SW and later South along the East Coast of Australia to form the East Australian Coast Current.
2	East Australian Current	Warm Current	It is continuation of the South Equatorial current flowing Southwards along the coasts of Australia and Tasmania.
3	South Pacific current	Cold Current	It flows Eastwards circumventing the Earth. It is joined by the East Australian current at South of New Zealand.
4	West Wind Drift	Cold Current	It flows eastward that encircles Antarctica and connects all three major ocean basins (Pacific, Atlantic, and Indian)
5	Humbolt current (Peru Current)	Cold Current	It flows Northwards along the Peru coast (western coast of South America), and it finally joins the South Equatorial current to complete an anti-clockwise circulation.



9.b) Describe the cause of formation of Kuroshio Current in North Pacific Ocean. (2 times)

The cause of formation of Kuroshio Current in North Pacific Ocean:

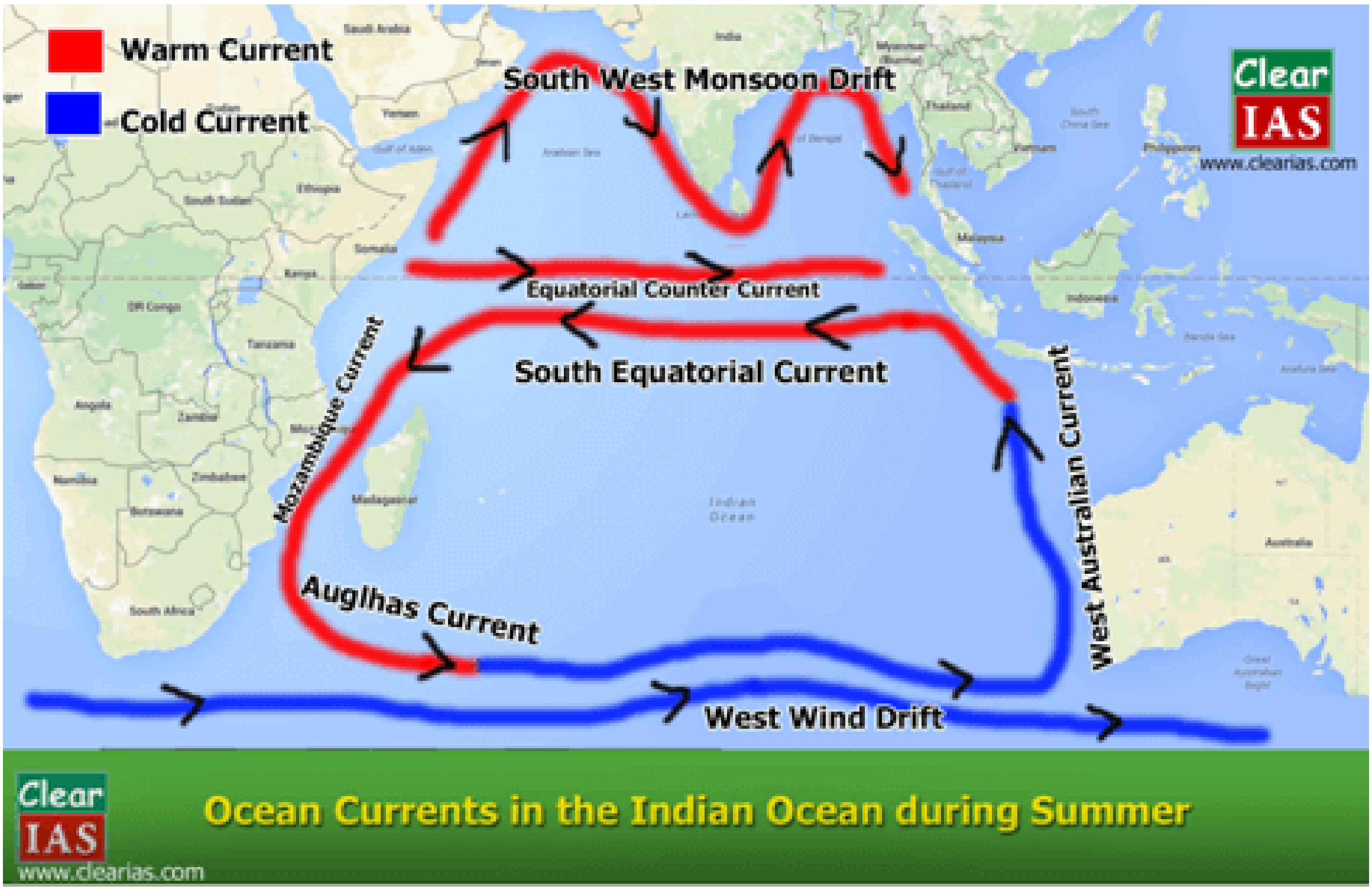
- Factors like wind patterns, water density differences (due to temperature and salinity), and the Coriolis effect (caused by Earth's rotation) play a role in shaping the Kuroshio ocean currents in North Pacific Ocean.
- The Kuroshio's origin from the westward-flowing North Equatorial Current. This current is driven by the trade winds and is part of the larger North Pacific Subtropical Gyre.
- Bifurcation: As the NEC approaches the Philippines, it encounters the archipelago and begins to split. This splitting is influenced by the Coriolis effect and the presence of landmasses.

10.a) Sketch and describe the currents of the **South Indian Ocean.** Also identify the warm and cold currents.

South Indian Ocean

Ocean currents in the South Indian Ocean are as follows:

Sr No	Name of Current	Warm or Cold current	Direction & Other description
1	South Equatorial Current	Warm Current	It is flowing Westwards, under the influence of Trade winds. It is found South of the Equator and parallel to it, in Lat. 20°S
2	Mozambique current	Warm Current	It is continuation of the South Equatorial current. After striking the East coast of Africa, it flows Southwards along the African coast.
3	Agulhas current	Warm Current	It is continuation of the Mozambique current. Part of it flows further Southwards and goes around the Cape of Good Hope to form the Benguela current on the West coast of Africa, and another part flows Eastwards.
4	Southern Ocean current	Cold Current	It flows Eastwards circumventing the Earth and is joined by the Agulhas current.
5	West Australian current	Cold Current	It is continuation of the Southern Ocean current flowing Northwards along the West coast of Australia, and finally joins the South Equatorial current to complete an anti-clockwise circulation.



b) Describe the current circulation in **Bay of Bengal** during SW Monsoon and NE Monsoon. (3 times)

During South West Monsoon:

- During the southwest monsoon season (June-September), there is a southwest ward-flowing current along the western coast of India.
- This current is caused by the southwest monsoon winds blowing from the Arabian Sea towards the Indian subcontinent.
- In the Open waters this current is Easterly.
- The coastal circulation of water in the Arabian Sea and Bay of Bengal is both clockwise and is strengthened.

