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 : 28th August 2023

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) A box shaped vessel floating on an even keel in salt water has the following particulars:

Length	120 m
Breadth	22 m
Draught	5.00 m

There is a mid ship cargo hold of length 16 m, extending the full breadth of the vessel which has a double bottom tank below. Permeability of the cargo hold is 0.65 and the height of the double bottom tank is 1.8 m.

If this compartment is bilged, calculate each of the following:

a) The final draught

(10 marks)

b) The change in GM

(20 marks)

2) A vessel's present particulars are as follows:

A vessel is floating in salt water with the following particulars:

Forward draught	8.3 m	KG	8.0 m
Aft draught	8.5 m	LBP	137.5 m

The vessel is to load bunkers of heavy fuel oil into No. 3 DB port and starboard tanks (LCG of both tanks, foap is 57.87 m) and sail upright at a maximum draught of 8.5 m.

Using the Hydrostatic particulars provided, calculate each of the following:

a) The maximum weight of bunkers to load.

(20 marks)

b) The weight of ballast water to transfer between the Aft Peak (LCG_{foap} 3.07 m) and Fore Peak (LCG_{foap} 130.56 m) so that the vessel sails on an even keel.

(10 marks)

3) a) Define the term angle of loll. Explain how such a condition can develop on board. Propose the possible remedial actions to improve the stability condition.

(15 marks)

b) M.V. Non Such, displacing 17,000 t has the following data;

KG	: 8.55 m	FSM	: 2550 tm
KM	: 8.265 m	KB	: 4.331 m

The KN values for the corresponding angles of heel are as follows;

Heel	0	5	10	15	20	30	40	60
KN	0	0.755	1.502	2.229	2.978	4.362	5.630	7.138

Find the angle of loll by constructing the GZ curve. (15 marks)

4) a. Write short notes on the following
   i) angle of flooding
   ii) angle of vanishing stability
   iii) angle of deck edge immersion (05 marks each)

   b. Describe the countermeasures that may be taken in the event of flooding.
   (15 marks)

5) A vessel is to load a cargo of grain (Stowage factor 1.48 m^3t^{-1}). Initial displacement is 3890 t and the initial KG is 6.54 m.
   No. 1, 2, 4, 5 lower holds are to be loaded full of grain (No. 3 is empty) as follows:

Hold	**Grain capacity (m^3)**	**Horizontal volumetric heeling moment (m^4)**	**VCG of hold (m)**
1 (FULL)	2215	409.5	5.089
2 (FULL)	4672	1284.9	4.947
4 (FULL)	3474	910.4	4.950
5 (FULL)	2605	454.9	8.764

The tween decks are to be loaded as follows (No. 3 & 5 are empty):

Hold	**Grain capacity (m^3)**	**Horizontal volumetric heeling moment (m^4)**	**VCG of hold (m)**
1 (FULL)	1695	352.4	11.26
2 (PART FULL)	1165	2874	10.5
3 (EMPTY)			
4 (FULL)	1674	604.4	10.57

Using the Maximum Permissible Grain Heeling Moment Tables, determine:

a) Compliance with stability criteria of the IMO Grain Rules;
(25 marks)

b) Approximate angle of heel after assumed shift of grain
(05 marks)

6) A box-shaped barge of uniform construction is 32 m long and displaces 352 t when empty, is divided by transverse bulkheads into four equal compartments. Cargo is loaded into each compartment and level stowed as follows:

No. 1 hold – 192 tonnes No. 2 hold – 224 tonnes
No. 3 hold – 272 tonnes No. 4 hold – 176 tonnes

a) Construct load and shearing force diagrams at the bulkheads (15 marks)

b) Construct bending moments curve for the above positions (10 marks)

c) Find the value of the maximum bending moment along the ship's length (05 marks)

