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1. Income_{14} = Freight rate X Cargo Weight X no. of trips in a year

$= 25 \times 89950 \times \frac{355}{37.226}$

$= 21444857.09$

working for above:

No. of days in a trip spent at sea $= \frac{11500}{14 \times 24} = 34.22619048$

No. of days in a trip spent in port = 3

Total no. of days in a trip $= 34.226 + 3 = 37.226$

Cost_{14} = Fuel consumption X cost of fuel X no. of trips / year X no. of days in a trip at sea + Average annual cost

$= 90 \times 320 \times \frac{355}{37.226} \times 34.226 + 9.35 \times 10^5$

$= 10335059.74$

$CRF_{14} = (21444857.09 - 10335059.74) / (29.3 \times 10^6) = 0.379173971$

$\text{Income}_{15} = 25 \times 89750 \times \frac{355}{34.9444}$

$= 22794217.01$

Days at sea / trip $= \frac{11500}{15 \times 24} = 31.9444$

Days in port / trip = 3

Total days / trip = 34.9444

$\text{Cost}_{15} = 112 \times 320 \times \frac{355}{34.9444} \times 31.9444 + 9.5 \times 10^5$

$= 12580890.02$

$CRF_{15} = (22794217.01 - 12580890.02) / (29.5 \times 10^6) = 0.3462144742$

$CRF_{14} > CRF_{15}$

∴ Ship is more able to recover its capital at 15 knots than at 14 knots

∴ Optimal speed = 14 knots.

2. $CH_4 + 2O_2 \rightarrow CO_2 + 2H_2O$

In one second,

$n(CH_4) = \frac{1}{12 + 4 \times 1} = 0.0625 \text{ kmol}$

$n_{minimum}(O_2) = 0.0625 \times 2 = 0.125 \text{ kmol}$

Mass of O_2 = 0.125 kmol × 32 kg/kmol = 4 kg

mass of air (minimum) = $\frac{4}{0.233} = 17.167$ kg

mass of excess air = 1.25 × 17.167 = 21.459 kg

∴ Required air flow rate = 21.459 kg/s

3. Ballast system helps reduce vessels freeboard and give sufficient immersion of propeller to reduce slip and possible propeller-excited vibration. It also provides better rudder action due to the greater depth of water flow around the rudder. It helps to trim vessel for depth of water forward so that possibility of pounding (slamming) damage is reduced to a minimum in heavy weather. It provides satisfactory stability. It gives better weight distribution and reduce hull stress. It gives the ship better seakeeping qualities in heavy weather.
The bilge system removes water or oil from machinery, boiler and cargo spaces. Bilges from machinery space has to be discharged through oily water separator. An emergency suction valve is fitted to be used in case of emergency.

4a Volume of displacement ∇_0 of empty pontoon:

$$\nabla_0 = LBT_0$$
$$= 108 \times 30 \times 1.55 = 5022 m^3$$

Mass of displacement Δ_0 of empty pontoon:

$$\Delta_0 = \rho \nabla_0$$
$$= 1 \times 5022 = 5022 \text{ ton}$$

4b Mass of water ballast Δ_{wb} in a fully filled tank:

$$\Delta_{wb} = \rho_{wb} \cdot l \cdot b \cdot h$$
$$= 1 \times 27 \times 7.5 \times 7.5 = 1518.75 \approx 1519 \text{ ton}$$