During Northeast Monsoon:

- During the northeast monsoon season (October-March), there is a reversal of the currents along the eastern coast of India.
- The northeast monsoon winds blow from the northeast towards the Indian Ocean, causing a northeast ward-flowing current along the eastern coast.
- In the open waters of both Arabian Sea and Bay of Bengal, the current sets in a westerly direction.
- Near the coasts of the Arabian Sea, there is a weak circulation in the anti-clockwise direction.
- In the northern part of Bay of Bengal, the circulation is clockwise.

Later NE Monsoon Circulation (FEB- APR)

- In the open waters near the Equator, the flow changes to Easterly.
- Near the coast of the Arabian Sea, circulation is reversed to Clockwise direction.
- The flow of water in Bay of Bengal however remains unchanged.
- The currents are much variable in this season than from November to January.

c) Give a brief description of the currents in the **Arabian Sea** for January and July. Explain the reasons for the difference during these months? (2 times)

Current in the Arabian Sea for January
See NE monsoon of 10.b

Current in the Arabian Sea for January
See SW monsoon of 10.b

11)a) What are the wind and current a ship will face in its journey from Liverpool to Cape Town? (2 times)

Region	Winds	Currents	Effect
North Atlantic (Liverpool)	Westerlies (SW)	North Atlantic Drift	Adverse wind and current
Subtropical High (~30°N)	Calm/light	Canary Current (southward)	Favorable current
NE Trade Belt (30°N-10°N)	NE Trade Winds	North Equatorial Current	Favorable wind, side current
Equator (ITCZ)	Calms, squalls	Equatorial Counter Current	Unpredictable
SE Trade Belt (5°S-30°S)	SE Trade Winds	South Equatorial Current	Favorable wind, westward set
Subtropical High (~30°S)	Calm/light	Benguela Current (northward)	Adverse current
Cape Town Approach	Westerlies (SW)	Benguela + eddies	Head wind, adverse current

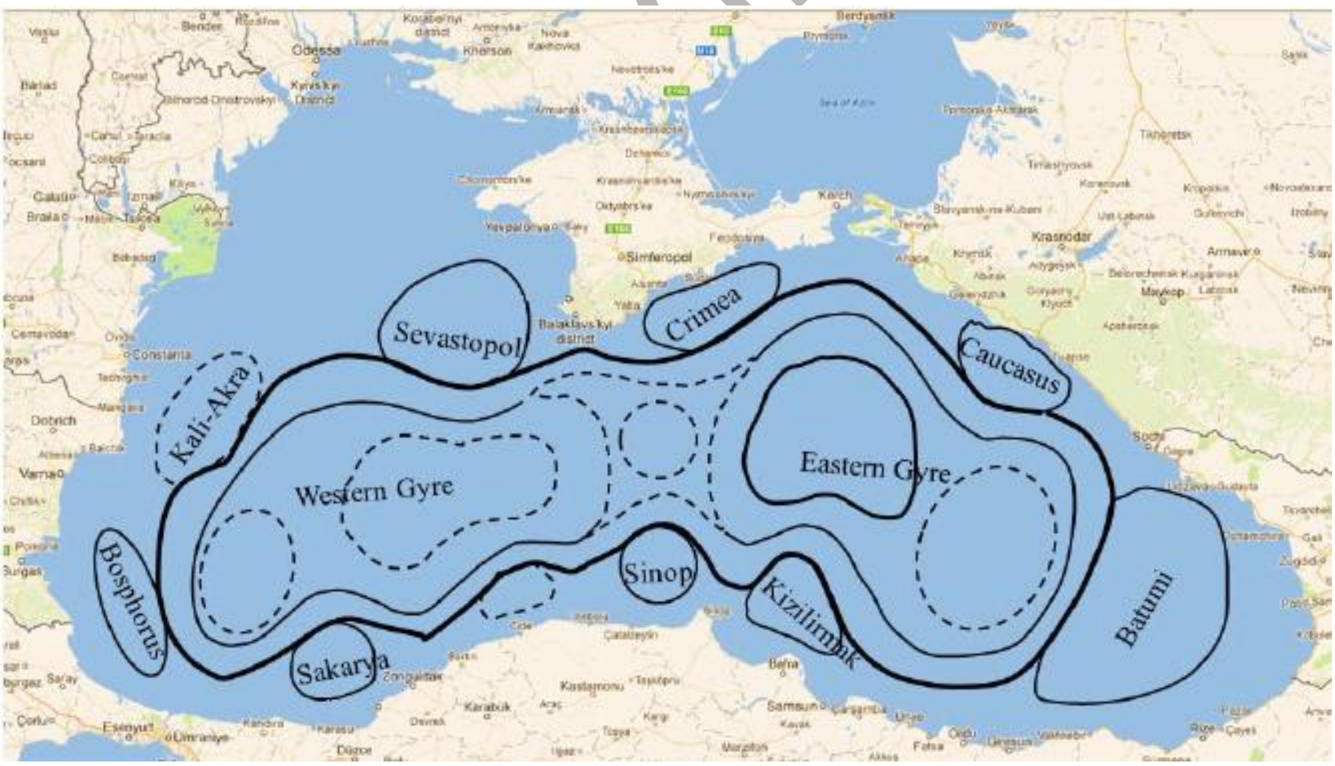
b) Describe the current prevailing in Mediterranean Sea and Black Sea. Give necessary sketches (2 times)

Mediterranean Sea

Sr No	Type of current	Name of Current	Direction & Other description
1	Surface Current	Levantine Current	It flows eastward along the southern coast of Turkey and then turns southward along the coast of Syria and Lebanon.
2	Surface Current	Western Mediterranean Current	It flows eastward along the northern coast of Africa and then northward along the eastern coast of Spain and France.
3	Intermediate and Deep Currents	Mediterranean Outflow Water (MOW)	This is a deep, saline water mass that flows out of the Strait of Gibraltar into the Atlantic Ocean.
4	Intermediate and Deep Currents	Western Mediterranean Deep Water	Cold and dense water that forms in the Gulf of Lions and flows towards the east in the deep layers of the western Mediterranean.

Black Sea

Sr No	Type of current	Name of Current	Direction & Other description
1	Surface Current	Black Sea Surface Current	This generally flows in a clockwise direction in the open sea, driven by the predominant wind patterns.
2	Intermediate and Deep Currents	Black Sea Deep Water	It forms in the central part of the Black Sea due to winter cooling and freshening of surface waters. It flows towards the Black Sea basin's deepest areas.
3	Inflow and Outflow	Bosporus Currents	The Bosporus Strait is a crucial chokepoint where water flows into the Black Sea from the Mediterranean (known as inflow) and out of the Black Sea into the Mediterranean (known as outflow)



12) Describe the forms of display which are commonly used to depict ocean current (2 times)

(OR),

Describe the various forms of depicting ocean currents on charts.

Ocean currents are depicted on charts using a variety of symbols and notations, including arrows, colour gradients, and contour lines, to represent direction, speed, and sometimes temperature.
These charts aid in navigation, weather forecasting, and understanding oceanographic patterns.

