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 : 21th August 2015

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, initially upright, is to carry out an inclining test. Present displacement 5700 t, KM 10.83m. Total weights on board during the experiment are:
   - Ballast 370 t, KG 3.47m, tank full.
   - Bunkers 165 t, KG 3.98m, free surface moment 956 tm.
   - Water 95 t, KG 4.44m, slack tank. Free surface moment 910 tm.
   - Boiler water 19 t, KG 4.18m, free surface moment 102 tm.
   - Two inclining weights each weighing 28 t, KG 8.44m
   - A deck crane weights 19 t and still ashore will be fitted on the vessel at a KG of 9.74m at a later date.

   a) The plumb lines have an effective vertical length of 7.85m. The inclining weights are shifted transversely 7.0 m on each occasion and the mean horizontal deflection of the plumb line is 0.65m. Calculate the vessel's lightship KG.

   (25 marks)

   b) Explain why a vessel's lightship KG may change over a period of time.

   (05 marks)

2) A box shaped vessel floating upright on an even keel in salt water has the following particulars:
   - Length BP : 150.00 m
   - Breadth: 28.00 m
   - Even keel draught: 8.60 m
   - KG: 9.20 m

   The vessel has two longitudinal bulkheads each 9.00 m from the side of the vessel. Calculate the angle of heel if an amidship side compartment having a length of 24.00m is bilged.

   (30 marks)

3) Answer the following questions with reference to GZ curves;

a) Derive the following formula with an aid of a diagram;

GZ = KN – KG x Sin θ

(05 marks)

b) A vessel has a displacement of 85,000 t, KG_{solid} of 10.68 m, FSM of 6761 tm. With the aid of Data sheet -1 and Data sheet – 2 draw a GZ curve and determine the following;

(16 marks)

i) Maximum GZ and the angle at which it occurs

(03 marks)

ii) The range of positive stability and

(03 marks)

iii) The angle of heel at which the deck edge would immerse

(03 marks)

4) A vessel is floating in SW at draught Fwd 3.80 m, aft 6.40 m. A total of 2400 tonne of cargo is to be loaded.

- Space is available in NO. 2 (LCG 100 m foap) and in No. 4 (LCG 54 m foap)
- Length B.P. 136 m
- LCF 67 m foap
- TPC 21.8
- MCTC 150

a) Calculate the weight of cargo to load in each space in order to finish with a trim of 1.0 m by the stern.

(20 marks)

b) Determine the final draughts fwd and aft.

(10 marks)

5) Answer the following questions with reference to loading grain in bulk;

a) State the intact stability criteria for ships carrying grain in bulk

(20 marks)

b) Derive the formula;

λ_o = Σ VHM / (Stowage Factor x W)

(05 marks)

c) The grain stability criteria states “After loading, the master shall ensure that the ship is upright before proceeding to sea”. Describe the reason for this criteria.

(05 marks)

6) A vessel initially upright and on an even keel, has the following particulars:
   - Draught in salt water 6.80 m
   - Breadth 20.42 m
   - KG 7.88 m
   - Further particulars of the vessel can be found in the "Hydrostatic particulars A" provided below.

The vessel's heavy lift derrick is to be used to discharge a 60 tonne tank from a centreline position, KG 5.23m. The derrick head is 29.28m above the keel and 15.80m out of the centreline when plumbing over side. Answer the following questions;

a) Calculate the maximum list angle.

(07 marks)

b) Calculate the increase in draught when the vessel is at maximum list angle as calculated in question (a) above, assuming rectangular cross section midships.