CG of wb in a fully filled tank wrt $\frac{1}{2}$ the length of $\bar{c}$ pontoon, $\bar{c}$ middle line plane & base plane:

$$x_{wb} = -13.50 m$$
$$y_{wb} = +3.75 m$$
$$z_{wb} = +3.75 m$$

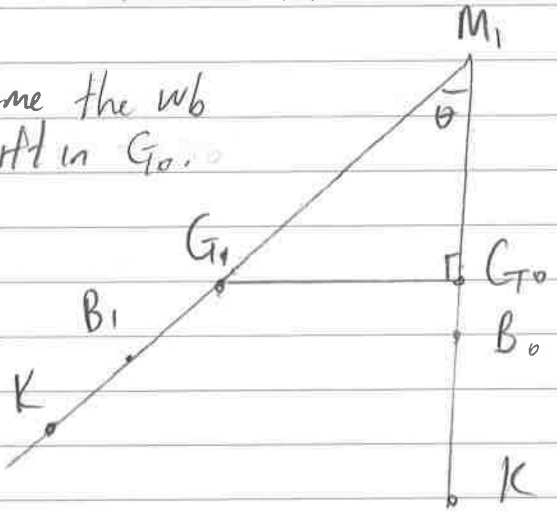
4c $\Delta_1 = \rho \cdot L \cdot B \cdot T_1 = 1 \times 108 \times 30 \cdot T_1 = 3240 T_1$

$= \Delta_0 + \Delta_{wb} = 5022 + 1519 = 6541$

$\therefore T_1 = \frac{6541}{3240} = 2.02 m$

4d $B_1M_1 = \dfrac{I_T}{\nabla_1} = \dfrac{\frac{1}{12} LB^3}{LBT_1} = \dfrac{B^2}{12 T_1} = \dfrac{30^2}{12 \times 2.02} = 37.13 m$

4e Since KG_0 is unknown, we assume the wb will only cause a transverse shift in G_0.



$$G_0G_1 = \frac{y_{wb} \times \Delta_{wb}}{(\Delta_{wb} + \Delta_0)}$$
$$= \frac{3.75 \times 1519}{(1519 + 5022)}$$
$$= 0.8708530806$$

4e $\tan 1.46° = \frac{G_1G_0}{G_1M_1}$

$G_1M_1 = \frac{0.8708530806}{\tan 1.46°} = 34.168 \text{ m}$

$KG_1 = KB_1 + B_1M_1 - G_1M_1$

$= \frac{T_1}{2} + 37.13 - 34.168$

$= \frac{2.02}{2} + 37.13 - 34.168 = 3.972 \text{ m}$

$\Delta_1 \cdot KG_1 = \Delta_0 KG_0 + \Delta_{wb} \cdot z_{wb}$
(pontoon +wb) (pontoon) (wb)

$(5022+1519) \times 3.972 = 5022 \times KG_0 + 1519 \times 3.75$

$KG_0 = 4.0391 \text{ m}$ → note: $4.0391 - 3.75 = 0.289 \text{ m} = 28.9 \text{ cm}$
There is actually a small vertical shift in G_0 we omit in assumption.

4f $B_0M_0 = \frac{I_T}{\nabla_0} = \frac{\frac{1}{12}LB^3}{LBT_0} = \frac{B^2}{12T_0} = \frac{30^2}{12 \times 1.55} = 48.387 \text{ m}$

$KB_0 = \frac{T_0}{2} = \frac{1.55}{2} = 0.78 \text{ m}$

$G_0M_0 = KB_0 + B_0M_0 - KG_0$

$= 0.78 + 48.387 - 4.0391 = 45.1279 \text{ m}$

4g Shift stores and equipment that is already on port side of ship to the starboard side of the ship such that weight is evenly distributed

5a $I_{Tr} = \left(\Sigma \left(\frac{1}{2} \text{ of } BWL_i\right)^3 \cdot SM_i\right) \times \frac{S}{3} \times \frac{2}{3}$

L_1	$L_2 = L_1^3$	$L_3 = SM_i$	$L_4 = L_2 \times L_3$
0.2	0.008	1	0.008
2.5	15.625	4	62.5
5	125	2	250
7	343	4	1372
6	216	2	432
2	8	4	32
0.2	0.008	1	0.008

