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 : November 2019

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) Worksheet -1 (Trim and Stability pro-forma) provides data relevant to a particular condition of the loading of a vessel in salt water.

By the completion of the Worksheet – 1 with the aid of the 'Hydrostatic Particulars Table A' and showing all additional calculations in your answer book, determine each of the following:

a) Final fwd and aft draughts

(12 marks)

b) Final transverse GM_f

(18 marks)

2) With the aid of labeled sketches, show the effects of each of the following on a vessel's curve of statical stability:

a) a strong beam wind on a vessel with a high freeboard and a large number of containers on deck;

b) a change in the KG of the vessel due to the consumption of fuel and water from double bottom tanks during the voyage (assume the tanks are full at the time of sailing);

c) the loading of a full cargo of timber on deck

(10 marks each)

3) Answer the following questions with regards to bilging of a vessel:
   a) Briefly describe the contents of a damage stability calculations book available onboard a vessel.

(05 marks)

   b) A box shaped vessel 120 m long and 15 m wide floats at an even keel draught of 6.5 m in salt water. A compartment at the forward end, 10 m long 15 m wide, is empty. Assuming the bilge GM_L is equal to bilge BM_L, find the new draughts fwd and aft if this compartment gets bilged.

(25 marks)

4) Answer the following questions with regards to change of density:
   a) With the aid of a labelled sketch explain why the trim is subjected to change when a vessel moves from one density of water to another.

(05 marks)

   b) A vessel floating in salt water has the following particulars:

Displacement	18,000 t	LBP	220 m
LCB	100 m foap	LCF	120 m foap
MCTC	200	TPC	23
Draft fwd	7.85 m	aft	8.55 m

The vessel has two bunker tanks. The forward tank has it's centroid 205 m forward of the aft perpendicular and the after tank has it's centroid 75 m forward of the aft perpendicular. Calculate the following;

i) The amount of fuel to transfer between the bunker tanks in order to arrive alongside at a fresh water berth on an even keel.

(15 marks)

ii) The arrival draft forward and aft.

(10 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 free surface effect and list:

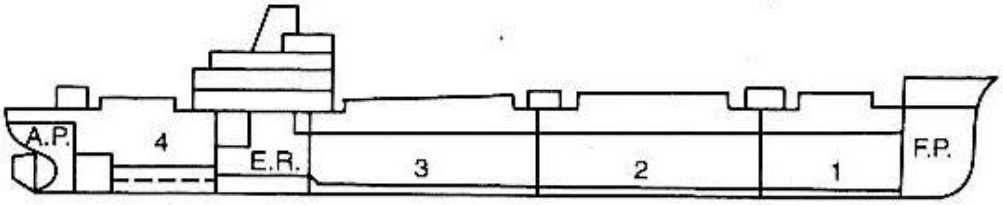
a) List the factors which affect the free surface effect.

(10 marks)

b) A vessel of 8200 t displacement, KG 6.3 m, KM 8.0 m is floating upright. A double bottom tank of regular cross section is divided in to two equal parts each 40.0 m long, 8.0 m wide and 1.6 m deep. The starboard side tank is full of fresh water and the port side tank is empty. Calculate the angle of list when half of the water is transferred to the port side tank.

(20 marks)

Worksheet -1 (Trim and Stability pro-forma)



CONDITION: FULLY LOADED – GENERAL CARGO

Compartment	Capacity m^3	Stowage Factor m^3/t	Weight t	KG m	Vertical Moment tm	Free Surface Moment tm	LCG foap m	Longitudinal Moment tm
All Holds	14 562	1.86		6.78			73.15	
1 TD	264	2.48		10.71			114.33	
2 TD	1688	2.74		10.60			93.57	
3 TD	1986	2.72		10.51			63.92	
Consumables			1464	–	4112	2560	–	58 675
Deadweight								
Lightship			3831	8.21			61.67	
DISPLACEMENT								

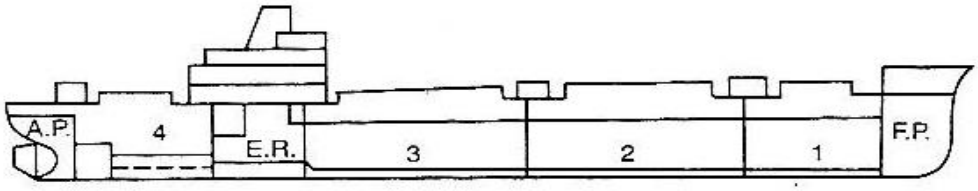
HYDROSTATICS	True Mean Draught	LCB foap	LCF foap
LENGTH B.P. 130.00 m	MCTC		
TRIM			KM_T
			KG
DRAUGHTS: F.	A.		GM_{fluid}