HYDROSTATIC PARTICULARS

DRAUGHT	DISPLACEMENT t		TPC t		MCTC tm		KM_T	KB	LCB foap	LCF foap
m	SW RD 1.025	FW RD 1.000	SW RD 1.025	FW RD 1.000	SW RD 1.025	FW RD 1.000	m	m	m	m
10.00	21789	21258	24.85	24.24	224.8	219.3	8.69	5.25	68.71	65.11
9.90	21541	21016	24.80	24.20	223.6	218.1	8.67	5.20	68.75	65.16
9.80	21293	20774	24.75	24.15	222.4	217.0	8.64	5.15	68.79	65.20
9.70	21046	20533	24.70	24.10	221.2	215.8	8.62	5.10	68.83	65.25
9.60	20799	20292	24.65	24.05	220.0	214.6	8.60	5.04	68.87	65.29
9.50	20553	20052	24.60	24.00	218.8	213.5	8.58	4.99	68.92	65.34
9.40	20307	19812	24.55	23.95	217.6	212.3	8.56	4.93	68.96	65.39
9.30	20062	19573	24.50	23.90	216.4	211.1	8.54	4.88	69.00	65.45
9.20	19817	19334	24.45	23.85	215.2	210.0	8.52	4.82	69.04	65.50
9.10	19573	19096	24.40	23.80	213.0	207.8	8.50	4.77	69.09	65.56
9.00	19329	18858	24.35	23.76	212.7	207.5	8.48	4.72	69.13	65.62
8.90	19086	18620	24.30	23.71	211.5	206.3	8.47	4.67	69.18	65.68
8.80	18843	18383	24.24	23.65	210.2	205.1	8.45	4.61	69.22	65.74
8.70	18601	18147	24.18	23.59	208.0	202.9	8.43	4.56	69.27	65.81
8.60	18359	17911	24.13	23.54	207.7	202.6	8.42	4.50	69.31	65.87
8.50	18119	17677	24.08	23.49	206.4	201.4	8.41	4.45	69.36	65.95
8.40	17878	17442	24.02	23.43	205.1	200.1	8.39	4.39	69.40	66.02
8.30	17639	17208	23.96	23.38	203.8	198.8	8.38	4.34	69.45	66.10
8.20	17399	16975	23.90	23.32	202.4	197.5	8.37	4.28	69.49	66.17
8.10	17161	16742	23.84	23.26	201.0	196.1	8.36	4.23	69.54	66.25
8.00	16922	16509	23.78	23.20	199.6	194.7	8.35	4.17	69.58	66.33
7.90	16685	16278	23.71	23.13	198.2	193.4	8.35	4.12	69.63	66.42
7.80	16448	16047	23.65	23.07	196.8	192.0	8.34	4.07	69.67	66.51
7.70	16212	15817	23.59	23.01	195.4	190.6	8.34	4.02	69.72	66.61
7.60	15976	15586	23.52	22.95	193.9	189.2	8.33	3.96	69.76	66.71
7.50	15742	15358	23.45	22.88	192.4	187.7	8.33	3.91	69.81	66.82
7.40	15507	15129	23.39	22.82	190.9	186.2	8.33	3.85	69.85	66.92
7.30	15274	14901	23.33	22.76	189.4	184.8	8.33	3.80	69.90	67.03
7.20	15040	14673	23.26	22.69	187.8	183.2	8.33	3.75	69.94	67.13
7.10	14808	14447	23.19	23.32	186.2	181.7	8.34	3.70	69.99	67.24
7.00	14576	14220	23.13	22.57	184.6	180.1	8.34	3.64	70.03	67.35
6.90	14345	13996	23.06	22.50	183.0	178.5	8.35	3.58	70.08	67.46
6.80	14115	13771	22.99	22.43	181.4	177.0	8.36	3.53	70.12	67.57
6.70	13886	13548	22.92	22.36	179.9	175.5	8.37	3.48	70.16	67.68
6.60	13657	13324	22.85	22.29	178.3	174.0	8.38	3.43	70.20	67.79
6.50	13429	13102	22.78	22.23	176.8	172.5	8.39	3.38	70.24	67.90
6.40	13201	12879	22.72	22.17	175.3	171.0	8.41	3.33	70.28	68.00
6.30	12975	12658	22.66	22.11	173.9	169.6	8.43	3.28	70.32	68.10
6.20	12748	12437	22.60	22.05	172.5	168.3	8.46	3.22	70.35	68.20
6.10	12523	12217	22.54	21.99	171.1	167.0	8.49	3.17	70.38	68.30
6.00	12297	11997	22.48	21.93	169.8	165.7	8.52	3.11	70.42	68.39
5.90	12073	11778	22.43	21.87	168.5	164.4	8.55	3.06	70.46	68.43
5.80	11848	11559	22.37	21.82	167.3	163.2	8.59	3.01	70.50	68.57
5.70	11625	11342	22.32	21.77	166.1	162.1	8.63	2.95	70.53	68.65