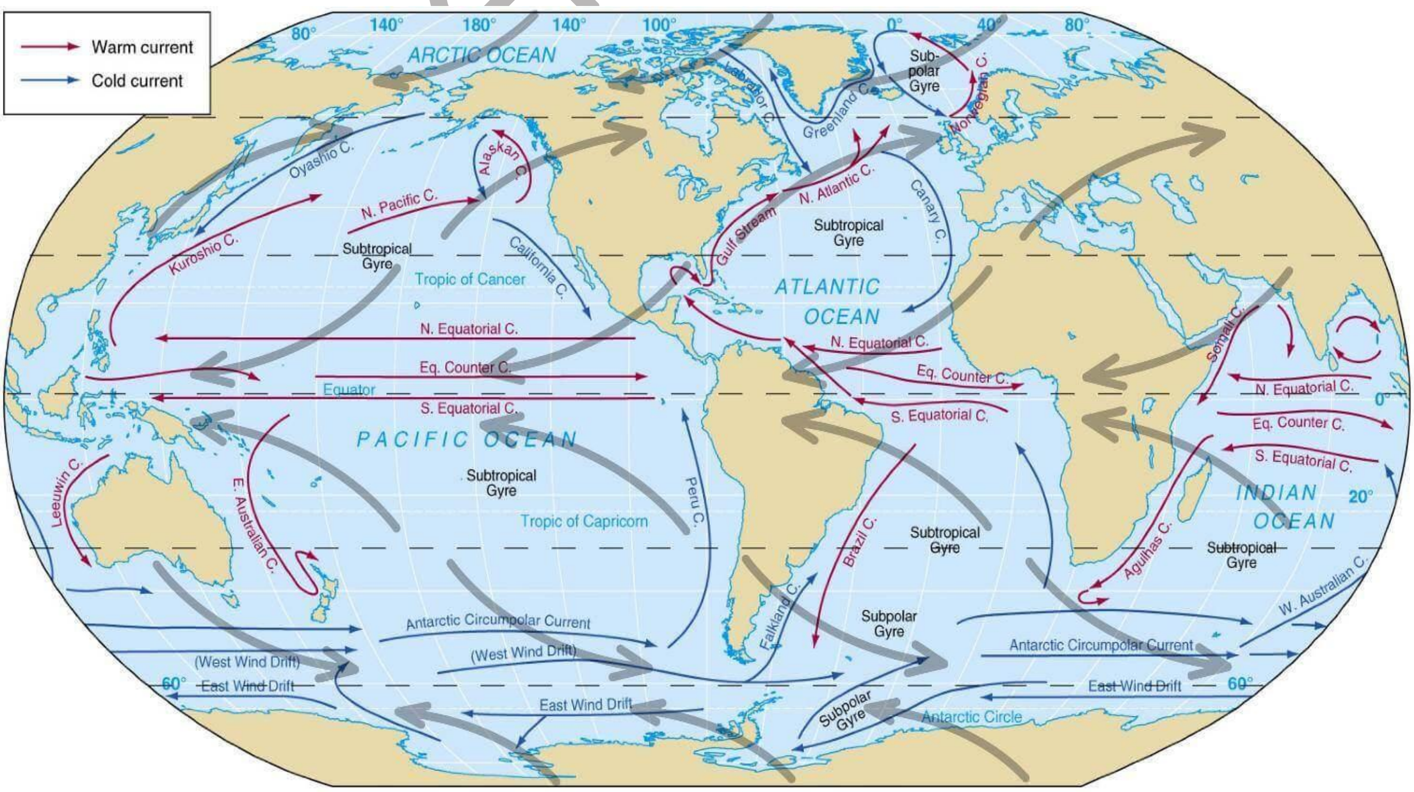
Here's a breakdown of the common methods:

1. Arrows:
Direction: The direction the arrow points indicates is the flow of water.
Length/Colour: The length or colour of the arrow can sometimes indicate the speed of the current. Longer or brighter arrows may represent faster currents, while shorter or paler arrows may indicate slower currents.
Example: A chart use a long, red arrow to show a strong, warm current like the Gulf Stream.

2. Colour Gradients:
Temperature: Colour gradients are commonly used to represent water temperature, with warmer waters often depicted in red or orange hues and colder waters in blue or green.
Example: A chart might show a warm current like the Kuroshio Current with a reddish hue, transitioning to cooler blues as it moves towards higher latitudes.

3. Other Symbols:
Current Roses: These diagrams show the frequency and direction of currents at a specific location.
Current Speed: In some charts, specific speed values are indicated alongside the current direction, often using text or numerical notations.
Streamlines: These lines represent the path of water flow and can be used to visualize complex current patterns.

4. Chart Types:
Routeing Charts: These charts are used for general route planning and often display major currents, wind patterns, and other navigational information.
Oceanographic Charts: These charts provide more detailed information about ocean currents, temperature, salinity, and other oceanographic parameters.



13) How does the ocean current charts help the mariners?

Ocean current charts help mariners in multiple important ways that enhance navigation safety, efficiency, and fuel economy.

1. Efficient Route Planning
    - Mariners can use favourable currents (e.g., Gulf Stream) to increase speed and save fuel.
    - Helps in avoiding adverse currents that may reduce vessel speed and increase fuel consumption.

2. Estimated Time of Arrival (ETA) Accuracy
    - By knowing current direction and speed, mariners can calculate more accurate ETA.
    - This is especially important for port scheduling and logistics.

3. Fuel and Cost Savings
    - Sailing with favourable currents reduces engine load, leading to less fuel usage and lower operational costs.

4. Safety and Maneuvering
    - Currents near coasts, straits, or river mouths can affect maneuverability.
    - Knowledge of local currents helps in safe berthing, unberthing, and transit through narrow waters.

5. Emergency Situations
    - In case of engine failure or drifting, current charts help predict drift direction and rescue planning.

6. Weather Routeing Integration
    - Ocean currents are used in combination with weather forecasts for optimum routeing, avoiding both heavy weather and unfavourable currents.

