GENERAL ENGINEERING SCIENCE II

Attempt ALL questions

Marks for each question are shown in brackets.

Section A

1. (a) State the characteristic gas equation in both of its forms. (2)

(b) A gas whose original pressure, temperature and volume were 150 kPa, 0.15 m^3 and 30°C respectively is compressed until its new temperature and pressure are 70°C and 800 kPa.

Determine EACH of the following:

(i) the new volume of the gas; (3)

(ii) the mass of the gas. (3)

Note: $R = 0.29\ kJ/kgK$

2. A quantity of gas whose original volume and temperature are 0.2 m^3 and 303°C respectively is cooled at constant pressure until its volume becomes 0.1 m^3. The gas is then heated at constant volume until its pressure is doubled.

Determine EACH of the following:

(a) sketch the processes on a pressure-volume diagram; (2)

(b) the temperature of the gas after the initial cooling process; (3)

(c) the temperature after the heating process. (3)

3. 0.5 kg Benzene (C_6H_6) is completely burned in 30% excess air.

Calculate EACH of the following:

(a) the mass of carbon dioxide in the exhaust gases of the fuel; (4)

(b) the mass of nitrogen in the exhaust gases per kg of fuel. (4)

4. (a) State TWO desirable properties of refrigerants. (1)

(b) In a vapour compression refrigeration plant, briefly explain EACH of the following:

(i) under-cooling and its effect; (2)

(ii) the cause of the low pressure side into which expansion occurs through the TEV; (2)

(iii) How the refrigerant flow rate is controlled. (3)

5. State and describe the THREE modes of heat transfer, giving an example of each. (9)

6. A 2 stroke diesel engine is tested over a 24 hour period and uses 18 tonnes of fuel. The power of the engine is tested using a dynamometer which gives a steady state torque reading of 50 kNm at 800 rpm. The mechanical efficiency was later found to be 87%.

Calculate EACH of the following:

(a) the brake power; (3)

(b) the indicated specific fuel consumption; (3)

(c) the brake thermal efficiency. (3)

Note: the calorific value of the fuel = 44 MJ/kg

10. A conductor with an effective length of 500 mm and a diameter of 12.5 mm is carrying a current of 45 A at right angles to a magnetic field. The force on the conductor is 7 N.

Calculate EACH of the following:

(a) the flux density; (4)

(b) the magnetic flux. (4)

11. A section of a water retaining wall with a gate at the bottom is shown in Fig Q11. The gate is 0.7 m wide and is hinged at point A.

Determine EACH of the following:

(a) the thrust force on the gate when the water level is 3.2 m; (4)

(b) the minimum force, F, required at the bottom of the gate to keep the gate closed if the thrust force acts at a point 0.02 m below the gate centroid. (4)

Note: density of water is 1020 kg/m³

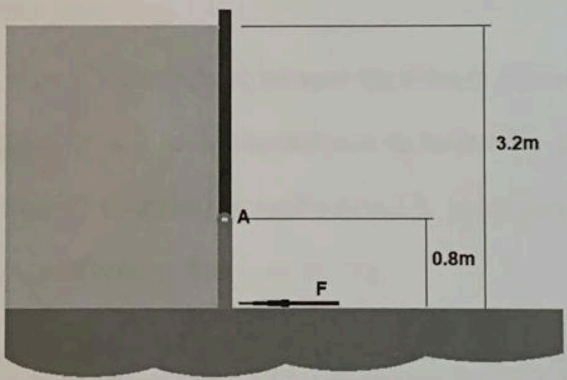


Fig Q11

12. A ship, initially upright, has a mass, M, of 8000 tonnes, KM is 8.6 m and KG is 8 m. During bad weather a piece of deck cargo was lost overboard which had a KG of 10 m and was 8 m from the centreline, this resulted in a list of 3°.

Determine EACH of the following:

(a) the mass of cargo lost overboard; (5)

(b) the new KG of the vessel after the loss of cargo; (4)

(c) the new GM after the loss of cargo. (1)

1. (a) State the characteristic gas equation in both of its forms. (2)

(b) A gas whose original pressure, temperature and volume were 150 kPa, 0.15 m³ and 30°C respectively is compressed until its new temperature and pressure are 70°C and 800 kPa.