TABLE OF MAXIMUM PERMISSIBLE GRAIN HEELING MOMENTS

D (tonnes)	FLUID KG (metres)															
	5.500	5.600	5.700	5.800	5.900	6.000	6.100	6.200	6.300	6.400	6.500	6.600	6.700	6.800	6.900	7.000
5000	8425	8315	8204	8094	7983	7873	7762	7651	7541	7430	7320	7209	7099	6988	6877	6767
5500	8336	8214	8093	7971	7850	7728	7606	7485	7363	7241	7120	6998	6877	6755	6633	6512
6000	8158	8026	7893	7760	7628	7495	7362	7230	7097	6964	6832	6699	6566	6434	6301	6168
6500	7987	7843	7699	7556	7412	7268	7124	6981	6837	6693	6550	6406	6262	6118	5975	5831
7000	7891	7737	7582	7427	7272	7117	6963	6808	6653	6498	6343	6189	6034	5879	5724	5569
7500	7911	7745	7579	7413	7248	7082	6916	6750	6584	6418	6252	6087	5921	5755	5589	5423
8000	7979	7802	7625	7448	7271	7094	6917	6741	6564	6387	6210	6033	5856	5679	5502	5325
8500	8006	7818	7630	7442	7254	7066	6879	6691	6503	6315	6127	5939	5751	5563	5375	5187
9000	8017	7818	7619	7420	7221	7022	6823	6624	6425	6226	6027	5828	5629	5430	5231	5032
9500	8062	7852	7642	7432	7222	7012	6802	6592	6382	6171	5961	5751	5541	5331	5121	4911
10000	8151	7930	7709	7488	7267	7046	6824	6603	6382	6161	5940	5719	5498	5276	5055	4834
10500	8270	8038	7800	7573	7341	7109	6877	6645	6412	6180	5948	5716	5484	5251	5019	4787
11000	8376	8133	7890	7647	7403	7160	6917	6674	6430	6187	5944	5701	5457	5214	4971	4728
11500	8437	8182	7928	7674	7419	7165	6911	6656	6402	6148	5893	5639	5385	5130	4876	4622
12000	8511	8245	7980	7714	7449	7184	6918	6653	6388	6122	5857	5591	5326	5061	4795	4630
12500	8655	8379	8102	7826	7549	7273	6997	6702	6444	6167	5891	5614	5338	5062	4785	4509
13000	8809	8522	8234	7947	7659	7372	7084	6797	6509	6222	5934	5647	5359	5072	4784	4497
13500	8909	8611	8312	8013	7715	7416	7118	6819	6521	6222	5924	5625	5327	5028	4730	4431
14000	9053	8743	8434	8124	7815	7505	7195	6886	7576	6267	5957	5647	5338	5028	4719	4409
14500	9347	9026	8706	8385	8065	7744	7423	7103	6782	6461	6141	5820	5499	5179	4858	4537
15000	9702	9371	9039	8707	8376	8044	7712	7380	7049	6717	6385	6053	5722	5390	5058	4727
15500	10010	9667	9325	8982	8639	8296	7954	7611	7268	6925	6583	6240	5897	5554	5211	4869
16000	10352	9998	9644	9290	8937	8583	8229	7875	7521	7167	6814	6460	6106	5752	5398	5045
16500	10823	10458	10093	9728	9363	8998	8634	8269	7904	7539	7174	6809	6444	6079	5715	5350
17000	11329	10953	10577	10201	9826	9450	9074	8698	8322	7946	7570	7194	6818	6442	6066	5690
17500	11762	11375	10988	10601	10214	9827	9440	9053	8666	8279	7892	7505	7118	6731	6344	5957
18000	12173	11775	11377	10979	10581	10183	9785	9387	8989	8590	8192	7794	7396	6998	6600	6202
18500	12626	12217	11808	11398	10989	10580	10171	9762	9353	8944	8535	8125	7716	7307	6898	6489
19000	13040	12619	12199	11779	11539	10939	10519	10098	9678	9258	8838	8418	7998	7577	7157	6737
19500	13376	12945	12514	12082	11651	11220	10789	10357	9926	9495	9064	8633	8201	7770	7339	6908