<u>**Waves**</u>

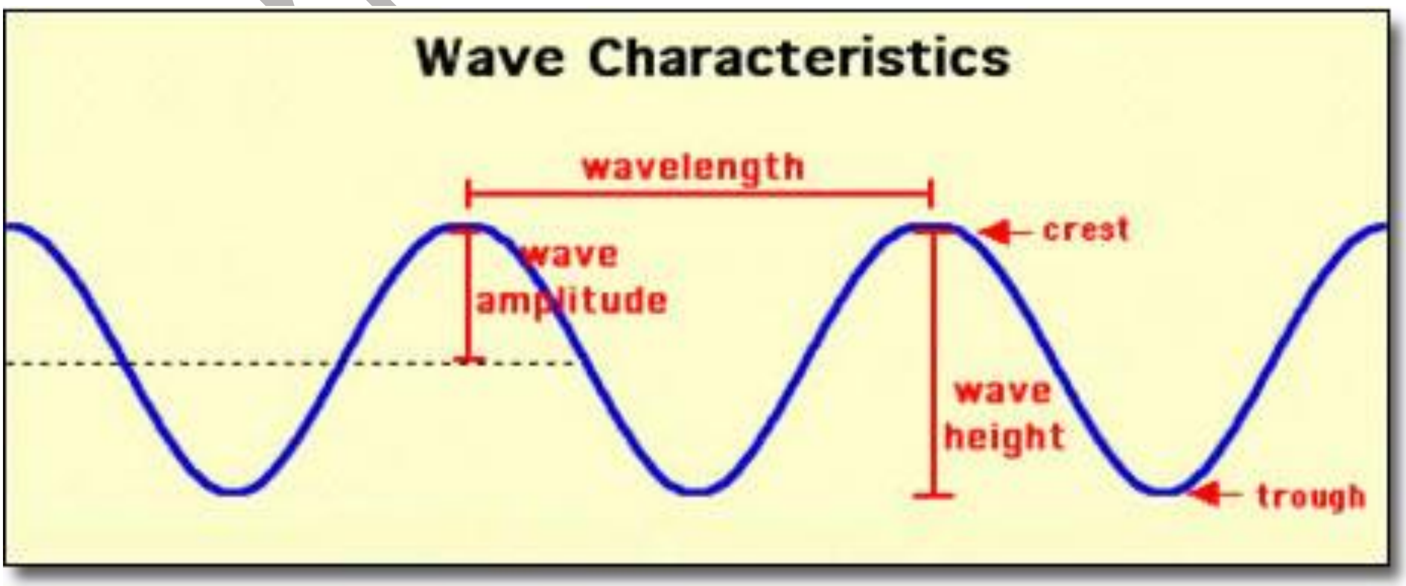
1) Explain: (i) Trough (ii) Crest (iii) Wave Length (iv) Wave Height (3 times)

(ii) Crest: A crest point on a wave is the highest point of the wave. A crest is a point on a wave where the displacement of the medium is at a maximum.

(i) Trough: A trough is the opposite of a crest, so the minimum or lowest point of the wave.

(iii) Wave Length: It is a horizontal distance between successive trough & crest.

(iv) Wave Height: It is twice of amplitude. It is vertical distance measured from crest to trough.



2) Define speed, period, length and significant wave height. What is their relationship? What are the factors governing wave height and direction. (2 times)

Wave Speed: Also known as wave velocity. It is a speed at which wave move forward.

Wave Period: It is the time taken for two successive crest (or trough) to pass a fixed point.

Or,

It is the time elapses (pass) between passing of two successive crest (or trough)

Wave Length: It is a horizontal distance between successive trough & crest.

Relation between them: Wave Speed (C) = Wavelength (λ)/Wave Period (T)

Where: C = Wave speed (in meters/second or knots)

λ = Wavelength (in meters)

T = Wave period (in seconds)

Factors Affecting Wave Height:

1. Wind Speed: Stronger winds means more energy transferred to water which causes higher waves.

2. Wind Duration: The longer the wind blows, the more energy it gives to the waves, increasing their height.

3. Fetch: Fetch is the uninterrupted distance over which the wind blows. So, Longer the fetch, larger the wave height.

4. Water Depth: In shallow water, wave height increases and the wave becomes steep and unstable. Waves slow down and rise as they approach shore (shoaling).

5. Current and Wind Interaction: When current opposes the wind, wave height increases and becomes choppier (e.g., Agulhas Current).

6. Original Sea State: Existing waves (swell or sea) may combine (constructive interference) or cancel out (destructive interference), affecting total wave height.

Factors Affecting Wave Direction:

1. Wind Direction: Waves generally travel in the same direction as the prevailing wind that generates them.

2. Coriolis Effect: Due to Earth's rotation, wave direction can bend slightly to the right in the Northern Hemisphere and to the left in the Southern Hemisphere.

3. Coastal Shape and Bathymetry: Waves bend when entering shallow water at an angle. Coastal headlands, islands, and seabed slope can steer waves.

4. Ocean Currents: Strong currents can deflect or steer waves from their original path.

5. Swell Influence: Distant storms generate swell waves that can travel long distances and influence local wave direction even when wind is calm.

3) Explain methods of estimating wave heights and wave periods. (3 times)

Method of estimating Wave Height/Wave Period

1. Visual Estimation (Shipboard Method): Mariners estimate wave height by comparing waves to the known height of the ship's parts, like Freeboard, Bulwark height, Height of deck from sea level. Used mostly at sea by officers on the bridge.

2. Use of Wave Buoys: Moored buoys are equipped with sensors to measure: Vertical displacement of sea surface & Significant wave height (average height of the highest one-third waves)

3. Radar or LIDAR Systems: It is mounted on ships or platforms to measure the wave profile using reflected signals. It calculates wave height from wave crests and troughs.

4. Satellite Altimetry: Satellites like Jason or Sentinel use radar altimeters to measure sea surface variations. Global wave height data can be obtained from this method.

4) Explain the shallow water effects on a wave when it is approaching a coast line.

Shallow water effect on a wave are as follows:

(i) Decrease in Wave Speed

- In deep water, wave speed depends on wavelength.
- In shallow water, speed is governed by water depth.

(ii) Reduction in Wavelength

- Since wave period remains constant, and speed decreases, wavelength also reduces.

(iii) Increase in Wave Height

- As the energy is compressed into a shorter wavelength, the wave height increases.
- This causes steepening of waves.

(iv) Wave Refraction

- When part of a wave enters shallow water before another part, it slows down earlier, causing the wave to bend (refract).
- Waves tend to align more parallel to the shore.

(v) Wave Breaking

- When the wave becomes too steep (height-to-length ratio 1:7), it becomes unstable and breaks.
- This creates surf and releases energy on the coastline.

(vi) Wave Shoaling

- The entire process of wave height increase, wavelength decrease, and speed reduction in shallow water is called shoaling.

5) Write short notes on: i) Storm surge ii) tsunami iii) freak waves iv) Refraction of Sea Waves

i) Storm surge: A storm surge is an abnormal rise in sea level generated by a storm, such as a hurricane or cyclone, that is separate from the normal astronomical tide. It's essentially the ocean water being pushed inland by the storm's powerful winds and low atmospheric pressure, causing coastal flooding.

ii) Tsunami: Tsunamis are giant waves caused by earthquakes or volcanic eruptions under the sea. Out in the depths of the ocean, tsunami waves do not dramatically increase in height. But as the waves travel inland, they build up to higher and higher heights as the depth of the ocean decreases.

iii) Freak waves: Rogue waves (also known as freak waves or killer waves) are large and unpredictable surface waves that can be extremely dangerous to ships and isolated structures such as lighthouses. It is defined as waves whose height is more than twice the significant wave height. They can be caused when currents or winds cause waves to travel at different speeds, and the waves merge to create a single large wave.

iv) Refraction of Sea Waves: Refraction of sea waves refers to the change in direction of waves as they move from deeper to shallower water. This happens because the speed of the wave changes as it enters shallower water, causing the wave to bend and align itself with the coastline.

