MERCHANT SHIPPING SECRETARIAT
GOVERNMENT OF SRI LANKA
CERTIFICATE OF COMPETENCY EXAMINATION

GRADE : CHIEF MATE ON SHIPS OF 500 GT OR MORE (UNLIMITED)
SUBJECT : SHIP'S STABILITY
DATE : 27.06.2024

Time allowed **THREE hours** Total marks : 180
ANSWER ALL QUESTIONS Pass marks : 60%

Formulae and all intermediate steps taken in reaching your answer should be clearly shown. You may draw sketches wherever required. Electronic devices capable of storing and retrieving are **not** allowed.

1) Answer the following questions with regards to bilging:
   a) "Sometimes the GM will increase after bilging and sometimes it will reduce after bilging". Describe this statement.

   (05 marks)

   b) A box shaped vessel of length 100 m and breadth 18 m, floats in salt water on an even keel at 7.5 m draught. The ship has a continuous centre line bulkhead which is watertight. Find the list if a compartment amidships, which is 15 m long and empty, is bilged on one side. Assume the KG is 4 m.

   (25 marks)

2) A vessel completes loading with a displacement of 26000 t and an effective KG of 8.86 m. With the aid of the Hydrostatic particulars and KN curves provided, verify whether the vessel complies with the IMO stability criteria. The progressive flooding angle for the above displacement is 55^0.

   (30 marks)

3) A vessel is to transit a canal with a minimum clearance of 0.30m under a bridge, the underside of which is 20.24m above the waterline.
Present draughts in SW:
Forward 5.22m Aft 6.38m

The foremast is 112m foap and extends 25.92m above the keel.
The aft mast is 37m foap and extends 26.94m above the keel.
LBP is 137.5 m

Her hydrostatic particulars are as follows;
LCF_{foap} 68.57
TPC 23 t cm^{-1}

Assuming masts are perpendicular to the waterline throughout, calculate EACH of the following:

a) The final draughts forward and aft in order to pass under the bridge with minimum clearance;

(20 marks)

b) The minimum weight of ballast to load in order to pass under the bridge with minimum clearance.

(10 marks)

4) A vessel is floating upright with the following particulars:

Displacement = 20000 t KG = 9.0 m

The following cargo and bunkers are then loaded:

500 t	Kg 12.0 m	6.0 m to starboard of centerline
340 t	Kg 4.5 m	4.5 m to starboard of centerline
200 t	Kg 11.0 m	6.0 m to port of centerline

Bunkers (relative density 0.9) 150 t (Kg 1.2 m), in a centre tank of length 8 m, breadth 15 m which is slack.

Calculate the list if the final KM is 10.55 m

(30 marks)

5) Answer the following questions with regards to change of density:

a) With the aid of a labelled sketch explain why the trim is subjected to change when a vessel moves from one density of water to another.

(05 marks)

b) A vessel floating in salt water has the following particulars:

Displacement	18,000 t	LBP	220 m
LCB	100 m foap	LCF	120 m foap
MCTC	200	TPC	23
Draft fwd	7.85 m	aft	8.55 m

The vessel has two bunker tanks. The forward tank has it's centroid 205 m forward of the aft perpendicular and the after tank has it's centroid 75 m forward of the aft perpendicular. Calculate the following;

i) The amount of fuel to transfer between the bunker tanks in order to arrive alongside at a freshwater berth on an even keel.

(15 marks)

ii) The arrival draft forward and aft.

(10 marks)

6) With reference to a modern shipboard stability and stress finding instruments:

a) state the hydrostatic and stability data already pre-programmed into the instrument;

(08 marks)

b) describe the information to be entered into the instrument by the ship's officer;

(10 marks)

c) describe the output information.

(12 marks)

