DIRECTORATE OF MERCHANT SHIPPING
GOVERNMENT OF SRI LANKA
CERTIFICATE OF COMPETENCY EXAMINATION

GRADE : CHIEF MATE ON SHIPS OF 500 GT OR MORE (UNLIMITED)
SUBJECT : SHIP'S STABILITY
DATE : August 2014

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 vessel is floating in salt water with the following particulars;

Fwd draft	4.2 m	Aft draft	5.4 m
LBP	142 m	LCG	68.906 m.

She is expected to carryout following operations at the port;

Remarks	Weight (t)	Lcg (m)	Load/discharge
No. 1 hold	650	132	Load
No. 2 hold	750	105	Load
No. 3 hold	1500	56	Load
No. 4 hold	1600	48	Load
No. 4 centre DB Tk	50	138	De-ballast
No. 2 centre DB Tk	25	58	De-ballast

With the aid of the hydrostatic particulars (Data sheet – 1) provided, calculate the anticipated drafts fwd and aft, at the completion of above operations.

(30 marks)

2) a) Define the term bilging and the effects on a vessel as a result.

(05 marks)

b) A vessel 180 m long & 20 m wide is boxed shaped and afloat in salt water at an even keel draft of 7.40 m. A double bottom tank at the midship, starboard side is rectangular 10 m long, 10 m wide, 1.0 m deep and empty. Calculate the list if this tank is now bilged, given that KG = 7.6 m and FSM = 900 tm.

(25 marks)

3) A vessel with a high deck cargo of containers will experience adverse affects due to strong beam winds on the lateral windage areas.

Explain how the effects of steady and gusting winds are determined and state the minimum stability requirements with respect to wind heeling under the current regulations.

(30 marks)

4) (a) Describe the effect of trim and GM on a vessel during dry docking.

(05 marks)

(b) A vessel being dry docked for the purpose of refitting of a lost rudder has the following particulars on entry to the dock.

Displacement	13000 t	KG	8.50 m	LCF	76.00 foap
KM	8.80 m	MCTC	170		
Draughts fwd	4.80 m	aft	6.70 m		

Calculate the GM at the critical instant, as the dock is being emptied.

(05 marks)

c) While in the dock, the rudder, weighing 28 t, Kg 3.20 m, is fitted in position at the aft perpendicular. Calculate the GM at the critical instant as the dock is being refilled.

(20 marks)

5) a) Derive the following formula which is relevant to grain calculations;

λ_o **= Σ VHM / (Stowage Factor x displacement)**

(05 marks)

b) A vessel is to load grain (stowage factor 1.39 m^3/t) into several compartments to a total displacement of 13250 t. She has a KG of 8.50 m before loading grain. The compartments are loaded as follows:

Hold	**Grain volume (m^3)**	**Kg (m)**	**Lcg (m) foap**	**Horizontal heeling moments (m^4)**
No. 1 LH (full)	2215	5.08	114.5	659.5
No. 2 LH (full)	4672	4.95	90.0	850
No. 3 LH (full)	1536	4.94	51.7	770
No. 4 LH (full)	3454	4.95	23.9	760
No. 2 TD (full)	1675	10.79	115.5	659.0

No. 3 TD is loaded to an ullage of 2.80 m.

With the aid of Data Sheets 2 and 3, determine whether the vessel complies with the minimum requirements under the statutory grain rules.

(25 marks)

6) a) With the aid of a diagram, derive the following formula;

Tan (list) = listing moment / (displacement x GM)

(05 marks)

A vessel is floating upright with the following particulars;

Displacement = 10180 t KM = 9.6 m

A locomotive weighing 120 t is to be loaded using the vessels heavy lift from a position 18.0 m to port of the vessel's centre line. The derrick head is 21.0 m above the keel.

a) Calculate the maximum allowable KG prior to loading in order to limit the list to a maximum of 6^0 during the loading operation.

(20 marks)

b) Using the KG calculated above, determine the final angle of list if the locomotive is stowed in a position, Kg 2.50 m, 4.00 m to port of the vessels centre line.