6) State the causes of Southwest Monsoon in the Arabian Sea. What effect does it have on the general surface current circulation in the Arabian Sea? (2 times)

Causes of Southwest Monsoon in the Arabian Sea:

(i) Differential Heating of Land and Sea: During summer (May–June), the Indian subcontinent heats up faster than the Arabian Sea. This creates a low-pressure area over land and a high-pressure area over the sea.

(ii) Shift of the Inter-Tropical Convergence Zone (ITCZ): The ITCZ moves northward over the Indian subcontinent. This attracts moist southwest winds from the Indian Ocean.

(iii) Development of the Mascarene High: A semi-permanent high-pressure area develops over the southern Indian Ocean near Madagascar. This high pushes strong south-easterly trade winds, which cross the equator and deflect due to Coriolis force.

(iv) Coriolis Effect: When winds cross the equator, they get deflected to the right (in the Northern Hemisphere), becoming southwesterly monsoon winds.

(v) Thermal Low Over Northwest India: A strong thermal low develops over Rajasthan and Pakistan, intensifying the pressure gradient, pulling moist air from the sea.

Effect on Surface Current Circulation in the Arabian Sea:

The southwest monsoon winds (June to September) dramatically alter the surface current pattern in the Arabian Sea. Key Effects are as follows:

(i) Reversal of Current Direction

- Normal (NE Monsoon or Winter): Surface currents flow clockwise (North Equatorial Current to West India Coastal Current).
- During SW Monsoon: Surface circulation becomes anticlockwise.

(ii) Somali Current Formation

- Strong SW monsoon winds cause the Somali Current (off the Horn of Africa) to flow northward.
- This current resembles a Western Boundary Current, similar to the Gulf Stream.

(iii) Eastward Flowing Monsoon Current

- A strong eastward monsoon current develops near 10°N, crossing the Arabian Sea toward India and Sri Lanka.

(iv) Upwelling Along Arabian Coast

- Offshore winds cause upwelling along the coast of Oman and Somalia, bringing cold, nutrient-rich water to the surface.
- This affects marine life and fishing activities.

(v) Strengthening of Surface Turbulence

- Strong winds lead to increased wave activity and surface mixing.

Q.6 Weather Forecasting/ Weather Routeing

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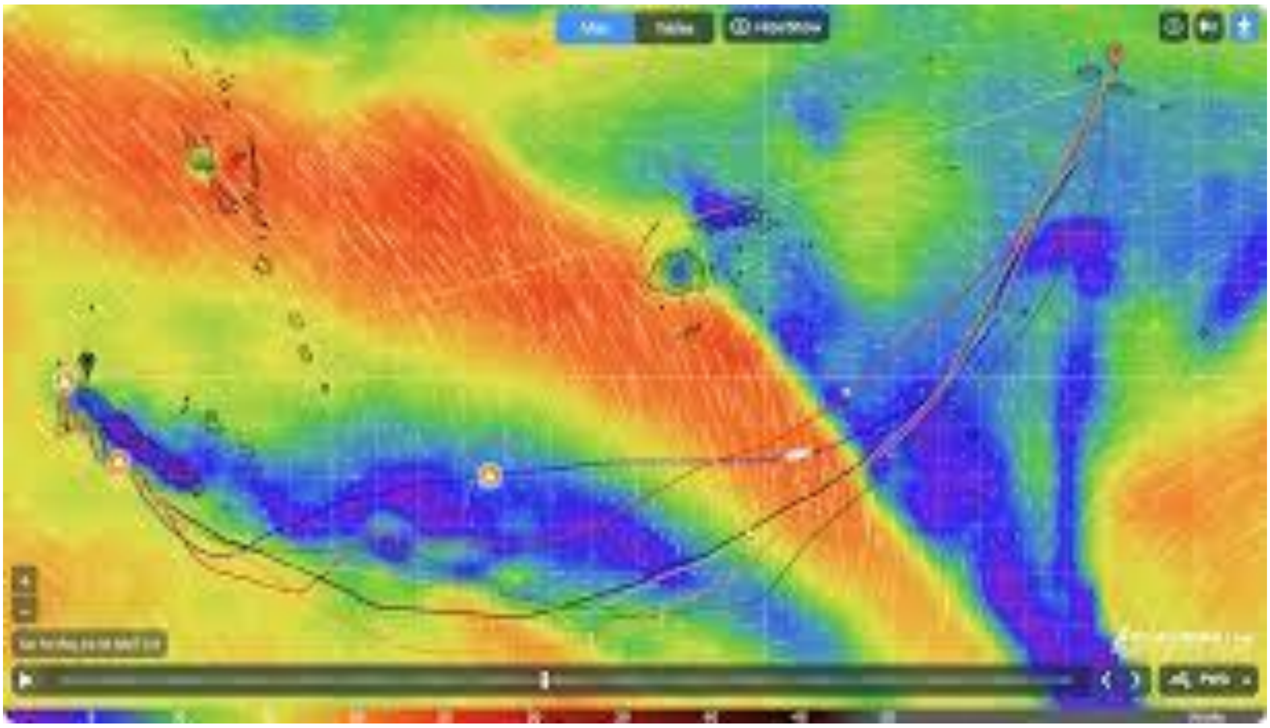

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Q.6 Weather Forecasting / Weather Routeing

Ques 1) Describe various types of Weather Facsimile charts / Weather related information available to the mariner. How are these charts used for Weather Routeing Purposes? What do you understand by vessel's performance curves and their use? (8 times)

(OR),

What is the different weather information available from the charts received by a facsimile receiver? (2 times)

(OR),

Describe Ship's Performance Curves and their use in ship's weather routeing (2 times)

Ans:- The various type of weather facsimile charts, their use for weather routeing purposes & weather related information available are as follows:-

(i) Surface weather analysis chart

Use: It helps to identify current weather condition at the surface.
It is used to determine safe areas, avoiding low pressure center.

Key Information: High & low pressure area, marked with isobars
Cold, warm, occulded & stationary fronts.
Wind speed & direction.
Areas of rain, snow or thunderstorm.

(ii) Forecast weather chart

Use: Since it predict the weather for future time, hence, it provides weather warning of developing system along the route.
It helps to plan deviation ahead of time to avoid cyclones or heavy seas.

Key information: Forecasted position of pressure system
Fronts
Wind pattern.

(iii) Wave Height chart

Use: Since it indicates wave height and direction, hence, it helps to avoid the areas with rough sea.
It helps choose a route with favorable sea condition.

Key information: Wave height
Wave direction
Wave period.

(iv) Tropical storm warning chart

Use: It is essential for tracking TRS & plotting dangerous & navigable quadrants.
It helps to keep vessel away from predicted storm track.

Key Information: Current location of TRS
Predicted path of TRS

(v) Ice Information chart

Use: It prevent routing through ice-covered water, protection hull and propulsion system.
It guides vessel to ice-breaker assisted routes.

Key Information: Type of sea ice
Location & density of sea ice.

