Ques:- A vessel laden with grain in bulk of SF 1.2 m³/t has a W = 88000t, her KG, calculated assuming the CG's of the cargoes in the filled compartment to be at the volumetric centroid of those compartment = 10.30 m, FSM = 2650 tm, KM = 13.0, the VHM of the filled hold is 5800 m⁴ and that of party filled hold is 14500 m⁴, the angle of flooding is 38°, The KN values for that W are as follows:- (see in solution)

PAGE NO : 1a
DATE : 20.05.25

Practice SUM ① Ascertain whether she satisfies the stability criteria for vessel's laden with grain in bulk.

KG : 10.30 m

FSC : 0.030 m (FSM/W = 2650/88000 = 0.030)

Corrected KG : 10.330 m

KM : 13.000 m

GM (Fluid) : 2.670 m

Heel	12	15	30	40	45
KN	2.75	3.45	6.86	8.59	9.30

GZ = KN - corrected KG sin θ (θ = Angle of heel)

corr. KG sinθ	2.148	2.674	5.165	6.640	7.304
GZ	0.602	0.776	1.695	1.950	1.996

PLOT THE GZ CURVE (i.e. righting arm curve)

λ_0 = VHM of filled compartment : 5800 m⁴ × 1 = 5800 m⁴
VHM of partly filled compartment : 14500 m⁴ × 1.12 = 16240 m⁴
Total VHM = 22040 m⁴

(If given KG of compartment then doesn't matter trimmed or untrimmed & so, no correction is required. correction factor to be taken as 1)

λ_0 = assumed volumetric heeling moment / SF × displacement

$\lambda_0 = \frac{22040}{1.2 \times 88000} = 0.209\,m$

$\lambda_{40} = \lambda_0 \times 0.8 \Rightarrow \lambda_{40} = 0.8 \times 0.209 = 0.167\,m$

Plot λ_0 & λ_{40} (i.e grain heeling arm curve)

① Angle of heel due to shift of grain shall not be greater than 12° or angle at which the deck edge is immersed, whichever is lesser.

Angle of heel due to shift of grain = 4.5° (From GZ curve)

i.e. less than 12° : COMPLIED

② The residual area between the heeling arm curve and the righting arm curve, upto the angle of heel of:- maximum difference between the ordinates of the two curve or 40° or angle of flooding, whichever is lesser shall be not less than 0.075 metre radian.

Angle of flooding : 38° (Given in ques) (less than 40°, so we make ordinate at 38)

So, $h = \frac{l}{n-1} \Rightarrow \frac{38}{5-1} = 9.5$

Teacher's Signature

Heel	GZ	SM	POA
0	0	1	0
9.5	0.5	4	2
19	1.08	2	2.16
28.5	1.59	4	6.36
38	1.92	1	1.92
			SOPA = 12.44

Area = $\frac{SOP \times h}{3} = \frac{12.44 \times 9.5}{3 \times 57.3} = 0.687$ meter radian

Area of $\Delta = \frac{1}{2} \times b \times h = \frac{1}{2} \times 4.5 \times 0.21 \times \frac{1}{57.3} = 0.008$ meter radian

Area of trapezium $= \frac{1}{2}(A_{heel} + A_{38}) \times (38 - heel) \times \frac{1}{57.3}$

$= \frac{1}{2} \times (0.21 + 0.14) \times (38 - 4.5) \times \frac{1}{57.3}$

$= \frac{1}{2} \times 0.35 \times 33.5 \times \frac{1}{57.3} = 0.102$ metre radian