(10 marks)

Data Sheet – 1

HYDROSTATIC PARTICULARS 'A'

Draught m	Displacement t		TPC t		MCTC tm		KMt M	KB m	LCB foap m	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				
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
5.60	11402	11124	22.26	21.72	165.0	161.0	8.67	2.90	70.57	68.73
5.50	11180	10908	22.21	21.66	163.9	160.0	8.71	2.85	70.60	68.80
5.40	10958	10691	22.15	21.61	162.9	158.9	8.76	2.80	70.64	68.88
5.30	10737	10476	22.10	21.56	161.8	157.9	8.81	2.74	70.68	68.95
5.20	10516	10260	22.05	21.51	160.8	156.9	8.86	2.69	70.72	69.02
5.10	10296	10045	22.00	21.46	159.8	155.9	8.92	2.63	70.75	69.09
5.00	10076	9830	21.95	21.41	158.8	154.9	8.98	2.58	70.79	69.16
4.90	9857	9616	21.90	21.36	157.9	154.0	9.06	2.53	70.82	69.23
4.80	9638	9403	21.85	21.32	156.9	153.1	9.13	2.48	70.86	69.29
4.70	9420	9190	21.80	21.27	156.0	152.2	9.22	2.43	70.90	69.35
4.60	9202	8978	21.75	21.22	155.1	151.3	9.30	2.38	70.93	69.42
4.50	8985	8766	21.70	21.17	154.2	150.5	9.40	2.32	70.96	69.48
4.40	8768	8554	21.65	21.12	153.3	149.6	9.49	2.27	71.00	69.55
4.30	8552	8344	21.60	21.07	152.4	148.7	9.60	2.22	71.04	69.62
4.20	8336	8133	21.55	21.02	151.5	147.8	9.71	2.17	71.08	69.68
4.10	8121	7923	21.50	20.97	150.6	146.9	9.83	2.12	71.12	69.74
4.00	7906	7713	21.45	20.93	149.7	146.0	9.96	2.07	71.15	69.81
3.90	7692	7505	21.40	20.88	148.7	145.1	10.11	2.01	71.18	69.88
3.80	7478	7296	21.35	20.83	147.8	144.2	10.25	1.96	71.22	69.94
3.70	7265	7088	21.30	20.78	146.8	143.3	10.41	1.91	71.25	70.00
3.60	7052	6880	21.24	20.72	145.9	142.3	10.57	1.86	71.29	70.07
3.50	6840	6673	21.19	20.67	144.9	141.3	10.76	1.81	71.33	70.14
THESE HYDROSTATIC PARTICULARS HAVE BEEN DEVELOPED WITH THE VESSEL FLOATING ON EVEN KEEL										

Data sheet – 2

TABLE OF MAXIMUM PERMISSIBLE GRAIN HEELING MOMENTS (tm)

Displacement tonne	FLUID KG (metres)									
	6.50	6.60	6.70	6.80	6.90	7.00	7.10	7.20	7.30	7.40
14 500	6141	5820	5499	5179	4858	4537	4217	3896	3575	3255
14 000	5957	5647	5338	5028	4719	4409	4099	3790	3480	3171
13 500	5924	5625	5327	5028	4730	4431	4132	3834	3535	3237
13 000	5934	5647	5359	5072	4784	4497	4209	3922	3634	3347
12 500	5891	5614	5338	5062	4785	4509	4232	3956	3679	3403
12 000	5857	5591	5326	5061	4795	4630	4265	3999	3734	3468
11 500	5893	5639	5385	5130	4876	4622	4368	4113	3859	3605
11 000	5944	5701	5457	5214	4971	4728	4484	4241	3998	3755
10 500	5948	5716	5484	5251	5019	4787	4555	4323	4090	3858
10 000	5940	5719	5498	5276	5055	4834	4613	4392	4171	3950
9500	5961	5751	5541	5331	5121	4911	4701	4491	4281	4071
9000	6027	5828	5629	5430	5231	5032	4833	4634	4435	4236
8500	6127	5939	5751	5563	5375	5187	4999	4811	4623	4435
8000	6210	6033	5856	5679	5502	5325	5148	4971	4795	4618
7500	6252	6087	5921	5755	5589	5423	5257	5091	4926	4760
7000	6343	6189	6034	5879	5724	5569	5415	5260	5105	4950
6500	6550	6406	6262	6118	5975	5831	5687	5543	5400	5256
6000	6832	6699	6566	6434	6301	6168	6035	5903	5770	5637
5500	7120	6998	6877	6755	6633	6512	6390	6268	6147	6025
5000	7320	7209	7099	6988	6877	6767	6656	6546	6435	6325