Answers

Answer – 1(a)

Initially,

KB = 5 / 2 = 2.5 m

BM = LB^3 / (12V) = 120 x 22^3 / (12 x 120 x 22 x 5)

= 8.07 m

Initial KM = 2.5 + 8.07 = 10.57 m

After bilging;

Increased draught = lost buoyancy / intact water plane area

= 22 x 16 x 3.2 x 0.65 / ((120 x 22) – (22 x 16 x 0.65))

= 0.304 m

Bilged draught = 5 + 0.304 m = 5.304 m

BM = LB^3 / (12V)

= (120 – 16 x 0.65) x 22^3 / (12 x 120 x 22 x 5)

Bilged BM = 7.368 m

	Volume	**KB**	**Volume x KB**
Bilged v/l	5.304 x 120 x 22	5.304 / 2	37134.8
Bilged compartment	- 3.504x16 x 22 x 0.65	3.552	- 2847.7
Final vessel	5 x 120 x 22	2.6	34287.1

Bilged KB = 2.6 m

Bilged KM = 7.368 + 2.6

Bilged KM = 9.968 m

Therefore, change of KM = 10.57 – 9.968 = 0.599 m (decreased)

Answer – 2(a)

AMD = (8.3 + 8.5) / 2 = 8.4 m

LCF for AMD = 66.02 m

TMD = 8.5 – (0.2 x 66.02) / 137.5 = 8.404 m

From table, for TMD

Disp. = 17887.64 t

MCTC = 205.2 tm

LCB = 69.4 m (foap)

Vessel is trimmed by stern, therefore, initially, LCB > LCG

Calculation of initial LCG

Trim = trimming moment / MCTC

0.2 x 100 = 17887.64 x (69.4 – LCG) / 205.2

Initial LCG = 69.17 m (foap)

The departure draught is 8.5 m, therefore, for the departure condition from table;

Displ. = 18119 t

MCTC = 206.4 tm

LCB = 69.36 m (foap)

Maximum weight of bunkers to load = 18119 – 17887.64 = 231.36 t

Answer – 2(b)

Assuming the weight of the ballast to transfer is 'w' tones, take moments about aft perpendicular

Weight (t)	LCG (m)	Longitudinal moments (tm)
17887.64	69.17	1237288.06
231.36	57.87	13388.8
'w' transferred	130.56 – 3.07	127.49 x w
Total		1250676.86 + 127.49w

Final LCG_{foap} = (1250676.86 + 127.49w) / 18119

But,

Final trim = 0, therefore,

On departure, LCG = LCB, therefore,

69.36 = (1250676.86 + 127.49w) / 18119

w = 47.5 t

Answer – 3(b)

KG solid = 8.55 m

FSC = 2550 / 17000 = 0.15 m

KG fluid = 8.55 + 0.15 = 8.7 m

Heel	KN	KG x Sinθ	GZ
0	0	0	0
5	0.755	0.758	- 0.003
10	1.502	1.511	- 0.009
15	2.229	2.252	- 0.023
20	2.978	2.976	0.002
30	4.362	4.35	0.012
40	5.630	5.592	0.038
60	7.138	7.534	- 0.396

Angle of loll = 21^0

Answer – 5(a)

Item	Vol (m^3)	SF	Weight	KG	Moment	Factor	VHM (m^4)
Initial ship			3890	6.54	25441	1.0	
1 LH	2215	1.48	1497	5.09	7618	1.0	410
2 LH	4672	1.48	3157	4.95	15618	1.0	1285
4 LH	3474	1.48	2347	4.95	11618	1.0	910
5 LH	2605	1.48	1760	8.76	15425	1.0	455
1 TD	1695	1.48	1145	11.26	12893	1.06	374
2 TD	1165	1.48	787	10.5	8264	1.12	3219
4 TD	1674	1.48	1131	10.57	11955	1.06	641
Totals			15714		108832		7294

Final KG = 108832 / 15714 = 6.93 t

Actual VHM = 7294 / 1.48 = 4928

From the maximum permissible volumetric heeling moments tables;