(vi) Surface Temperature chart

Use: Since It identifies the TRS formation zone, hence, it helps to avoid low pressure center.
It helps avoid fog prone areas and plan safe passage.

Key Information: Temperature gradient
Upwelling zones.

(vii) Ocean current chart

Use: It provide information on ocean current that can influence the movement of vessels.
It helps mariner to optimise navigation & fuel consumption.

Key Information: Speed of major ocean current
Direction of major ocean current.

(viii) Significant weather prognosis chart

Use: It helps to visualize future atmospheric state.
It helps to choose a route with favorable weather condition.

Key Information: Pressure pattern
Fronts
Wind
Temperature
Precipitation
Cloud cover

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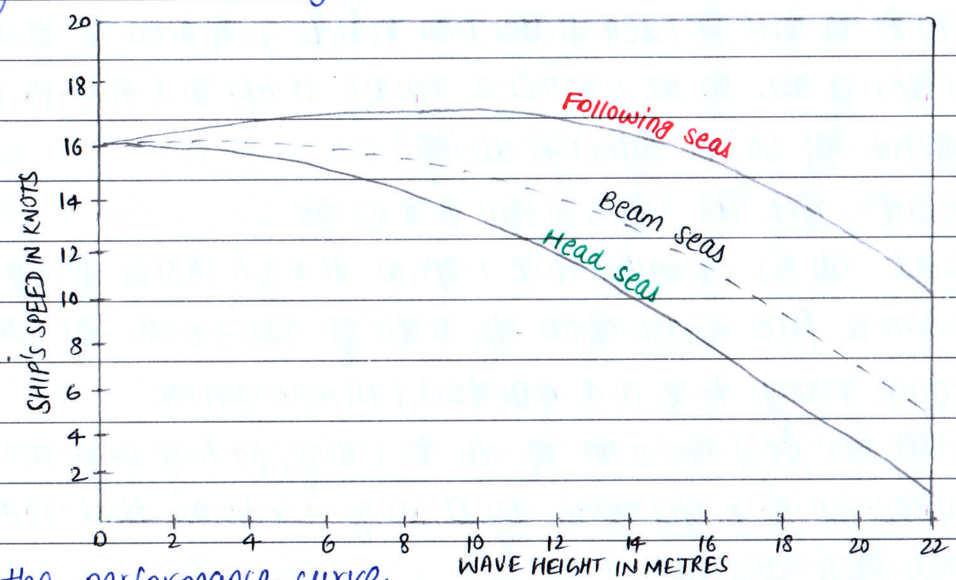
Ship's Performance Curve

- It is a graphical or tabular representations how the ship's speed (fuel consumption, and engine power) vary under different sea states.
- It is used to estimate the ship's speed while transitting the forecast sea states.
- The curves indicate the effect of head, beam & following seas of various significant wave height on the ship's effect.



- In the performance curve,

  head means any direction between right ahead & 60° on either side of bow.

  beam means any direction between beam & 30° on either side.

  following means any direction between right astern & 60° on either side of quater.
- seperate performance curve should be drawn for ballast & loaded condition.
- Each curve is usually drawn at engines full ahead.
- These curves are based on actual ship's trail or model testing and are unique to each vessel.

Use in ship's weather Routeing

(i) voyage planning

It helps to estimate total passage time and fuel consumption under forecast weather condition.

(ii) Route selection

It helps to select route where ships speed would drop significantly.

(iii) ETA management

It helps to adjust speed to maintain ETA by taking weather factor into account.

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Ques 4) What is Ship weather Routeing? Write its objective. Also, write the process of carrying out Weather Routeing. (5 times)

(OR),

Explain the method of shipboard weather routeing with suitable diagram (5 times)

Ans:- Ship Weather Routeing

It is the process of planning and selecting the most safest, efficient and economical route for a ship's voyage based on real-time forecasted weather conditions, sea states and vessel's performance characteristics.

It helps avoid severe weather & ensure timely and fuel efficient passage.

Objective of Ship weather Routeing:

- Ensure safety of vessel, crew and cargo.
- Avoid adverse weather like tropical storm, high seas, strong winds.
- Minimize fuel consumption by selecting route with favorable wind & current.
- Reduce voyage time and assist in ETA management.
- Protect cargo from damage due to rolling, pitching or ingress of water.
- Improve ship's performance by choosing condition that reduce stress on machinery and hull.

Method of carrying out weather routeing:

(i) Voyage planning.

- Master studies intended route and identifies critical weather zones, alternate route and operational limits.
- Using historical weather data and routeing charts, an initial route is choosen, considering prevailing weather condition, seasonal storm and ocean current.
- Factors like ship's hull design, speed capablity and its response to various sea states are considered.

(ii) Weather Routeing Service or software (if used)

- Input ship's performance curve.
- System suggest optimum route based on current and forecast condition.
- Master has final authority to accept or modify it.

(iii) Real time weather monitoring

- Real time weather information is recieved on-board via weather facsimile, Navtex, INMARSAT-EGC (SafetyNet), or, internet (if available)

- The ship recieves weather forecast and advisories including information on wind, wave height, visiblity and atmospheric pressure..
- This data is analyzed to identify potential weather hazards and optimize the ship's course.

(iv) Real time adjustment

- If adverse weather is predicted, the ship may be advised to divert to a safer route or adjust its speed.
- If adverse weather is predicted, the ship may alter its course to avoid the roughest sea and high winds.
- If adverse weather is predicted, the ship's speed may be adjusted to optimise fuel efficiency and minimize the effect of waves.

Example: weather routing to avoid a Tropical storm

(i) voyage Planning.

- The initial route was planned based on prevailing westerlies, currents and seasonal weather.
- As the ship depart, forecast predict the formation of TRS.

(ii) Weather Routeing service or software (if used)

- The weather routing software detects that the storm's projected path intersects the ship's route.
- Based on the forecast, the software recommends a northerly deviation, taking the ship above the storm's track.

(iii) Real time weather monitoring.

- Continuos monitoring of weather forecast and advisories via weather facsimile, Navtex, INMARSAT-EGC (SafetyNet) or Internet (if available)
- Monitor the path & track of TRS

(iv) Real time adjustment

- Vessel will alter its course to avoid the roughest sea and high winds.
- Along the new route, the captain opt to reduce speed slightly to minimize fuel consumption and avoid unnecessary stress on ship.
- The storm passes south, and the ship resumes its original route once clear of the hazardous weather.

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Ques 3) Enumerate the factors to be taken into consideration for ship's weather routeing? (3 times)

Ans:- The factors to be taken into consideration for ship's weather routeing are as follows:-

Ship's Characteristics

(i) Type of vessel, size, draft
(ii) Loaded/Ballast
(iii) Nature of cargo
(iv) Ship's performance curve
(v) Navigational equipment

Weather condition

(i) Weather forecast (wind, waves, swell, pressure system, visiblity, fog etc.)
(ii) Sea state (wave height, direction, period)
(iii) TRS warning.
(iv) Currents and tidal stream
(v) Ice information.

