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 : 10th July 2018

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) A vessel, initially upright, is to carry out an inclining test.
Present displacement 5300 t and KM 10.96 m

Total weights on board during the experiment are:
Ballast 390 t, Kg 3.45 m (tank is full)
Bunkers 175 t, Kg 4.01 m (FSM 996 tm)
Water 102 t, Kg 4.45 m (FSM 890 tm)
Boiler water 20 t, Kg 4.19 m (FSM 101 tm)
Two inclining weights (each) 24 t, Kg 8.42 m

A weather deck hatch cover, weight 20 t, ashore for repairs will be fitted on the vessel at a Kg of 9.46 m prior to sailing.

The pendulum line has an effective vertical length of 8.00 m. The inclining weights are shifted transversely 7.6 m on each occasion and the mean horizontal deflection of the pendulum is 0.68 m.

Calculate the vessel's light ship KG.

(25 marks)

b) List five possible causes for a change to the vessel's light ship KG over a period of time.

(05 marks)

2) WORKSHEET (Trim and Stability) provides data relevant to a particular condition of loading in a vessel in salt water.
With the aid of the HYDROSTATIC PARTICULARS provided, complete the WORKSHEET and calculate EACH of the following:
   a) The effective metacentric height
   b) The draughts forward and aft

(30 marks)

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

   Length 146.0 m Breadth 29.4 m Draught 6.52 m KG 9.9 m

   The vessel has a centerline watertight bulkhead with an empty amidships side compartment of length 24.0 m on EACH side of the watertight bulkhead.

   Calculate the angle of heel if the starboard side compartment is bilged.

(30 marks)

4) With the aid of labeled sketches, show the effects on a vessel's curve of statical stability of EACH of the following:
   a) Increasing the beam;
   b) Increasing the free board;
   c) Reducing free surface effect;
   d) Shifting a weight transversely;
   e) Movement of centre of gravity above metacenter

(06 marks each)

5) A vessel's loaded particulars in salt water are as follows:

   Displacement = 18000 t KG_f = 8.10 m

   Using the HYDROSTATIC PARTICULARS and the KN curves provided and assuming the angle of down flooding is 40.6^0, sketch the vessel's statical stability curve and compare the vessel's stability with the minimum stability criteria required by the current Load Line regulations.

(30 marks)

6) A vessel, initially upright, with a timber deck cargo, has the following particulars:

Displacement	- 10,000 t	KG	- 9.336 m
KB	- 4.26 m	BM	- 5.13 m

60 t of FO (RD 0.90), is transferred from the settling tank (previously full & now empty), to a rectangular DB (double bottom) tank, (previously empty and now slack). There is a transverse distance between centroids of 4.0 m and a vertical distance between centroids of 6.00 m. Remember the settling tank is above the DB tank.

The DB tank dimensions are length 12.00 m & breadth 10.00 m.

Calculate the final list assuming the KM & KB remains constant throughout.

(30 marks)

WORKSHEET (Trim and Stability)

Condition : loaded – General Cargo						Length of vessel : 137.5 m		
Comp.	**Cargo capacity (m^3)**	**Stowage factor (m^3/t)**	**Weight (t)**	**KG (m)**	**Vertical moment (tm)**	**Free surface moment (tm)**	**LCG $_{foap}$ (m)**	**Long. Moment (tm)**
All holds	14606	1.88		5.86			68.6	
1 TD	1365	2.22		10.98			114.0	
2 TD	1332	2.36		10.50			95.6	
3 TD	1435	2.14		10.37			74.0	
4 TD	1230	2.28		10.28			53.0	
Oil fuel			856	1.2		1786	57.2	
FW			83	7.1		610	28.7	
Lightship			3831	8.21			69.68	
Displacement								
HYDROSTATICS			**TMD**			**LCB_{foap}**		**LCF_{foap}**
LBP = 137.5 m			**MCTC**			**KM_T**		**GM_F**
COT			T_a			T_f		
Draughts: Fwd			Aft					