Draught	Displ.	TPC	MCTC	LCB	LCF	KB	KML	KMT
7.00	21600	32.82	335	86.78	85.53	3.60	265	9.49
7.10	21930	32.88	337	86.76	85.45	3.65	262	9.46
7.20	22260	32.94	339	86.74	85.37	3.70	260	9.44
7.30	22590	33.00	341	86.72	85.28	3.76	258	9.42
7.40	22920	33.07	343	86.70	85.19	3.81	256	9.40
7.50	23250	33.13	345	86.67	85.10	3.86	254	9.39
7.60	23580	33.20	347	86.65	85.01	3.91	525	9.37
7.70	23920	33.27	349	86.63	84.92	3.96	250	3.36
7.80	24250	33.34	351	86.61	84.82	4.02	248	9.35
7.90	24590	33.41	353	86.58	84.72	4.07	246	9.34
8.00	24920	33.48	355	86.55	84.62	4.12	245	9.33
8.10	25250	33.55	357	86.53	84.51	4.17	243	9.32
8.20	25590	33.63	359	86.50	84.40	4.22	242	9.32
8.30	25930	33.71	362	86.47	84.29	4.28	240	9.31
8.40	26270	33.79	365	86.44	84.17	4.33	238	9.31
8.50	26610	33.87	368	86.41	84.05	4.38	237	9.31
8.60	26950	33.95	370	86.38	83.94	4.43	236	9.31
8.70	27290	34.03	373	86.35	83.83	4.48	234	9.32
8.80	27630	34.11	375	86.32	83.72	4.54	233	9.32
8.90	27970	34.19	378	86.29	83.62	4.59	232	9.33
9.00	28310	34.27	381	86.25	83.52	4.64	231	9.34
9.10	28650	34.35	384	86.22	83.41	4.69	230	9.35
9.20	28990	34.43	386	86.19	83.30	4.74	229	9.36
9.30	29340	34.51	389	86.15	83.20	4.80	228	9.37
9.40	29690	34.59	391	86.12	83.10	4.85	227	9.38
9.50	30040	34.67	394	86.09	83.00	4.90	226	9.39
9.60	30390	34.75	396	86.05	82.90	4.96	225	9.40
9.70	30740	34.82	399	86.01	82.80	5.01	224	9.41
9.80	31090	34.89	401	85.97	82.70	5.06	223	9.43
9.90	31440	34.96	404	85.93	82.60	5.11	221	9.44
10.00	31790	35.03	406	85.89	82.50	5.17	220	9.46
10.10	32140	35.10	409	85.86	82.41	5.22	219	9.47
10.20	32490	35.17	411	85.82	82.32	5.27	218	9.49
10.30	32840	35.24	413	85.78	82.24	5.33	217	9.51
10.40	33190	35.31	415	85.74	82.16	5.38	216	9.53
10.50	33540	35.38	418	85.70	82.08	5.44	215	9.55
10.60	33890	35.45	420	85.66	82.00	5.49	214	9.57
10.70	34250	35.52	423	85.62	81.93	5.55	213	9.59
10.80	34610	35.59	425	85.59	81.86	5.60	212	9.61
10.90	34970	35.66	427	85.55	81.79	5.65	211	9.63
11.00	35330	35.72	429	85.51	81.72	5.71	210	9.66

DISPLACEMENT (t)	ANGLE OF HEEL - DEGREES					
	10	20	30	40	60	80
7000	2.97	5.35	6.72	7.55	8.53	8.32
8000	2.75	5.10	6.52	7.47	8.60	8.35
9000	2.56	4.87	6.38	7.40	8.65	8.38
10000	2.39	4.65	6.22	7.34	8.69	8.40
11000	2.25	4.45	6.10	7.28	8.71	8.40
12000	2.13	4.26	5.97	7.24	8.70	8.40
13000	2.03	4.10	5.86	7.20	8.69	8.40
14000	1.94	3.95	5.75	7.16	8.67	8.39
15000	1.88	3.83	5.65	7.14	8.63	8.38
16000	1.82	3.72	5.58	7.10	8.58	8.36
17000	1.78	3.63	5.50	7.05	8.54	8.34
18000	1.74	3.55	5.44	7.01	8.48	8.32
19000	1.70	3.49	5.36	6.96	8.44	8.30
20000	1.69	3.45	5.30	6.90	8.38	8.28
21000	1.66	3.40	5.25	6.85	8.34	8.25
22000	1.65	3.36	5.20	6.80	8.28	8.23
23000	1.65	3.34	5.15	6.72	8.23	8.22
24000	1.64	3.32	5.10	6.65	8.17	8.17
25000	1.64	3.31	5.08	6.58	8.11	8.15
26000	1.64	3.30	5.04	6.50	8.06	8.14
27000	1.64	3.30	5.00	6.44	8.00	8.11
28000	1.65	3.31	4.95	6.36	7.93	8.10
29000	1.65	3.31	4.93	6.30	7.86	8.07
30000	1.65	3.31	4.89	6.22	7.80	8.05
31000	1.65	3.32	4.84	6.14	7.74	8.03
32000	1.66	3.34	4.80	6.06	7.69	8.00
33000	1.66	3.36	4.75	5.99	7.62	7.99

The volumes of buoyancy include poop and forecastle but not hatches.

Answers

Answer 1(a)

Volume of gained buoyancy = Volume of gained buoyancy

S = 15 x 9 x 7.5 / (100 x 18 – 15 x 9)
= 0.61 m

Bilged hydraft = 7.5 + 0.61 m = 8.11 m

Transverse shift of centre of buoyancy = 15 x 9 x 4.5 / (100 x 18 – 15 x 9)
= 0.37 m

Ixx = $(9^3 \times 100 + 9^3 \times 85) / 3$ = 44955 m^4

I_{II} = Ixx – Ad^2 = 44955 – (100 x 18 – 15 x 9) x 0.365^2
= 44733 m^4

BM = I_{II} / V = 44733 / (100 x 18 x 7.5)
= 3.31 m

KB = bilged hydraft / 2 = 8.11 / 2 = 4.06 m

KM = KB + BM = 4.06 + 3.31 = 7.37 m

GM after bilging = KM – KG = 7.37 – 4.00 = 3.37 m

Tan list = shift of buoyancy / bilged GM
= 0.37 / 3.37

List = 6.3^0

Answer 2

From tables;
KM = 9.31 m
GM = KM – KG = 9.31 – 8.86 = 0.45 m

From KN curves;