Determine EACH of the following:

(i) the new volume of the gas; (3)

(ii) the mass of the gas. (3)

Note: R = 0.29 kJ/kgK

Ideal | Combined

1a) $PV = mRT$ $\qquad \frac{P_1V_1}{T_1} = \frac{P_2V_2}{T_2}$

b) i) $P_1 = 150{,}000$ (Pa) $\qquad P_2 = 800{,}000$ (Pa)

$V_1 = 0.15\ m^3 \qquad V_2 = x$

$T_1 = 30°C = 303\ K \qquad T_2 = 70°C = 343$

$$\frac{P_1V_1}{T_1} = \frac{P_2V_2}{T_2}$$

$$\frac{150{,}000 \times 0.15}{303} = \frac{800{,}000x}{343}$$

$$\boxed{0.031837\ m^3}$$

bii) $PV = mRT$

$$150{,}000 \times 0.15 = x \times 290(303)$$

$$\frac{150{,}000 \times 0.15}{290(303)} = x$$

$$\boxed{0.25606\ kg} = x$$

2. A quantity of gas whose original volume and temperature are 0.2 m^3 and 303°C respectively is cooled at constant pressure until its volume becomes 0.1 m^3. The gas is then heated at constant volume until its pressure is doubled.

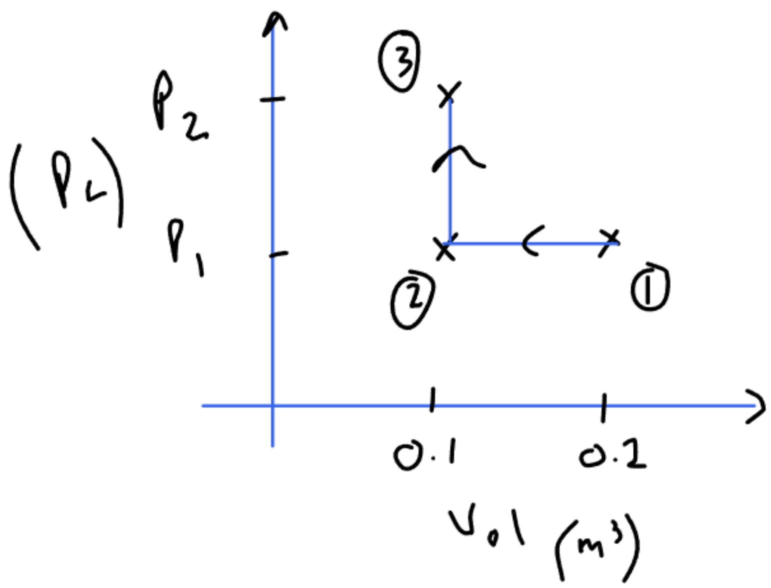
Determine EACH of the following:

(a) sketch the processes on a pressure-volume diagram; (2)

(b) the temperature of the gas after the initial cooling process; (3)

(c) the temperature after the heating process. (3)

a)



a)

b)

$P_1 =$

$V_1 = 0.2 m^3$

$T_1 = 303°C = 576 K$

thats nasty ^ for dyslexics
easy to get mixed up with Q1

$P_2 = 1$

$V_2 = 0.1 m^3$

$T_2 = x = 288 K$

×2

$P_3 = 2$

$V_3 = 0.1 m^3$

$T_3 = x$

as the pressure is not given, we can just sub in a value, you could use 100,000 Pa, im just gunna use 1

$$\frac{P_1 V_1}{T_1} = \frac{P_2 V_2}{T_2}$$

$$\frac{0.2}{576} = \frac{0.1}{x}$$

$$x = 288 K$$

c)

$$\frac{P_2 V_2}{T_2} = \frac{P_3 V_3}{T_3}$$

$$\frac{1}{288} = \frac{2}{x}$$

$$x = 576 K$$

3. 0.5 kg Benzene (C_6H_6) is completely burned in 30% excess air.