$\text{Sum}(L_4) = 2148.516$, $S = \frac{180}{6} = 30$

$I_{Tr} = 2148.516 \times \frac{30}{3} \times \frac{2}{3} = 14323.44 \, m^4$

5b $GM_T = KB + BM - KG$ note: wall-sided, $\therefore KB = \frac{T}{2}$

$= \frac{T}{2} + \frac{I_{Tr}}{\nabla} - 2$

$C_B = \frac{\nabla}{BTL}$ Assume $B = 7 \times 2 = 14$

$= \frac{3}{2} + \frac{14323.44}{0.6 \times 14 \times 3 \times 180} - 2$

$= 1.5 + 3.157724868 - 2$

$= 2.6577 \, m$

5c $W_e = W_W - \frac{W_w^2}{g} V \cos\mu$ μ: anticlockwise ∡ from direction of wave

$\frac{2\pi}{T_{roll}} = \frac{2\pi}{8.07} - \frac{\left(\frac{2\pi}{8.07}\right)^2}{9.81} 10 \times 0.514 \cos\mu$

Note: $T_{roll} = \frac{2C \times B}{\sqrt{GM_T}}$

$= \frac{2 \times 0.39 \times 14}{\sqrt{2.6577}}$

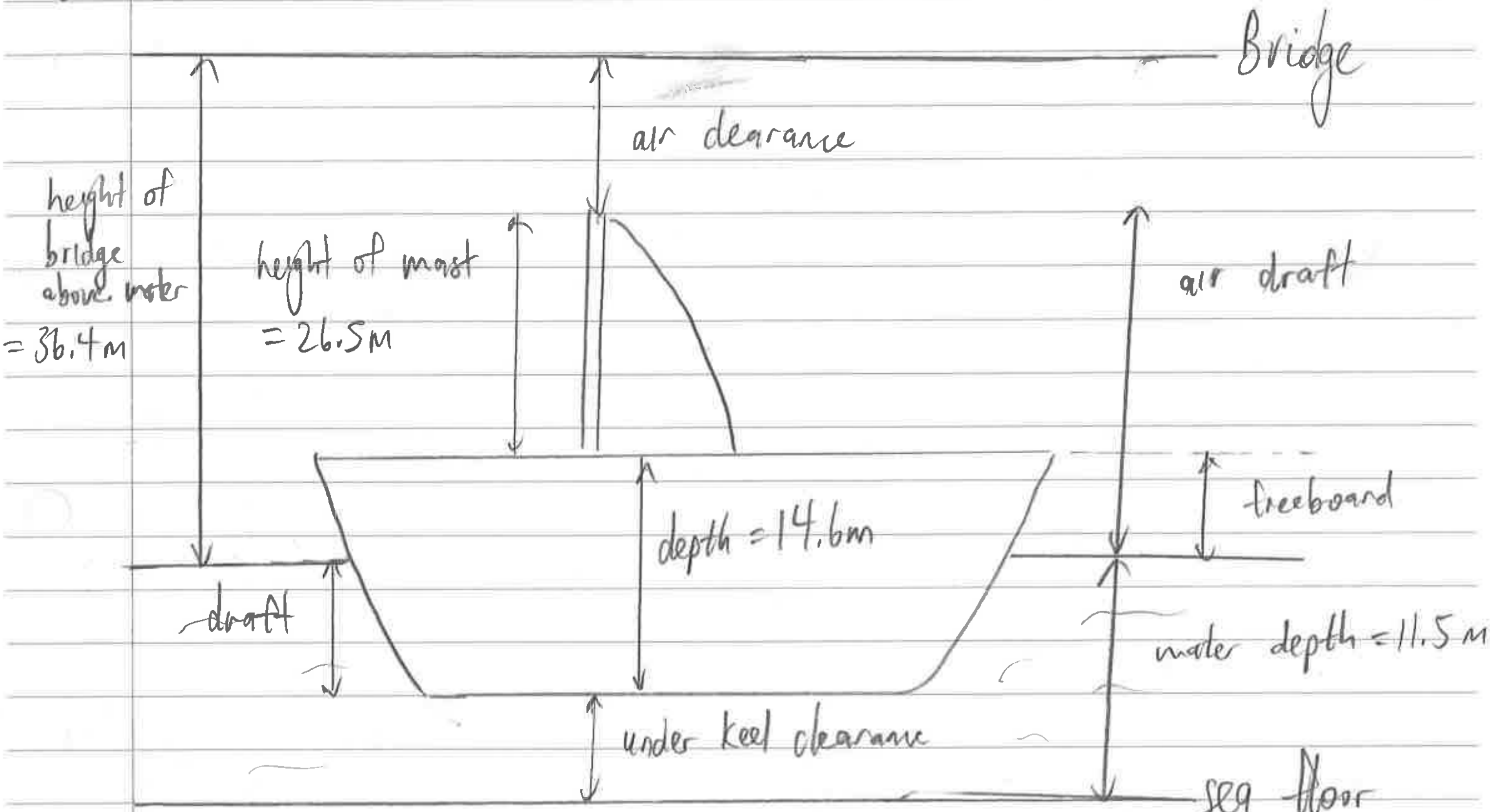
$= 6.69838 \text{ sec}$

$\cos\mu = -0.5019536104$

$\mu = 120.13°$

Avoid taking 120.13° anticlockwise from direction of wave

6.



Maximum draft when under keel clearance is at minimum i.e 1m.
Hence $T_{max} = 11.5 - 1 = 10.5$ m

Minimum draft when air clearance is at minimum i.e. 1.2m.
freeboard $= 36.4 - 1.2 - 26.5 = 8.7$m
$T_{min} = 14.6 - 8.7 = 5.9$ m

7a ① Price: affects your capital recovery factor.
② Delivery date: if it takes too long to deliver, the market condition may not be as favourable as before.
③ Specialisation: China and Korea are more specialised in bulk carrier and containerships while Germany and Norway are more specialised in cruise ships.
④ Payment terms: Is there any shipyard credit scheme or other financing options available? Are you expected to deposit a large sum of money?

7b. Strengths:
① Good location. Ships in the Asia-Europe trade have to pass through Singapore. Hence it is convenient to stop over for repair during transit, loading or unloading.