Heel	10	20	30	40	60	80
KN	1.64	3.3	5.04	6.5	8.06	8.14
KG x Sin heel	1.54	3.03	4.43	5.7	7.67	8.73
GZ	0.10	0.27	0.61	0.8	0.39	- 0.59

Area up to 30º

Heel	GZ	SM	Product
0	0.00	1	0.0
10	0.10	3	0.3
20	0.27	3	0.81
30	0.61	1	0.61
Total			1.720

Area = 3 x 10 x 1.72 / (8 x 57.3) = 0.113 m rad

Area up to 40º

Heel	GZ	SM	Product
0	0.00	1	0.0
10	0.10	4	0.4
20	0.27	2	0.54
30	0.61	4	2.44
40	0.8	1	0.8
Total			4.18

Area = 10 x 4.18 / (3 x 57.3) = 0.243 m rad

Area between 30º and 40º = 0.243 – 0.113 = 0.13 m rad

Area between 0 and 30 – Complies
Area between 0 and 40 – Complies
Area between 30 and 40 – Complies
GZ shall be at least 0.2 m – Complies
Maximum righting lever – Complies
Initial GM at least 0.15 m – Complies

Answer 3(a)

Max air draught available = 20.24 – 0.3 = 19.94 m

Max draught under fwd mast = 25.92 – 19.94 = 5.98 m
Max draught under aft mast = 26.94 – 19.94 = 7.00 m

Trim between masts = 26.94 – 25.92 = 1.02 m
Distance between masts = 112 – 37 = 75 m

Req. draught aft = 7 + 1.02 x 37 / 75 = 7.503 m
Req. draught fwd = 5.98 – 1.02 x (137.5 – 112) / 75 = 5.633 m

Answer 3(b)

Initial trim = 6.38 – 5.22 = 1.16 m
Initial TMD = 6.38 – 1.16 x 68.57 / 137.5 = 5.802 m

Final trim = 7.503 – 5.633 = 1.87 m
Final TMD = 7.503 – 1.87 x 68.57 / 137.5 = 6.57 m

Req. increase of draught = 6.57 – 5.802 = 0.768 m = 76.8 cm

Ballast to take = 76.8 x 23 = 1766.4 t

Answer 4

Take moments about keel and centreline:

Load	Kg	Moments	Dist. From centre line	Moments about centre line	
				P	S
20000	9.0	180000			
500	12.0	6000	6 (Stbd)		3000
340	4.5	1530	4.5 (Stbd)		1530
200	11.0	2200	6 (Prt)	1200	
150	1.2	180			
21190		**189910**		**1200**	**4530**
					3330

KG = 8.962 m
KM = 10.550 m

FSE = $8 \times 15^3 \times 0.9 / (12 \times 21190)$

= 0.096 m

GM solid = 1.588 m

GM fluid =1.492

Tan list = 3330 / (21190 x 1.492)

List = 6^0 stbd

Answer 5 (a)

Change of trim will occur depending upon the position of the LCF and LCB. Stern trim will occur if the LCF > LCB and head trim will occur if the LCF < LCB. This has to be explained by means of a diagram.

Answer 5 (b) (i)

FWA = Displacement / (40 x TPC)

= 18000 / (40 x 23) = 19.565 cm = 0.196 m

$TPC_{fresh\ water}$ = 23 x 1.000 / 1.025 = 22.4

Weight of increased under water volume = FWA x $TPC_{less\ density}$ = 19.565 x 22.4

= 438.26 t

Trimming moment = Weight of increased under water volume x (LCB – LCF)

= 438.26 x (100 – 120) = 8765.2 tm

$MCTC_2$ = 200 x 1.000 / 1.025 = 195.1

COT = Trimming moment / $MCTC_2$ = 8765.2 / 195.1 = 44.9 cm

= 0.449 m by stern

Total trim after arriving into fresh water = initial trim + COT

= 0.7 m + 0.449 = 1.149 m

Distance between the tanks = 205 – 75 m = 130 m

COT = trimming moment / $MCTC_2$

100 x 1.149 = ballast water to transfer to make her even keel x 130 / 195.1

Ballast water to transfer to make her even keel = 172.4 t

Answer 5 (b) (ii)

COT due to change of density = 0.449 m (by stern)

T_a due to change of density = 0.449 x 120 / 220 =0.245 m

T_f due to change of density = 0.449 – 0.245 = 0.204 m

COT required to make her even keel = 1.149 m (by head)

T_a when making her even keel = 1.149 x 120 / 220 = 0.627 m

T_f when making her even keel = 1.149 – 0.627 = 0.522 m

	Fwd (m)	**Aft (m)**
Initial draught	7.85	8.55
Bodily sinkage	+ 0.196	+ 0.196
	8.046	8.746
T_f / T_a	- 0.204	+0.245
Arrival draught at fresh water	7.842	8.991
T_f / T_a (to make her even keel)	+ 0.522	- 0.627
Even keel draughts	8.364	8.364