Calculate EACH of the following:

(a) the mass of carbon dioxide in the exhaust gases of the fuel; (4)

(b) the mass of nitrogen in the exhaust gases per kg of fuel. (4)

H = 1 C = 12 O = 16 Air = 23% oxygen

Carbon

$6 \times 12 = 72$

Hydrogen

$6 \times 1 = 6$

(Benzene) total

$72 + 6 = 78$

$\frac{72}{78} \times 0.5 \text{ kg} = 0.461538 \text{ kg}$

$\frac{6}{78} \times 0.5 \text{ kg} = 0.0384615 \text{ kg}$

Burn Carbon

$C + O_2 = CO_2$

moles = $\frac{mass}{RAM}$ $\frac{0.461538}{12} = \frac{x}{32}$

1.230768 kg of oxy to burn Carbon

Burn Hydrogen

$H_2 + O = H_2O$

moles = $\frac{mass}{RAM}$ $\frac{0.0384615}{2} = \frac{x}{16}$

0.307692 kg of oxygen req to burn Hydrogen

a) mass of CO_2 = mass oxy + mass Carbon

= 1.230768 + 0.461538

= **1.6923 kg**

b) stoich oxy = 1.230768 + 0.307692

= 1.53846 kg

Stoich Air @ 23%

$x \times 0.23 = 1.53846$

$x = \frac{1.53846}{0.23} = 6.688956$ kg

Actual air @ 30% excess

$6.688956 \times 1.3 = 8.69564$ kg

Nitrogen @ 77%

$8.69564 \times 0.77 =$ **6.69564 kg**

4. (a) State TWO desirable properties of refrigerants. (1)

(b) In a vapour compression refrigeration plant, briefly explain EACH of the following:

(i) under-cooling and its effect; (2)

(ii) the cause of the low pressure side into which expansion occurs through the TEV; (2)

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5. State and describe the THREE modes of heat transfer, giving an example of each. (9)

6. A 2 stroke diesel engine is tested over a 24 hour period and uses 18 tonnes of fuel. The power of the engine is tested using a dynamometer which gives a steady state torque reading of 50 kNm at 800 rpm. The mechanical efficiency was later found to be 87%.

Calculate EACH of the following:

(a) the brake power; (3)

(b) the indicated specific fuel consumption; (3)

(c) the brake thermal efficiency. (3)

Note: the calorific value of the fuel = 44 MJ/kg

$$Imep = \frac{A\phi}{L}$$

$$IP = x\,p\,l\,a\,n$$

$$Isfc = \frac{kg}{kWh} = \frac{kg/h}{kW} = \frac{consump}{IP}$$

$$BP = T\,2\pi N$$

$$Eff = \frac{BP}{IP}$$

$$Bte = \frac{BP}{\underset{kg/sec}{consump} \times \underset{J/kg}{cal\ content}}$$

a) $BP = T 2\pi N$

$T = 50{,}000$

$N = \frac{800 \text{ Rev}}{\text{min}} = 13.333 \text{ Rev/sec}$

$BP = 50{,}000 \times 2\pi \times 13.3333$

4,188,790.205 Watts

b) $Isfc = \frac{kg/h}{kW}$

$\text{consumption} = \frac{18000}{24} = 750\,kg/h$

$Eff = \frac{BP}{IP}$

$0.87 = \frac{4{,}188{,}790.205}{x}$

$x = \frac{4{,}188{,}790.205}{0.87}$

$IP = 4{,}814{,}701.385$ Watts

4814.701 kW

$Isfc = \frac{kg/h}{kW} = \frac{750}{4814.701} = \boxed{0.1557729\ kg/kWh}$

c) $Bte = \dfrac{BP}{\text{Consump Kg/sec} \times \text{cal content J/kg}}$

Fuel consumption kg/sec

750 kg/h ÷ 3600 = 0.2083333 kg/sec

Cal content 44,000,000 J/kg

$Bte = \dfrac{4,188,790.205}{0.2083333 \times 44,000,000}$

Bte = 0.456958 x100

Bte = 45.6959 %

7.