(05 marks)

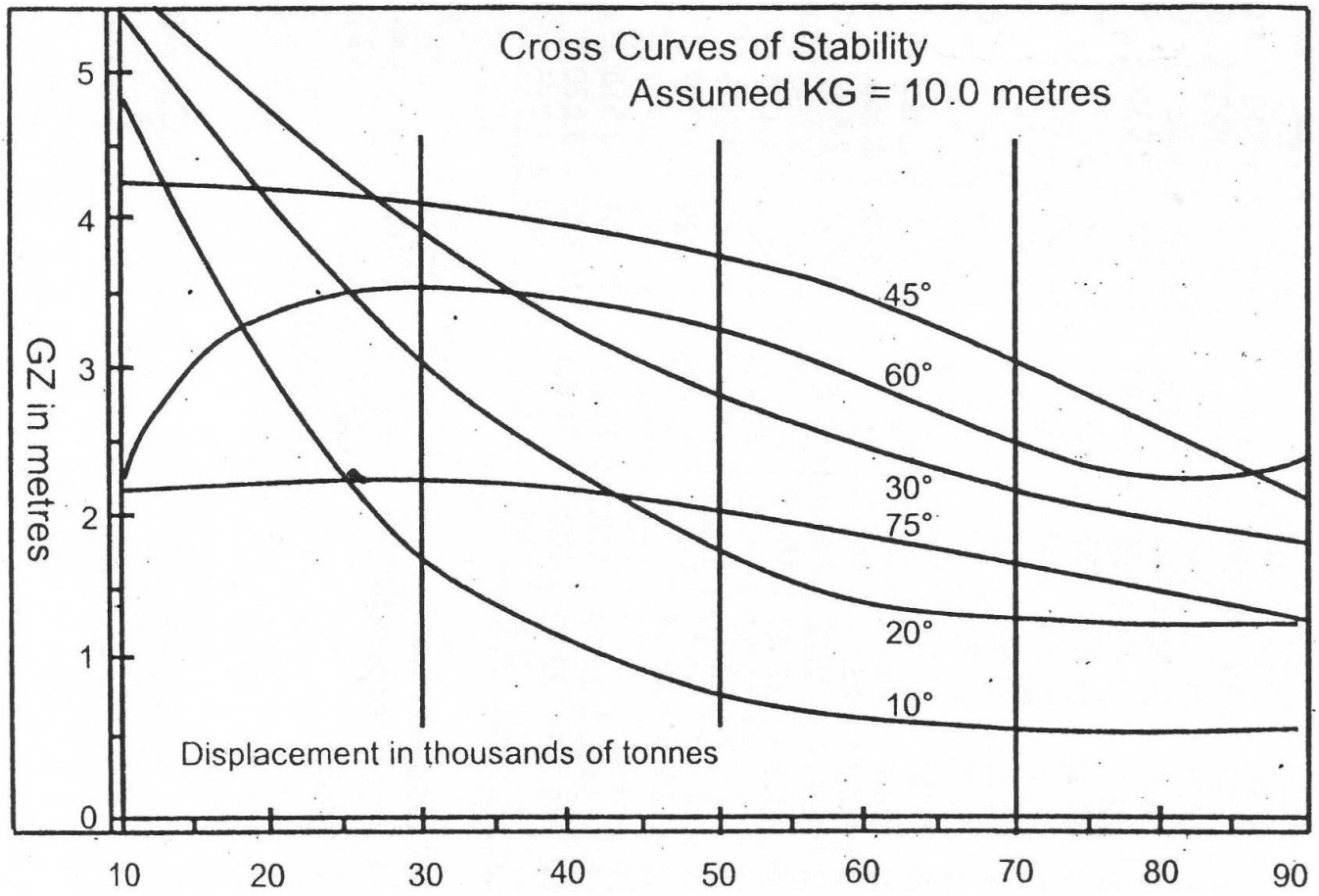
c) Calculate the maximum allowable KG prior to discharging the tank in order to limit the list angle to 5°.

(10 marks)

d) List the methods available to reduce the KG from 7.88 m to the required KG as calculated in above (c).