② Good supply chain management. Ship repair requires spare parts, equipment and machinery. Singapore, being an efficient port, has an inventory of spare parts that can be obtained at short notice.
Weakness:
① Cost: Singapore has high cost of labour and docking charges. The cost of steel is also high
② Expertise. Our expertise may be limited for specialised vessels. E.g cruise

7c. Visual inspection. Check for presence of bio fouling and wearing down of anti-fouling paint. There may be an obvious deterioration in ship speed. You can also use a hull roughness gauge. At each location, the gauge is run over 750-1000 mm to generate 10-15 readings. The average of which is the mean hull roughness. At least 100 locations are required and the average of all readings give the average hull roughness.
If the hull is no longer smooth, you can use water jet to remove rust, sand blast to remove barnacles, grind welded seams on the shell and spray paint with anti-fouling paint. All these are carried out in a dry dock.

7d ① Capacity of holds and tanks: Affects how much cargo you can carry and how much fuel you can carry. This will determine your trade route and distance you can cover.

② Type of engine. E.g. gas turbine, 2-stroke, 4-stroke diesel engine or combined plant. This will affect the speed of vessel and its usage. This also affects thermal efficiency.

③ Width: Affects ability to pass through canal such as Suez and Panama canal.

④ Block coefficient. Affect resistance of hull

⑤ Type of material. E.g. wood, fibreglass, steel or aluminium. Affects cost and strength of hull.

⑥ GM. Large GM results in a stiff ship that is very stable but the period is small and hence poor sea keeping quality. This could result in passengers and crew having motion sickness. Small GM results in a tender ship that is less stable but have a large period and hence good seakeeping quality.