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

Answer 1



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All Holds	14 562	1.86	**7829**	6.78	**53 081**		73.15	**572 691**
1 TD	264	2.48	**106**	10.71	**1135**		114.33	**12 119**
2 TD	1688	2.74	**616**	10.60	**6530**		93.57	**57 639**
3 TD	1986	2.72	**730**	10.51	**7672**		63.92	**46 662**
Consumables			1464	–	4112	2560	–	58 675
Deadweight			**10 745**					
Lightship			3831'	8.21	**31 453**		61.67	**236 258**
DISPLACEMENT			**14 576**	7.13	**103 983**	**2560**	**67.51**	**984 044**

HYDROSTATICS	True Mean Draught **7.00 m**	LCB foap **70.03**	LCF foap **67.35 m**
LENGTH B.P. 130.00 m	MCTC = **184.6**		

TRIM $= \dfrac{14\,576 \times (70.03 - 67.51)}{184.6} = 199$ cm by the STERN

$KM_T = 8.34$ m

$KG_{fluid} = 7.13 + \dfrac{2560}{14\,576} = 7.13 + 0.18$

KG = 7.31 m

DRAUGHTS: F. = 6.04 m A. = 8.03 m

$GM_{fluid} = 1.03$ m

Answer 3 (b)

S = 10 x 15 x 6.5 / (120 x 15 – 10 x 15) = 0.591 m

New hydraft = 6.5 + 0.591 = 7.091 m

New AB = New AF = 55 m

New BG = 5 m

She will be trimmed by head

Displacement = 120 x 15 x 6.5 x1.025 = 11992.5 t

Trimming moment = W x BG = 11992.5 x 5 = 59962.5 t

MCTC = W x GM_L / (100 x L)

Since, GM_L = BM_L

MCTC = W x BM_L / (100 x L)

BM_L = I / V = 15 x 110^3 / (12 x 120 x 15 x 6.5) = 142.2 m

MCTC = 11992.5 x 142.2 / (100 x 120) = 142.1

COT = trimming moment / MCTC = 59962.5 / 142.1 = 422 cm = 4.22 m

T_a = COT x AF / LBP = 4.22 x 55 / 120 = 1.934 m

T_f = 4.22 – 1.934 = 2.286

	FWD draught (m)	**AFT draught (m)**
New hydraft	7.091	7.091
T_f / T_a	+ 2.286	- 1.934
New draughts	9.377	5.157

Answer 4 (b) (i)

FWA = Displacement / (40 x TPC)

= 18000 / (40 x 23) = 19.565 cm = 0.196 m

$TPC_{fresh\ water}$ = 23 x 1.000 / 1.025 = 22.4

Weight of increased under water volume = FWA x $TPC_{less\ density}$ = 19.565 x 22.4

= 438.26 t

Trimming moment = Weight of increased under water volume x (LCB – LCF)

= 438.26 x (100 – 120) = 8765.2 tm

$MCTC_2$ = 200 x 1.000 / 1.025 = 195.1

COT = Trimming moment / $MCTC_2$ = 8765.2 / 195.1 = 44.9 cm

= 0.449 m by stern

Total trim after arriving into fresh water = initial trim + COT

= 0.7 m + 0.449 = 1.149 m

Distance between the tanks = 205 – 75 m = 130 m

COT = trimming moment / $MCTC_2$

100 x 1.149 = ballast water to transfer to make her even keel x 130 / 195.1

Ballast water to transfer to make her even keel = 172.4 t

Answer 4 (b) (ii)

COT due to change of density = 0.449 m (by stern)

T_a due to change of density = 0.449 x 120 / 220 =0.245 m

T_f due to change of density = 0.449 – 0.245 = 0.204 m

COT required to make her even keel = 1.149 m (by head)

T_a when making her even keel = 1.149 x 120 / 220 = 0.627 m

T_f when making her even keel = 1.149 – 0.627 = 0.522 m

	Fwd (m)	**Aft (m)**
Initial draught	7.85	8.55
Bodily sinkage	+ 0.196	+ 0.196
	8.046	8.746
T_f / T_a	- 0.204	+0.245
Arrival draught at fresh water	7.842	8.991
T_f / T_a (to make her even keel)	+ 0.522	- 0.627
Even keel draughts	8.364	8.364

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 (b)

Initial GM = 8 – 6.3 = 1.7 m

Transferred weight downward = 0.8 x 40 x 8 x 1 = 256 t

GG_1 downward = 256 x 0.8 / 8200 = 0.025 m

New solid GM = 1.7 + 0.025 = 1.725 m

FSE both tanks = [I x d_i / displacement] x 2

= [40 x 8^3 / (12 x 8200)] x 2 = 0.416 m

GM fluid = 1.725 – 0.416 = 1.309 m

Tan θ = final listing moment / (displacement x GM)

= 256 x 8 / (8200 x 1.309) = 0.1908

List = 10.8^0 (port)