(08 marks)

DATA SHEET – 1


Cross Curves of Stability
Assumed KG = 10.0 metres
GZ in metres
Displacement in thousands of tonnes
45°
60°
30°
75°
20°
10°
0
1
2
3
4
5
10
20
30
40
50
60
70
80
90

DATA SHEET – 1

Hydrostatic particulars

d	W sw	TPC	MCTC	HB	HF	KB	KM_T	KM_L
11.00	70941	68.58	1083.0	5.37F	1.96F	5.64	13.24	366
11.20	72315	68.74	1091.3	5.30F	1.72F	5.75	13.22	362
11.40	73693	68.91	1099.5	5.23F	1.47F	5.85	13.20	358
11.60	75074	69.07	1107.8	5.16F	1.22F	5.95	13.18	354
11.80	76458	69.24	1115.9	5.09F	0.98F	6.06	13.17	351
12.00	77845	69.40	1124.0	5.02F	0.74F	6.16	13.16	347
12.20	79237	69.56	1131.3	4.94F	0.53F	6.26	13.16	343
12.40	80633	69.72	1138.4	4.87F	0.32F	6.37	13.16	340
12.60	82032	69.88	1145.5	4.79F	0.12F	6.47	13.16	336
12.80	83434	70.03	1152.4	4.71F	0.08A	6.58	13.17	333
13.00	84839	70.19	1159.1	4.62F	0.27A	6.68	13.18	329
13.20	86246	70.34	1165.8	4.54F	0.46A	6.79	13.19	326
13.40	87657	70.49	1172.3	4.46F	0.64A	6.89	13.21	323
13.60	89070	70.63	1178.8	4.38F	0.81A	7.00	13.22	320
13.80	90485	70.78	1185.1	4.29F	0.98A	7.10	13.25	316
14.00	91904	70.92	1191.3	4.21F	1.14A	7.21	13.27	313
14.20	93324	71.06	1197.4	4.13F	1.29A	7.31	13.30	310
14.40	94747	71.19	1203.3	4.04F	1.44A	7.42	13.33	308
14.60	96173	71.32	1209.2	3.96F	1.58A	7.52	13.36	305
14.80	97600	71.45	1215.0	3.88F	1.72A	7.63	13.39	302
15.00	99030	71.57	1220.7	3.79F	1.84A	7.73	13.43	299

d = draft in metres, K = keel, H = amidships, LOA 245 m,

LBP 236 m, GT 42000 Tons, NT 28000 Tons

Light W 14000 t, Load W 98000 t, Deadweight 84000 t.

DATA SHEET – 3

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

Answers

Answer 1 (a)

GM_f = w x d x plum length / W x deflection = 28 x 7 x 7.85 / 5700 x 0.65 = 0.42 m

KM = 10.83 m
GM_f = 0.42 m
KG_f = 10.41 m

Remarks	Weight	KG	Moments about keel
Initial Dipl.	+ 5700	10.41	+ 59337
Ballast	- 370	3.47	- 1283.9
Bunkers	- 165	3.98	- 656.7
$FSM_{bunkers}$			- 956.0
Water	- 95	4.44	- 421.8
FSM_{water}			- 910.0
Inclining weights	- 56	8.44	- 472.64
Deck crane	+ 19	9.74	+ 185.06
Total	5033		64223.1

Light ship KG = 64223.1 / 5033 = 12.76 m

Answer 2 (a)

Volume of buoyancy lost = Volume of Buoyancy gained

24 x 9 x 8.6 = [(150 x 28) – (24 x 9)] x S

S = 1857.6 / 3984 = 0.466 m

Bilged draught= 8.6 + 0.466 = 9.066 m

Moments of areas about the axis XX

	Area	Distance from XX	Moments
Total area	150 x 28	14.0	58800
Bilged area	24 x 9	4.5	- 972
Resultant	3984		57828

New location of LCF = 14.515 m

Distance BB_H = 14.515 – 14.0 = 0.515 m

Calculate moment of inertia about new LCF

$I_{LL} = I_{xx} - Ad^2$

$= (150 \times 28^3 / 3) - 24 \times 9^2 / 3) - [(150 \times 28) - (24 \times 9) \times 14.515^2]$