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

TABULATED KN VALUES

KN values in metres

KN values calculated for vessel on even keel and fixed trim

	ANGLE OF HEEL - DEGREES						
D tonnes	12	20	30	40	50	60	75
20000	1.80	2.90	4.14	5.14	5.92	6.51	6.84
19500	1.79	2.90	4.17	5.19	5.97	6.55	6.86
19000	1.78	2.91	4.20	5.24	6.02	6.59	6.88
18500	1.77	2.92	4.23	5.29	6.07	6.63	6.90
18000	1.75	2.93	4.27	5.36	6.12	6.67	6.92
17500	1.74	2.94	4.30	5.43	6.18	6.71	6.94
17000	1.73	2.95	4.34	5.48	6.23	6.75	6.96
16500	1.73	2.97	4.37	5.54	6.29	6.79	6.98
16000	1.72	2.98	4.40	5.60	6.35	6.83	7.00
15500	1.72	2.98	4.44	5.66	6.44	6.87	7.02
15000	1.72	2.98	4.48	5.72	6.48	6.91	7.04
14500	1.73	2.98	4.51	5.79	6.58	6.95	7.07
14000	1.74	2.98	4.53	5.81	6.68	7.00	7.10
13500	1.75	2.99	4.56	5.86	6.73	7.05	7.13
13000	1.76	3.00	4.59	5.90	6.78	7.10	7.16
12500	1.77	3.03	4.64	5.96	6.83	7.15	7.19
12000	1.78	3.06	4.68	6.02	6.88	7.20	7.21
11500	1.80	3.10	4.73	6.07	6.93	7.25	7.24
11000	1.82	3.14	4.78	6.12	6.98	7.30	7.26
10500	1.83	3.19	4.81	6.17	7.02	7.35	7.29
10000	1.86	3.24	4.85	6.21	7.08	7.40	7.31
9500	1.93	3.28	4.91	6.25	7.11	7.45	7.34
9000	2.00	3.36	4.96	6.28	7.18	7.50	7.36
8500	2.05	3.43	5.03	6.32	7.20	7.55	7.39
8000	2.10	3.52	5.09	6.35	7.22	7.60	7.41
7500	2.17	3.62	5.17	6.38	7.24	7.65	7.43
7000	2.22	3.70	5.25	6.41	7.26	7.70	7.45
6500	2.32	3.85	5.35	6.44	7.27	7.70	7.47
6000	2.42	4.00	5.45	6.48	7.28	7.70	7.49
5500	2.57	4.15	5.55	6.53	7.29	7.68	7.47
5000	2.72	4.32	5.67	6.58	7.30	7.66	7.45
4500	2.92	4.55	5.79	6.64	7.25	7.60	7.42
4000	3.15	4.75	5.91	6.71	7.22	7.52	7.40
3500	3.45	5.00	6.08	6.78	7.20	7.42	7.38

Answers

Answer 1(a)

GM_f = inclining weight x shifted distance x pendulum length / (displacement x deflection)

= 24 x 7.6 x 8 / (5300 x 0.68) = 0.405 m

KG_f = 10.96 – 0.41 = 10.55 m

	Weight		KG	Moments	
	Load	**Disch.**		**Load**	**Disch.**
Ship	5300		10.55	55915	
Ballast		390	3.45		1345.5
Bunkers		175	4.01		701.8
FSM					996
Water		102	4.45		453.9
FSM					890
Inclining weights		48	8.42		404.2
Hatch cover	20		9.46	189.2	
Total	5320	715		56104.2	4791.4
Resultant	4605			51312.8	

Light ship KG = 51312.8 / 4605 = 11.14 m

Answer – 2

Condition : loaded – General Cargo					Length of vessel : 137.5 m			
Comp.	**Cargo capacity (m^3)**	**Stowage factor (m^3/t)**	**Weight (t)**	**KG (m)**	**Vertical moment (tm)**	**Free surface moment (tm)**	**LCG $_{foap}$ (m)**	**Long. Moment (tm)**
All holds	14606	1.88	7769.1	5.86	45526.9		68.6	532960.26
1 TD	1365	2.22	614.9	10.98	6751.6		114.0	70098.6
2 TD	1332	2.36	564.4	10.50	5926.2		95.6	53956.6
3 TD	1435	2.14	670.6	10.37	6954.1		74.0	49624.4
4 TD	1230	2.28	539.5	10.28	5546.1		53.0	28593.5
Oil fuel			856	1.2	1027.2	1786	57.2	48963.2
FW			83	7.1	589.3	610	28.7	2382.1
Lightship			3831	8.21	31452.5		69.68	266944.1
Displacement			14928.5	6.95	103773.9		70.57	1053522.8
HYDROSTATICS			**TMD**			**LCB$_{foap}$**		**LCF$_{foap}$**
			7.15 m			69.96 m		67.18 m
LBP = 137.5 m			**MCTC**			**KM$_T$**		**GM$_F$**
			187.03 m			8.33 m		1.22 m
COT			T_a			T_f		
0.49 m			0.24 m			0.25 m		
Draughts:								
Fwd 7.4 m			Aft 6.91 m					

Effective KG = 103773.9 / 14928.5 = 6.95 m

Therefore, effective GM = 8.33 – 6.95 = 1.38 m

Total FSM = 2396 tm

FSC = 2396 / 14928.5 = 0.16 m

Therefore, GM fluid = 1.38 – 0.16 = 1.22 m

LCG_{foap} = 1053522.8 / 14928.5 = 70.57 m

Therefore, LCG larger than LCB. Trimming moment is by head.