Others

(i) Navigation hazard
(ii) TSS, restricted water, NO-GO areas.
(iii) ECA areas, MARPOL special areas.
(iv) Fuel availability and bunkering plan
(v) ETA requirement or charter party terms.

Ques 4. a) What are the advantage of ship's weather routeing?

Write answer from Q.NO. 2 ; Objective of weather routeing.

b) What are the limitations of weather routeing? (2 times)

Ans:-
- Forecast inaccuracies may lead to poor routing decisions.
- Sudden changes in weather condition, such as rapid development of a storm or incorrect storm tracks, can limit the effectiveness of weather routing decisions.
- In some remote regions or during periods of poor satellite coverage, ships may not recieve timely weather data.

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- Not suitable for all ship types
- 5 Requires accurate ship performance data for optimal results.
- Over-reliance on software may reduce human judgement.
- In some cases, increased voyage distance.
- Communication issues may delay updated weather information.
- Regulatory or navigational restrictions may limit route flexiblity such as TSS.
- Some weather routing system can be complex to operate and may require specialized training for officers and crew.

Ques 5) Identify the various types of weather routing services available for shipping and describe any one of them. (6 times)

Ans:- (i) Ship performance optimization system
(ii) BonVoyage System
(iii) MeteoGroup
(iv) StormGeo
(v) WNI (Weather news INC) Ocean routing.
(vi) Navimeteo
(vii) Applied weather technology.
(viii) FleetWeather
(ix) Jepessen Marine (C-Map)
(x) Fleet Decision Support system (FDSS) by ABS.

Description of one of them:

StormGeo

- It ensures vessel safety and fuel efficiency while avoiding adverse weather.
- It offers detailed voyage planning and providing real time advice for route adjustments based on updated forecasts.

Key features:

Real time weather updates
Route optimization
Fleet monitoring services
Customizable reports based on vessel operating condition including energy efficiency.

Ques 6) Describe optimum routeing. How would you achieve the objective of weather routeing in optimum routeing? (6 times)

Ans:- Optimum routeing is a process of optimising (planning & adjusting) a ship's voyage, ensuring vessel's safety, fuel efficiency and reduced voyage time while taking weather forecasts, real-time weather condition and ship's performance characteristics into account.

The goal is not to avoid all adverse weather but to find the best balance to minimize time of transit and fuel consumption without placing the vessel at risk.

The optimum routeing also refers to least time track i.e. the route that minimizes travel time between two points considering various factors like weather forecasts, ship characteristics and special cargo requirement.

The objective of weather routeing in optimum routeing is achieved by:-

(a) Analyzing the Condition

Look to avoid storm tracks, rough seas and ice hazards, minimizing risks to the vessel, crew and cargo.

(b) Improving fuel efficiency.

By taking favorable winds and currents and avoiding adverse conditions, it can significantly reduce fuel consumption.

(c) Evaluating Route option

By utilizing real-time weather data, which allow for adjustment to the route, minimising delay caused due to the weather.

(d) Selecting safe route

By adjusting courses & speed based on weather routeing, it helps protect vessel, crew & cargo from effect of rough seas and minimize damages.

(e) Optimising speed and efficiency.

By utilizing ship's performance characteristics, it helps improve ship's performance by choosing condition that reduce stress on machinery and hull.

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Ques 7-a) Describe the procedure for climatological routeing (3 times)

Ans:- Climatological routeing involves using long-term weather and oceanographic data to plan ship's route, thus, minimizing travel time and fuel consumption and maximising safety.

This process relies on understanding historical patterns of winds, currents and weather to select the most favorable route for specific season and regions.

More detailed procedure for climatological routeing are as follows:-

- Collect voyage related information like departure & destination port, draft, nature of cargo etc.
- Take references from Pilot charts, Routeing charts, sailing direction and ocean passages for the world.
- Gather historical data on wind and current patterns, wave heights, weather condition and sea surface temperature.
- Analyze this data to identify prevailing condition and typical seasonal variations.
- Identify seasonal hazards.
- Compare with alternative routes.
- Based on the climatological data, plan route that minimises the impact of adverse weather and ocean conditions.
- Identify alternate route in case actual condition differs from average condition
- Include choosen route in passage plan.
- Though climatology routeing is based on historical data, always check actual weather forecast before sailing.

b) Explain the purpose for Maritime Forecast code and data given by the MARFOR (3 times)

Ans:- The Maritime Forecast code (MARFOR) is a standardized format used by the meteorological organisation to transmit marine weather forecast clearly and concisely to ships at sea.

It provides essential weather-related information that helps the vessel plan for safe navigation and optimum routeing.

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Purposes of MARFOR:

- To provide standardized marine weather forecast.
- To ensure uniform interpretation of meteorological data.
- To assist in safe voyage planning.
- To support optimum weather routeing.
- To aid in decision making during heavy weather.

Data given by MARFOR:

- Specific sea area name or coordinates.
- Date and time (UTC) of forecast validity.
- Wind speed and directions.
- Wave height and direction
- 5 Swell height, direction and period.
- Expected visiblity range.
- Rain, fog, squalls, snow etc. (if any)
- Mean sea level pressure.
- Pressure tendancy.
- Gale, storm or tropical cyclone (if any)

Ques 8) State the difference between weather routeing and climatology routeing. Explain how will you carry out weather routeing on-board your vessel (2 times)

Ans:-

Aspect	Weather Routeing	Climatology routeing
Based on	Real time or forecasted weather data	Historical data
When used	During voyage or a few days before departure	In intial voyage planning stage.
Purpose	To determine the best route based on real-time weather condition	To determine the best route based on long term weather patterns.
Data source	Weather forecasts, satellite data, INMARSAT-EGC (safetyNet), Navtex etc.	Pilot chart, Routeing charts, Sailing direction, Ocean Passages for the world

Accuracy	High accuracy as it uses current data and forecasts.	Generalized guidance may vary from present condition.
Flexibility	Route are adjusted during the voyage.	Routes are pre-determined and usually fixed.
Example	Avoiding a TRS developing en route to JAPAN	Choosing a northern route across in Atlantic in July to avoid hurricanes

Procedure to carry out weather routeing on-board:-
Same as Q.2

Ques 9) List the information given in shipping forecast issued for coastal areas (2-times)
(OR),
Explain the contents of coastal weather bulletin issued by Indian Meteorological Department.

Ans:- Same as Q.7(b) : Data given by MARFOR.

Ques 10.a) List the information given in synoptic weather chart. What information can a mariner obtain from it? How would you find pressure gradient from it? (4-times)

Ans:- Synoptic weather chart

The word "synoptic" means a summary of the current situation
It is a weather chart which provides current weather situation by displaying various meteorological elements and their distributions like air pressure, wind, temperature and cloud cover, using symbol and lines.
Information given in synoptic weather chart:
- Isobars
- High(H) and Low(L) pressure areas
- Pressure tendancy.
- Fronts.
- Wind direction and speed.
- Cloud cover.
- Temperature
- Visiblity

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- Weather phenomena like Rain, fog, snow, thunderstorms etc.
- Precipitation.