$= (1097600 - 5832) - 839369.936 = 252398.064\ m^4$

Calculate bilged BM, KB, KM and GM

BM = 252398.064 / (150 x 28 x 8.6) = 6.988 m

KB = 9.066 / 2 = 4.533 m

KM = 4.533 + 0.593 = 11.521 m

GM = 11.521 – 9.2 = 2.321 m

Calculate list

Tan θ = 0.515 / 2.321

List = $\underline{\underline{12.5^0}}$

Answer 3 (b)

a) FSC = FSM / W = 6761 / 85000 = 0.080 m

KG_{fluid} = 10.68 + 0.08 = 10.760 m

GM_{fluid} = 13.181 – 10.76 = 2.421 m

From the data sheets;

Heel	$GZ_{assumed}$	GG_1	Sin θ	GZ_{actual}
10	0.58	0.76	0.1736	0.448
20	1.30	0.76	0.3420	1.040
30	1.90	0.76	0.5	1.520
45	2.35	0.76	0.7071	1.813
60	2.28	0.76	0.8660	1.622
75	1.35	0.76	0.9659	0.616

i) Maximum GZ = 1.83 m at 47^o heel
ii) Range of positive stability = 0^o to 81^o
iii) Deck edge immersion = 16^o

Answer 4 (a)

Bodily sinkage = 2400 / 21.8 = 110.09 cm

Weight of cargo to load in hold no 2 is Y tones.

Initial trim = 6.4 – 3.8 = 2.6 m by stern

Required trim = 1.0 by stern

Therefore, COT = 2.6 -1.0 = 1.6 m by head

Take moment about LCF

Weight	LCG from COF	Head moments	Stern moments
Y	33	33Y	
2400 - Y	13		13 x (2400 – Y)

Since COT is 1.6 m by head, 33Y should be higher than 13 x (2400 – Y).

Trimming moment = 33Y – 13 x (2400 – Y)

COT = trimming moment / MCTC

1.6 x 100 = [33Y – 13 x (2400 – Y)] / 150

24000 = 33Y – 31200 + 13Y

46Y = 55200

Y = 1200 t

Number 4 hold = 2400 – 1200 = 1200 t

Answer 4 (b)

T_a = COT x LCF / LBP

= 1.6 x 67 / 136 = 0.788 m

T_f = 1.6 – 0.788 = 0.812 m

	FWD	**AFT**
Initial drafts	3.8	6.4
Bodily sinkage	+ 1.101	+ 1.101
	4.901	7.501
T_f / T_a	+ 0.812	- 0.788
Final drafts	5.713	6.713

Answer 6 (a)

The maximum angle of list occurs when the weight is hanging over the side at the derrick's maximum outreach.

From tables:

Displacement = 14115 t

KM = 8.36 m

Horizontal GG_1 when the derrick is swung out = 60 x 15.80 / 14115 = 0.067 m

Vertical GG_1 when the derrick is swung out = (29.28 – 5.23) x 60 / 14115 = 0.102 m

KG when swung out = 7.982 m

GM = 8.36 – 7.982 = 0.378 m

Tan list = final listing moment / (W x GM)

= 60 x 15.80 / (14115 x 0.378) = 0.1777

= $\underline{\underline{10.1^0}}$

Answer 6 (b)

Tan θ = Increase in draught / half breadth

Therefore, increase in draught = half breadth x Tan θ

= 20.42 x Tan 10.1 / 2 = 1.814 m

Answer 6 (c)

Tan list = final listing moment / (W x GM)

Tan 5 = 60 x 15.8 / (14115 x GM)

Therefore GM required = 0.768 m (at the time of discharge)

Therefore KG required = 7.592 M (at the time of discharge)

Vertical GG_1 if the weight is kept back on the initial position

= w x d / W = 60 x (29.28 – 5.23) / 14115 = 0.102 m

Therefore, the required initial KG = 7.592 – 0.102 = 7.49 m