COT = W x (LCG – LCB) / MCTC = 48.69 cm = 0.49 m

Ta = COT x LCF / LBP = 0.24 m

T_f = 0.25 m

Answer 3

Volume of lost buoyancy = 24 x 14.7 x 6.52 = 2300.3 m^3

Area of intact water plane = (146 x 29.4) – (24 x 14.7) = 3939.6 m^2

Sinkage = 2300.3 / 3939.6 = 0.584 m

New mean draught = 6.52 + 0.584 = 7.104 m

Shift of rolling axis = 24 x 14.7 x 7.35 / 3939.6 = 0.658 m

Moment of inertia of the bilged waterplane = $LB^3 / 3 – lb^3 / 3$ = 146 x $29.4^3 / 3$ – 24 x $14.7^3 / 3$

= 1236726 – 25412 = 1211314 m^4

By parallel axis theorem:

Inertia around rolling axis = 1211314 – 3939.6 x $(14.7 + 0.568)^2$ = 282088 m^4

Bilged BM = 282088 / (146 x 29.4 x 6.52) = 10.079 m

KB = Draught / 2 = 7.104 / 2 = 3.552 m

KM = 13.631 m

Therefore, bilged GM = 13.631 – 9.9 = 3.731 m

Tan list = 0.658 / 3.731

List = 10^0 (stbd)

Answer 5

Heel	KN	KG x Sinθ	GZ
12	1.75	1.68	0.07
20	2.93	2.77	0.16
30	4.27	4.05	0.22
40	5.36	5.21	0.15
50	6.12	6.2	- 0.08
60	6.67	7.01	- 0.34
75	6.92	7.82	- 0.90

From tables, KM_T = 8.4 m

Therefore, initial GM = 8.4 – 8.1 = 0.3 m

Area up to 30^0 of heel

Angle	GZ	SM	Product
0	0	1	0
10	0.06	3	0.18
20	0.16	3	0.48
30	0.22	1	0.22

Area up to 30 degrees = 3 x 10 x 0.88 / (8 x 57.3) = 0.058 m rad

Area between 0 and 40 degrees

Angle	GZ	SM	Product
0	0	1	0
10	0.06	4	0.24
20	0.16	2	0.32
30	0.22	4	0.88
40	0.15	1	0.15

Area between 0 and 40 degrees = 1 x 10 x 1.59 / (3 x 57.3) = 0.092 m rad

Area between 30 & 40 degrees = 0.092 – 0.058 = 0.040 m rad

Max GZ is 0.22 m and it occurs beyond 30 degrees.

Vessel complies with Load Line regulations

Answer – 6

KM = KB + BM = 4.26 + 5.13 = 9.39 m

Initial GM = $KM - KG_{initial}$

= 9.39 – 9.336 = 0.054 m

Downward shift of GG_1 due to oil transfer

= w x d / W = 60 x 6 / 10000 = 0.036 m

New GM_{solid} = 0.054 + 0.036 = 0.09 m

FSC = I x d_i / W = LB^3 x d_i / (12 x W) = 12 x 10^3 x 0.9 / (12 x 10000)

= 0.09 m

Therefore, new GM_{fluid} = New GM_{solid} – FSC = 0.09 – 0.09 = 0.0 m

Since the initial GM after the oil transfer is zero, the normal formula for the list calculation can not be used. In this case;

Cos θ = GZ / GG_1

But, GG_1 = wd / W

Therefore,

Cos θ = GZ x W / wd

GZ = wd x Cos θ / W

At the same time,

GZ = (GM + ½ x BM x $\tan^2$ θ) x sin θ

Since, initial GM is zero,

$GZ = ½ \times BM \times \tan^2 \theta \times \sin \theta$

Therefore,

$wd \times \cos \theta / W = ½ \times BM \times \tan^2 \theta \times \sin \theta$

$\tan^3 \theta = (2 \times wd) / (BM \times W)$

$\tan \theta = \sqrt[3]{[(2 \times wd) / (BM \times W)]}$

The list can be calculated by this formula.

Therefore, $\tan \theta = \sqrt[3]{[(2 \times 60 \times 4) / (5.13 \times 10000)]}$

$= 0.009356725$

List $= 11.9^0$