Data sheet – 3

VOLUMETRIC HEELING MOMENTS OF PARTLY FILLED COMPARTMENTS

ULLAGE DATUM: Top of Hatch-Side Coaming at its Mid-Length

COMPARTMENT No: 3TD (NO C.L. DIVISION)

ULLAGE m	VOLUME OF GRAIN m^3	HORIZONTAL HEELING MOMENT m^4	Kg of GRAIN m
0.25	1686	598	11.24
0.50	1668	659	11.19
0.75	1649	746	11.13
1.00	1628	864	11.07
1.25	1607	1016	11.01
1.50	1510	1176	10.94
1.75	1416	1372	10.98
2.00	1324	1577	10.82
2.25	1232	1799	10.75
2.50	1144	2017	10.69
2.75	1059	2218	10.63
3.00	970	2388	10.59
3.25	883	2512	10.55
3.50	800	2579	10.50
3.75	714	2575	10.45
4.00	633	2500	10.39
4.25	550	2362	10.31
4.50	467	2155	10.21
4.75	384	1908	10.10
5.00	302	1592	9.98
5.25	222	1239	9.81
5.50	143	848	9.56
5.75	64	380	9.27
5.95	0	0	8.70

ULLAGE FOR MAXIMUM HORIZONTAL MOMENT

3.60	764	2580	10.49

Answers

Question – 1

AMD = (4.2 + 5.4) / 2 = 4.8 m

From tables, LCF for AMD = 69.29 m

Correction to calculate TMD = 1.2 x 69.29 / 142 m = 0.586 m

TMD = 5.4 – 0.586 = 4.814 m

= 4.81 m

Initial displ. = 9659.9 t

Take moments about aft perpendicular to calculate the final LCG

Remarks	Weight (t)	Lcg (m)	Moments (tm)	
			Load (t)	Discharge (t)
Ship	+ 9659.9	68.91	665663.7	
No. 1 hold	+ 650	132	85800	
No. 2 hold	+ 750	105	78750	
No. 3 hold	+ 1500	56	84000	
No. 4 hold	+ 1600	48	76800	
No. 4 centre DB Tk	- 50	138		6900
No. 2 centre DB Tk	- 25	58		1450
Total	**14084.9**		**991013.7**	**8350**
			- 8350	
Resultant			**982663.7**	

Final LCG = 982663.7 / 14084.9 = 69.77 m

For the displacement of 14084.9 t, from tables;

Hydraft = 6.79 m

MCTC = 181.20

LCB = 70.125 m

LCF = 67.584 m

Final LCB is larger than the final LCG, therefore, she is trimmed by stern

COT = W x (LCB – LCG) / MCTC

COT = 14084.9 x (70.125 - 69.77) / 181.2

= 27.6 cm = 0.28 m

T_a = 0.28 x 67.58 / 142 = 0.133 m

T_f = 0.28 – 0.133 = 0.147 m

	FWD draft (m)	**AFT draft (m)**
Final hydraft	6.79	6.79
T_f / T_a	- 0.147	+ 0.133
Final drafts	6.643	6.923

Question – 2(b)

S = 10 x 10 x 1 / (180 x 20) = 0.028 m

Bilged draft = 7.428 m

Take moments of volumes about the keel to calculate the bilged KB,

180 x 20 x 7.4 (bilged KB) = 180 x 20 x 7.4 x (7.4 / 2) – 10 x 10 x 1 x (1/2) + 10x10x 1 x (7.414)

Bilged KB = 3.726 m

BM_T = LB^3 / (12 x V) = 180 x 20^3 / (12 x 180 x 20 x 7.4)

= 4.505 m

Bilged KM_T = 4.505 + 3.726 m = 8.231 m

Bilged GM = 8.231 – 7.6 m = 0.631 m

FSC = 900 / (180 x 20 x 7.4 x 1.025)

= 0.033 m

Bilged fluid GM = 0.631 – 0.033 m = 0.598 m

To calculate BB_1 take moments of volumes about vertical axis through the initial COB;

BB_1 = 10 x 10 x 1 x (5) / (180 x 20 x 7.4)
= 0.019 m
BG = 0.019 m

Tan (list) = BG / GM_f = 0.019 / 0.598

List = 1.8^0 (STBD side)

Question – 4(b)