Residual area = Total area - Area under grain heeling arm curve

$= 0.687 - (0.008 + 0.102)$

$= 0.577$ metre radian

↓

i.e. not less than 0.075 metre radian : COMPLIED

③ The initial GM after correction for FSC, shall be not less than 0.30 metre

Initial GM(F) = 2.670 meter

↓

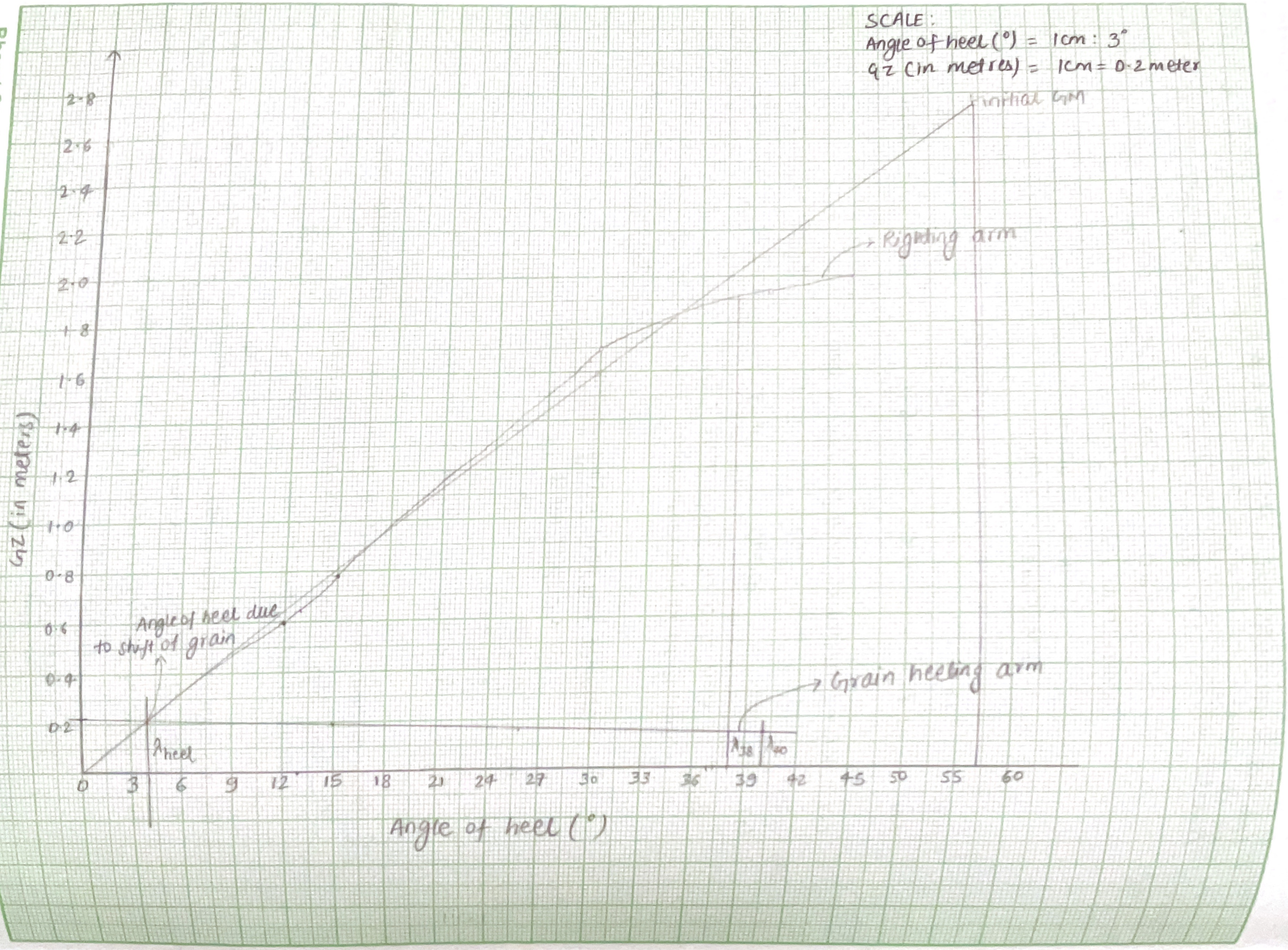
i.e. not less than 0.30 meter : COMPLIED

④ After loading, the master shall ensure that the ship is upright before proceeding to sea