The maximum allowed VHM for the departure KG = 5202

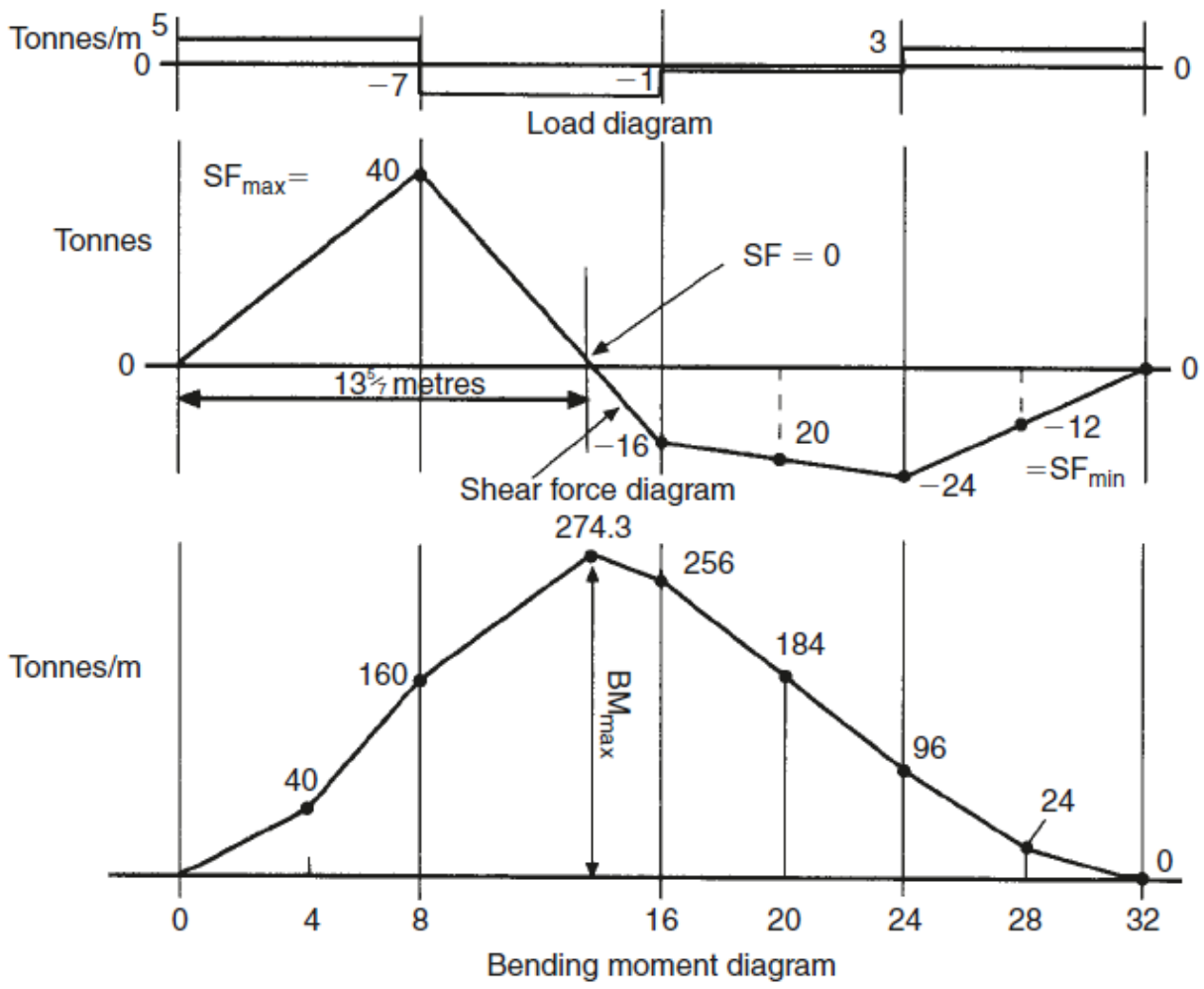
Therefore, vessel complies with grain criteria.

Answer – 5(b)

Approximate angle of heel due to grain shift = Actual VHM x 12 / Max. VHM

$= 11.4^0$

Answer – 6



Maximum bending moment = 274.3 tm (14 m fwd of stern)