P = MCTC x COT / LCF

P at critical instant = 170 x (6.7 – 4.8) x 100 / 76

= 425 t

Virtual loss of GM = P x KM / Displacement

= 425 x 8.8 / 13000 = 0.288 m

Initial GM = 8.8 – 8.5 = 0.30

GM at the critical instant = 0.30 – 0.288 m

= 0.012 m

Question – 4(c)

After fitting the rudder, by taking moments about the keel to calculate the new KG of the vessel;

Remark	Weight (t)	KG (m)	Moment (tm)
Ship	13000	8.5	110500
Rudder	28	3.2	89.6
Total	**13028**		**110589.6**

Final KG = 110589.6 / 13028

= 8.489 m

Trimming moment caused due to new rudder = 76 x 28 tm = 2128 tm

COT = Trimming moment / MCTC

COT = 2128 / 170 = 12.51 cm = 0.125 m

New trim = initial trim + 0.125

= 1.9 + 0.125 = 2.025 m

New P at critical instant = MCTC x COT / LCF = 170 x 2.025 x 100 / 76

= 452.96 t

New virtual loss of GM at the critical = P x KM / W = 452.96 x 8.8 / 13028

= 0.306 m

KG after fitting the rudder = 8.488 m

KM = 8.8 m

New GM after fitting the rudder = 0.312 m

New GM at the critical instant = 0.312 – 0.306 m

= 0.006 m

Question – 5(b)

For the partly filled compartment (from tables);

Ullage	Volume	HHM	Kg
2.8	1041.2	2252	10.622

Calculation of weight of cargo and VHM;

Hold	Grain volume (m^3)	Weight	Correction factor	Horizontal heeling moments (m^4)
No. 1 LH (full)	2215	1593.53	1.0	659.5
No. 2 LH (full)	4672	3361.15	1.0	850
No. 3 LH (full)	1536	1105.04	1.0	770
No. 4 LH (full)	3454	2484.89	1.0	760
No. 2 TD (full)	1675	1205.04	1.0	659.0
No. 3 TD (part)	1041.2	749.06	1.12	2522.24
TOTAL		**10498.71**		**6220.74**

Final displacement = 13250 t

Therefore, lightship displacement = 13250 – 10498.71 = 2751.29 t

Take moments about the keel to calculate the final KG;

Remark	Weight t)	Kg (m)	Moments (mt)
No. 1 LH (full)	1593.53	5.08	8095.13
No. 2 LH (full)	3361.15	4.95	16637.69
No. 3 LH (full)	1105.04	4.94	5458.90
No. 4 LH (full)	2484.89	4.95	12300.21
No. 2 TD (full)	1205.04	10.79	13002.38
No. 3 TD (part)	749.06	10.6	7940.04
Light ship	2751.29	8.5	23385.97
TOTAL	**13250**		**86820.32**

Final KG = 86820.32 / 13250 = 6.552 m

The total VHM = 6220.74 m^4

Actual heeling moment = 6220.74 / 1.39 = 4475.35 tm

The maximum permissible heeling moment for KG of 6.552 m (from table)

= 5776.64 tm

The maximum permissible heeling moment is higher than the actual heeling moment. Therefore, vessel is complying with the grain regulations.

Question – 6(b)

If the initial KG is 'Q', KG after taking the weight by the derrick is KG_1 and the GM after taking the weight by the derrick is GM_1;

Vertical GG_1 = w x d / W

= 120 (21 – Q) / 10300

KG_1 = Q + 120 (21 – Q) / 10300

= (10180 x Q + 2520) / 10300

KM = 9.6 m

GM_1 = 9.6 – (10180 x Q + 2520) / 10300

= 96360 – 10180 x Q / 10300

Horizontal GG_1 = w x d / W

= 120 x 18 / 10300

= 0.21 m

But, Tan (list) = horizontal GG_1 / (displacement x GM_1)

Tan 6 = 0.21 / 96360 – 10180 x Q

Q = 7.44 m

Maximum allowable KG = 7.44 m

Question – 6(c)

Vertical GG_1 after loading = 120 x (7.44 – 2.5) / 10300

= 0.058 m

Initial GM = 9.6 – 7.44 = 2.16 m

Therefore GM after loading = 2.16 + 0.058 = 2.218 m

Tan list = w x d / (Displacement x GM)

= 120 x 4 (10300 x 2.218)

List = 1.2^0 (Port)