GZ value at 0° heel = 0°

That means vessel is upright : COMPLIED

SCALE:
Angle of heel (°) = 1cm : 3°
GZ (in metres) = 1cm = 0·2 meter



Angle of heel due to shift of grain = λ_0

1·C

APRIL 2024
PAPER 2

KG : 7.827m
FSC : (+)0.150 m (FSM/W = 2625/17500)
Corrected KG : 7.977m
KM : 8.288 m
GM(F) : 0.311 m } Just to verify from curve

17116 8.270 0.022/482 × 334 = 0.018
17598 8.292

Against W = 17,500t,

Angle of Heel (°)	0	5	10	12	15	20	25	30	40°
KN (in metres)	0	0.755	1.505	1.799	2.236	2.984	3.660	4.345	5.580
Corrected KG · sin θ	0	0.695	1.385	1.659	2.065	2.728	3.371	3.989	5.128
GZ	0	0.060	0.120	0.140	0.171	0.256	0.289	0.356	0.452

PLOT THE GZ CURVE (i.e. righting arm curve)

COMPARTMENT	TRANSVERSE VHM	CORRECTION FACTOR	CORRECTED VHM
NO. 1 HOLD	372 m⁴	1	372
NO. 2 HOLD	702 m⁴	1	702
NO. 3 HOLD	580 m⁴	1	580
NO. 4 HOLD	472 m⁴	1	472
NO. 5 HOLD	160 m⁴	1	160
NO. 1 TDK	282 m⁴	1	282
NO. 2 TDK	301 m⁴	1.12	337.12
NO. 3 TDK	280 m⁴	1	280
NO. 4 TDK	242 m⁴	1	242
NO. 5 TDK	370 m⁴	1.12	414.4

TOTAL VHM : 3841.52 m⁴

$\lambda_0 = \frac{\text{Total VHM}}{\text{SFX displacement}} = \frac{3841}{1.181 \times 17500} = 0.121\,m$

$\lambda_{40} = 0.8 \times \lambda_0 = 0.8 \times 0.121 = 0.097\,m$

PLOT λ_0 & λ_{40} (i.e. grain heeling arm curve)

① Angle of heel due to shift of grain shall not be greater than 12° or angle at which the deck edge is immersed, whichever is lesser.

Deck edge immersion : 18.9°
Angle of heel due to shift of grain = 9° (From GZ curve)

↓ Teacher's Signature

i.e. less than 12° : COMPLIED

② The residual area between the heeling arm curve and the righting arm curve, upto the angle of heel of : maximum difference between the ordinates of the two curve or 40° or angle of flooding, whichever is lesser shall be not less than 0.075 metre radian.

Angle of flooding = 43° (Given in ques) (more than 40°, so we make ordinates at 40)

So, $h = \frac{l}{n-1} = \frac{40}{5-1} = 10$

Heel	GZ	SM	POA
0	0	1	0
10	0.120	4	0.480
20	0.256	2	0.512
30	0.356	4	1.424
40	0.452	1	0.452
		SOPA:	2.868

$\text{Area} = \frac{\text{SOPA} \times h}{3} = \frac{2.868 \times 10}{3 \times 57.3} = 0.167$ meter radian

$\text{Area of } \Delta = \frac{1}{2} \times b \times h \times \frac{1}{57.3} = \frac{1}{2} \times 9 \times 0.121 \times \frac{1}{57.3} = 0.009$ meter radian

$\text{Area of trapezium} = \frac{1}{2} (\lambda_{heel} + \lambda_{40}) \times (40 - heel) \times \frac{1}{57.3}$

$= \frac{1}{2} \times (0.115 + 0.097) \times (40 - 9) \times \frac{1}{57.3}$

$= \frac{1}{2} \times 0.212 \times 31 \times \frac{1}{57.3} = 0.057$ meter radian

Residual area = Total area − Area under grain heeling arm curve

$= 0.167 - (0.009 + 0.057) = 0.101$ meter radian

↓

i.e. not less than 0.075 meter radian : COMPLIED //

③ The intial GM after correction for FSC, shall be not less than 0.30 meter

Initial GM(F) = 0.310 meter

↓

i.e. not less than 0.30 meter : COMPLIED //

④ After loading the master shall ensure that the ship is upright before proceeding to sea.

