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 : 19th July 2021

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 an inclining experiment:
   a) Explain the purpose of the inclining experiment.
   (05 marks)
   b) List the occasions when the inclining experiment must be undertaken.
   (05 marks)
   c) Describe the procedure and precautions to be taken before and during the inclining experiment.
   (15 marks)
   d) Explain why a vessel's lightship displacement and KG will change over a period of time.
   (05 marks)

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

Length	120 m	Breadth	20.0 m
Draught	4.0 m	KG	3.5 m

There is an empty forward end compartment of 10.0 m length that extends the full width of the vessel with a water tight flat 1.5 m above the keel.

Calculate the following if the compartment above the water tight flat is bilged.

   a) GM_T of the bilged vessel
   (10 marks)
   b) Final draughts forward and aft
   (20 marks)

3) A vessel initially upright and on an even keel, has the following particulars:

Draught (in salt water)	7.0 m
Breadth	20.42 m
KG	7.82 m

The vessel's heavy lift derrick is to be used to discharge a 58 t boiler from a centerline position, Kg 5.30 m. The derrick head is 30.0 m above the keel and 16 m from the ship's centerline when plumbing over side. With the aid of hydrostatic particulars, calculate the following:

a) Calculate the maximum list angle when the boiler is suspended by the derrick at its maximum outreach during discharge.

(15 marks)

b) Calculate the increase in draught when the vessel is at the maximum list angle calculated in above, assuming the midship section is box shaped.

(10 marks)

c) Describe the remedial measures that could be taken prior to discharge in order to reduce the angle of heel at the time of discharging the boiler.

(05 marks)

4) On sailing, a vessel had a displacement of 11,000 t and KG of 7.79 m. On passage 500 t of fuel oil, Kg 3.38 m, were consumed.
Using the KN Tables, draw the curve of statical stability (GZ curve) for the arrival condition and from it find:

(15 marks)

a) The maximum GZ and the angle it occurs.

(10 marks)

b) The range of positive stability

(05 marks)

5) A box shaped vessel of length 98.0 m, breadth 14.2 m, depth 9.3 m is floating in salt water at an even keel draught of 5.6 m.

a) Calculate the righting moment when the vessel is heeled to the angle of deck edge immersion if the KG is 5.50 m.

(20 marks)

b) Calculate the angle of loll if the KG is 6.0 m.

(10 marks)

6) Answer the following questions with regards to shear forces and bending moments:
   a) Describe the meaning of shear forces
   b) Describe the meaning of bending moments

(05 marks each)

   c) A box shaped barge 40 m long, 8 m wide floats at an even keel draught of 4.00 m in fresh water. The barge consists of 4 holds each 10 m long. Number 1 and 4 holds are empty and Number 2 and 3 holds each contain 400 t of bulk cargo trimmed level. Calculate the load, shear force and bending moment curves along the length of the barge.

(20 marks)

HYDROSTATIC PARTICULARS

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

TABULATED KN VALUES

DISPLACEMENT — TONNE	ANGLE OF HEEL — DEGREES						
	12	20	30	40	50	60	75
15000	1.72	2.98	4.48	5.72	6.48	6.91	7.05
14500	1.73	2.98	4.51	5.79	6.58	6.95	7.08
14000	1.74	2.98	4.55	5.85	6.68	7.00	7.10
13500	1.75	2.99	4.58	5.90	6.73	7.08	7.13
13000	1.77	3.00	4.62	5.93	6.78	7.14	7.16
12500	1.78	3.03	4.63	5.98	6.83	7.18	7.18
12000	1.78	3.05	4.65	6.04	6.88	7.20	7.20
11500	1.80	3.12	4.70	6.10	6.93	7.25	7.22
11000	1.82	3.15	4.75	6.15	6.98	7.30	7.24
10500	1.83	3.19	4.79	6.18	7.02	7.35	7.27
10000	1.86	3.23	4.83	6.22	7.07	7.40	7.30
9500	1.93	3.28	4.91	6.25	7.11	7.45	7.35
9000	2.00	3.36	5.00	6.28	7.18	7.50	7.40
8500	2.05	3.43	5.04	6.32	7.20	7.55	7.41
8000	2.10	3.52	5.10	6.36	7.22	7.60	7.42
7500	2.17	3.62	5.18	6.38	7.24	7.65	7.46
7000	2.22	3.70	5.25	6.40	7.26	7.70	7.50
6500	2.32	3.85	5.35	6.43	7.27	7.70	7.51
6000	2.42	4.00	5.45	6.48	7.28	7.70	7.52
5500	2.57	4.15	5.55	6.53	7.29	7.68	7.51
5000	2.72	4.32	5.65	6.58	7.30	7.66	7.50

Answers

Answer 2(a)

Increased draught = 2.5 x 10 x 20 / (120 x 20 – 10 x 20) = 0.227 m

Bilged hydraft = 4.227 m

Take moments of volumes around keel to calculate bilged KB

Remarks	Volumes	KB	Moments
Bilged v/l	4.227 x 120 x 20	4.227 / 2	21441
Bilged compartment	- 2.727 x 10 x 20	2.727 / 2 + 1.5	- 1561.8
Final v/l	9600		19879.2