Information a mariner can obtain from it:-

- Lines joining points of equal atmospheric pressure.
- Areas of developing or decaying system.
- Change in atmospheric pressure in last three hours.
- Area of two distinct air masses
- Wind direction and speed
- Likelihood and intensity of precipitation
- Temperature
- Visiblity range
- Prediction of rain, fog, snow, thunderstorm etc.
- Sea conditions.

To find pressure gradient from synoptic chart:-

- Identify isobars around the area of interest
- Note the pressure value
- Measure the distance between isobars on the chart using the chart scale.
- Use the formula:-

$$\text{Pressure gradient} = \frac{\text{Pressure difference (hPa)}}{\text{Distance (NM or KM)}}$$

10.b) List out various information given in weather fascimile charts and wave charts? (2 times)

Ans:- A weather fascimile chart is a graphical weather chart that is transmitted via radio or satellite and recieved on-board ship which help mariners understand and prepare for current or forecasted weather condition at sea.

The various type of weather fascimile charts, their use for weather routeing purposes & weather related information available are:-

Same as Q.1.

Write all types & key information given in those charts.

Wave charts

- It is weather charts that provides wave conditions over a large sea area at a specific time, based on actual observation.
- It helps understand the current state of the sea.
- It is used during voyage planning and weather routeing.

Purpose:

- To identify areas of high sea and swell.
- To help ships avoid rough sea condition.
- To plan optimum routes for comfort, fuel efficiency and cargo safety.
- To anticipate pitching, rolling, slamming and parametric rolling.

Information given in wave charts:

- Significant wave Height
- Wave direction
- Wave period
- Swell
- Sea state
- Colour shaded contour.

10.c) Write down the information given in a weather routeing chart

Ans:-

- It is a weather routeing chart that provides climatic and navigational data for a specific ocean area at a specific month.
- These charts are based on long-term climatological averages and are commonly published monthly.
- It is used during voyage planning and climatology routeing.

Purpose

- To identify areas of frequent storms or adverse current
- To help ship avoid rough sea condition.
- To plan optimum routes for comfort, fuel efficiency and cargo safety.
- To anticipate wind and sea conditions.
- To cover weather condition that change throughout the year.
- To support in route planning.

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Information given in weather routeing chart:

- Position of major ports
- Recognised shipping routes and distances between them.
- Wind roses showing wind speed and direction.
- Frequency and intensity of storms.
- Low visiblity areas
- Sea and air temperature
- Air pressure
- Ice limits
- Ocean currents.
- Limits of loadline zones.

Ques 11) Describe various methods/ sources of information inputs for making of analytical weather for synoptic hour.

Ans:- The various methods/sources of information inputs for making of analytical weather for synoptic hour are as follows:

(i) Surface weather observation.

- Land based stations
- Voluntary observing ships
- Offshore platforms
- Moored ocean buoys.

(ii) Upper air observations

- Radiosondes
- Weather ballons

(iii) Satellite data

Polar and geostationary satellite

(iv) Radar data

Provides rainfall intensity, movement of thunderstorms etc.

(v) Aircraft observations

Commercial aircraft provides wind and temperature at various altitudes.

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Ques 12) How is weather forecasting carried out? Show by an example how you would make a short time weather forecast.

Ans:-
- Weather forecast are made by collecting quantitative data about the current state of the atmosphere, land and ocean, and using meteorology to project how the atmosphere will change at a given place.
- There are various technique involved in weather forecasting, from simple sky observation to highly complex computerized mathematical models.
- High speed computers, meteorological satellites and weather radars are tools that have played major roles in improving weather forecast.

Techniques for weather forecasting:-

(i) Use of a barometer
- The larger the change in pressure, the larger the change in weather can be expected.
- If the pressure drop is rapid, a low pressure system is approaching, and there is a greater chance of rain.

(ii) Looking at the sky
- Thickening of cloud cover or the invasion of an higher cloud is an indication of rain in near future.
- Morning fog portends fair condition, as rainy condition are associated with wind or clouds which prevent fog formation.

(iii) Nowcasting
- The forecasting of weather within the next six hours is often referred to as nowcasting.
- Small features such as showers and thunderstorm are possible to forecast in this time range.

(iv) Radar
- Weather radar can sense many characteristics of precipitation, its location, motion, intensity and the likelihood of future precipitation.
- Radar can outline the structure of the storm.

(v) Weather satellites
- Satellites are the best way to monitor large scale system like storm.
- They are able to record long term changes.

Example of short-term forecast

Area : 15°N, 65°E (radius 100NM)

Forecast valid : 0600 UTC to 1800 UTC

Wind : NE 25-30 Knots, gusting 35 Kts in squall

Sea : Rough

Weather : Overcast, Frequent showers and thunderstorms.

Visibility : Reduced <2 NM in rain

Pressure : Falling steadily.

Outlook : Deepning low moving NW. Conditions likely to deteriorate further.

Ques 13) Describe significant wave height and fetch (5 times)

(OR),

Describe significant wave height and the factors that influence the height of wave (4 times)

Ans:- Significant wave height

- It is defined as mean wave height of the highest 1/3rd of the waves in a wave spectrum, often used to characterize sea state.
- It was intended to mathematically express the height estimated by trained observer.
- It is calculated as four times the square root of the area of the wave spectrum
- Significant wave height is an important parameters for the statical distribution of ocean waves.
- The most common waves are lower in height than significant wave height.
- That means, encountering the significant wave is not too frequent.
- However, it is possible to encounter a wave that is much higher than the significant wave.
- For example, given that significant wave height is 10 metres, statistically:
  - → 1 in 10 will be larger than 10.5 metres
  - → 1 in 100 will be larger than 15 metres
  - → 1 in 1000 will be larger than 18 metres.

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Fetch

- It is the uninterruped distance (distance of open water) over which wind can blow in a single direction and interact with the surface, allowing waves to develop.
- Longer fetches allow more wind energy to be transferred to the water, leading to larger and more energetic waves.
- If a fetch is limited (e.g. a short stretch of water), the resulting wave height will also be limited, regardless of the wind speed or duration.
- Waves that have travelled outside their generating area (fetch) are called swells.

Ques 14)a) Explain:- (5 times)

(i) Wave chart

Ans:- Same as Q. 10.b

(ii) MAFOR chart

Ans:- Same as Q.7.b

(iii) Significant wave height

Ans:- Same as Q.No. 23.

b) Explain wind rose chart (5 times)

Ans:- Wind roses are found on climatological charts that summarizes information about the wind at a particular location over a specified time period.

They depict the frequency and strength of the wind blowing from various direction.

(OR), in other words

Wind rose is a graph showing the speed, direction and frequency of wind

Wind rose diagram consist of three components:-

ⓐ 8 or 16 radial lines, which represents the wind direction.

ⓑ 5 to 10 concentric lines, which indicates the wind frequency.

ⓒ Colour coded bars on each radial line, which indicates the wind speed.