GZ value at 0° heel = 0

That means, vessel is upright : COMPLIED //

Teacher's Signature

0.5
0.45
0.4
0.35
0.3
0.25
0.2
0.15
0.1
0.05

λ_0

Angle of heel due to shift of grain

λ_{40}

0 5 10 15 20 25 30 40 45 50 55 60

OCT 2023
AM

GM(F) : 0.90 m , W : 13674 t

Angle of heel	0	5	10	15	20	25	30	35	40	45	50
GZ	0	0.09	0.21	0.35	0.45	0.51	0.55	0.58	0.59	0.58	0.55

PLOT THE GZ CURVE (i.e Righting arm curve)

	COMPARTMENT	TRASVERSE VHM	CORRECTION FACTOR	CORRECTED VHM
FULL-KG OF CARGO IS USED PARTLY FILLED	NO.1 HOLD	774 m⁴	1	774
	NO.2 HOLD	929 m⁴	1	929
	NO.3 HOLD	995 m⁴	1	995
	NO.4 HOLD	1022 m⁴	1	1022
	NO.1 TD	608 m⁴	1.06	644.48
	NO.2 TD	601 m⁴	1.12	673.12
	NO.3 TD	407 m⁴	1.06	431.42

Given in Ques:- 1) For lower hold, KG of compartment is used Total VHM = 5469.02 m⁴
2) For tween deck, KG of cargo is used | 2 TD is partiaiy full

$$\lambda_0 = \frac{\text{Total VHM}}{\text{SFX displacement}} = \frac{5469.02}{1.60 \times 13674} = 0.250\ m$$

$$\lambda_{40} = 0.8 \times \lambda_0 = 0.8 \times 0.250 = 0.200 m$$

PLOT λ_0 & λ_{40} (i.e. grain heeling arm curve)

① Angle of heel due to shift of grain shall not be greater than 12° or angle at which the deck edge is immersed, whichever is lesser

Angle of heel due to shift to grain = 11° (From GZ curve)
↓
i.e. less than 12° : COMPLIED //

② The residual area between the heeling arm curve and the righting arm curve, upto the angle of heel of : maximum difference between the ordinates of the two curve or 40° or angle of flooding, whichever is lesser shall be not less than 0.075 meter radian

$$\text{So, } h = \frac{1}{n-1} = \frac{40}{5-1}$$

$$= 10$$

Teacher's Signature

Heel	GZ	SM	POA
0	0	1	0
10	0.21	4	0.84
20	0.45	2	0.90
30	0.55	4	2.20
40	0.59	1	0.59

SOPA : 4.53

Total area = $\frac{SOPA \times h}{3} = \frac{4.53 \times 10}{3 \times 57.3}$ = 0.264 meter radian

Area of $\Delta = \frac{1}{2} \times b \times h \times \frac{1}{57.3} = \frac{1}{2} \times 11 \times 0.250 \times \frac{1}{57.3}$ = 0.024 meter radian

Area of Trapezium = $\frac{1}{2}(A_{heel} + A_{40}) \times (40 - heel) \times \frac{1}{57.3}$

$= \frac{1}{2}(0.24 + 0.20) \times (40 - 11) \times \frac{1}{57.3}$

$= \frac{1}{2} \times 0.44 \times 29 \times \frac{1}{57.3}$ = 0.111 meter radian.

Residual area = Total area - Area under grain heeling arm curve

= 0.264 - (0.024 + 0.111)

= 0.129 meter

↓

i.e. not less than 0.075 meter radian : COMPLIED

③ The initial GM after correction of FSC, shall not be less than 0.30 meter.

Initial GM(F) : 0.880 m

↓

i.e. not less than 0.30 meter : COMPLIED //

④ After loading, the master shall ensure that the ship is upright before proceeding to sea.

GZ value at 0° heel = 0

That means, vessel is upright : COMPLIED //

Teacher's Signature _____