Bilged KB = 19879.2 / 9600 = 2.07 m

BM_T = $(LB^3 – lb^3) / 12V$ = $(120 \times 20^3 – 10 \times 20^3) / (12 \times 9600)$ = 7.639 m

KM_T = 2.07 + 7.64 = 9.71 m

Bilged GM_T = 9.71 – 3.5 = 6.21 m

Answer 2(b)

Take moments of volumes around aft perpendicular to calculate LCB_{foap}

Remarks	Volume	LCB_{foap}	Moments
Bilged vessel	4.227 x 120 x 20	120 / 2	608688
Bilged compartment	- 2.727 x 10 x 20	115	- 62721
	9600		545967

Bilged LCB_{foap} = 545967 / 9600 = 56.87 m

Trimming lever = 60 – 56,87 = 3.13 m

BM_L = B x $(L – l)^3$ / 12V = 20 x $(120 – 10)^3$ / (12 x 9600) = 231.08 m

KM_L = KB + BM_L = 2.07 + 231.08 = 233.15 m

GM_L = KM_L – KG = 233.15 – 3.5 = 229.65 m

MCTC = W x GM_L / (100 x LBP) = 9600 x 1.025 x 229.65 / (100 x 120) = 188.31 m

COT = disp. X Trimming lever / MCTC = 9600 x 1.025 x 3.13 / 188.31 = 1.64 m

Ta = 1.64 x 55 / 120 = 0.752 m

Tf = 1.64 – 0.752 = 0.888 m

FWD = 4.227 + 0.888 = 5.115 m

AFT = 4.227 – 0.752 = 3.475 m

Answer 3(a)

For 7.0 m draught, from tables;

Dispplacement = 14576 t

KM = 8.34 m

When the derrick head is in it's maximum outreach;

GG_1 ↑ = w x d / W = 58 x (30 – 5.3) / 14576 = 0.098 m

KG at the maximum outreach = 7.82 + 0.098 = 7.918 m

GM at the maximum outreach = 8.34 – 7.918 = 0.422 m

Tan (list) = listing moment / (GM x W) = 16 x 58 / (0.422 x 14576) = 0.151

Therefore, maximum list = 8.58^0

Answer 3(b)

Draught when healed = upright draught x Cos θ + ½ x beam x Sin θ

= 7 x Cos 8.58 + ½ x 20.42 x Sin 8.58

= 8.44 m

Therefore, increase in draught = 8.44 – 7.0 = 1.44 m

Answer 4

Arrival displacement = 11,000 – 500 = 10,500 t

GG_1 ↑ = w x d / (W – w) = 500 x (7.79 – 3.38) / (11,000 – 500) = 0.21 m

Arrival KG = 7.79 + 0.21 = 8.0 m

For 10,500 t displacement, from hydrostatic tables;

KM_T = 8.864 m

Arrival GM_T = 8.864 – 8.0 = 0.864 m

θ	KN	KG x Sinθ	GZ
12	1.83	1.663	0.167
20	3.19	2.736	0.454
30	4.79	4.000	0.79
40	6.18	5.142	1.038
50	7.02	6.128	0.892
60	7.35	6.928	0.422
75	7.27	7.727	- 0.457

Max GZ 1.05 m at 42^0

Range of positive stability 0^0 to 67^0

Answer 5 (a)

Free board = 9.3 – 5.6 = 3.7 m

Tan (DEI) = free board / half breadth = 3.7 / 7.1

DEI = 27.5^0

KB = half draught = 5.6 / 2 = 2.8 m

BM = I / V = LB^3 / (12 x V) = 98 x 14.2^3 / (12 x 5.6 x 14.2 x 98) = 3.0 m

KM = 2.8 + 3 = 5.8 m

GM = 5.8 – 5.5 = 0.3 m

At the angle of DEI;

GZ = (GM + ½ x BM Tan^2 DEI) x Sin DEI

= (0.3 + 1.5 x Tan^2 27.5^0) Sin 27.5^0

= 0.326 m

Righting moment at DEI = 0.326 x (5.6 x 14.2 x 98 x 1.025)

= 2604 tm

Answer 5 (b)

GZ = (GM + ½ x BM Tan^2 θ) x Sin θ

When the GM is negative

0 = (GM + ½ x BM Tan^2 θ) x Sin θ

θ = angle of loll = Tan^{-1} [square root of (2 x GM / BM)]

= Tan^{-1}[square root of (2 x 0.2 / 3)]

= 20.1^0

Answer 6(c)

Light displacement = 40 x 8 x 4 x 1 = 1280 t

Total weight of cargo = 400 + 400 =800 t

Total displ. = 800 + 1280 = 2080 t

Buoyancy = 2080 t

Buoyancy per m run = 2080 / 40 = 52 t/m

Light disp. Per m run = 1280 / 40 = 32 t/m

Cargo weight per m run = 400 /10 = 40 t/m

	Hold 1 & 4	**Holds 2 & 3**
Light v/l weight per m run	- 32	- 32
Cargo weight per m run	00	- 40
Total weight per m run	- 32	- 72
Buoyancy m run	+ 52	+ 52
Load per m run	+ 20	- 20

Shear forces and mending moments at 5 m intervals

Position	SF	BM
A	0	0
B	100	250
C	200	1000
D	100	1750
E	0	2000
F	- 100	1750
G	- 200	1000
H	- 100	250
I	0	0