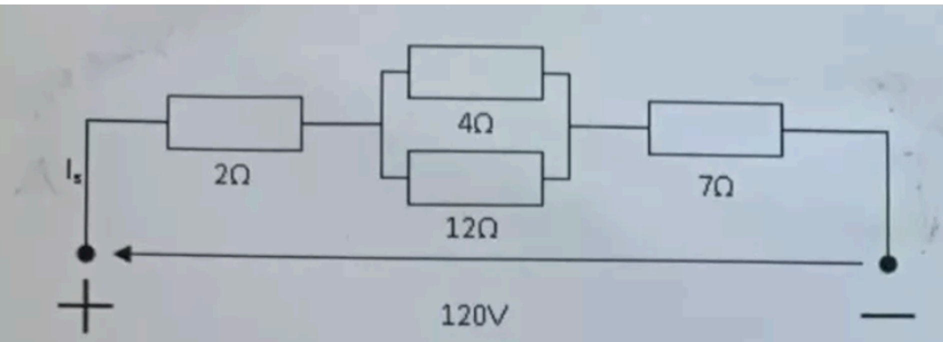


Fig Q7

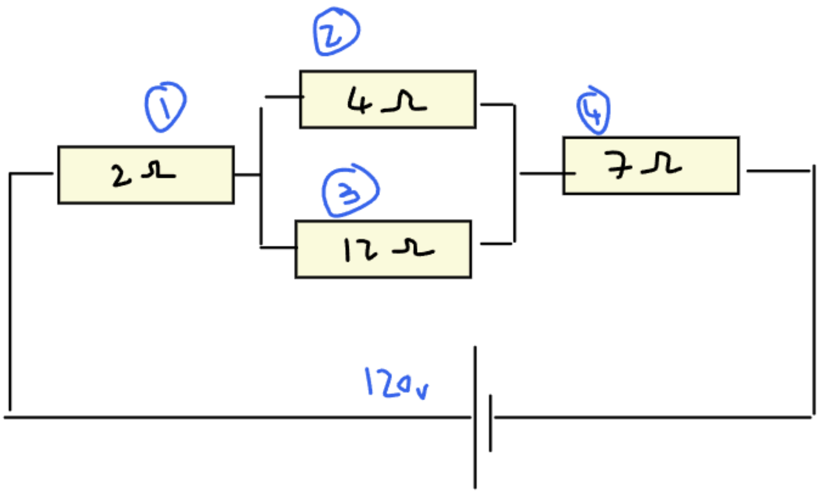
For the circuit diagram in Fig Q7, determine EACH of the following:

(a) the total circuit resistance; (2)

(b) the circuit current; (2)

(c) the potential difference across the 7 Ω resistor; (2)

(d) the circuit current if the 4 Ω resistor went open circuit. (2)



$$R_s = R_1 + R_2$$

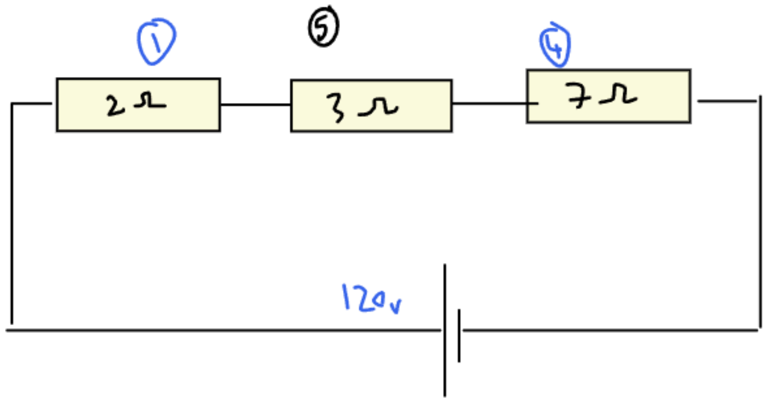
$$\frac{1}{R_p} = \frac{1}{R_1} + \frac{1}{R_2}$$

$$P = IV$$

combine resistors in parrallel over R2 and R3

$$\frac{1}{R_T} = \frac{1}{4} + \frac{1}{12}$$

$$R_T = 3\ \Omega$$



Res over series section R1 R5 R4

$R_T = 2 + 3 + 7 = 12\Omega$

Circuit

$V = 120v$

$I = 10$ Amps

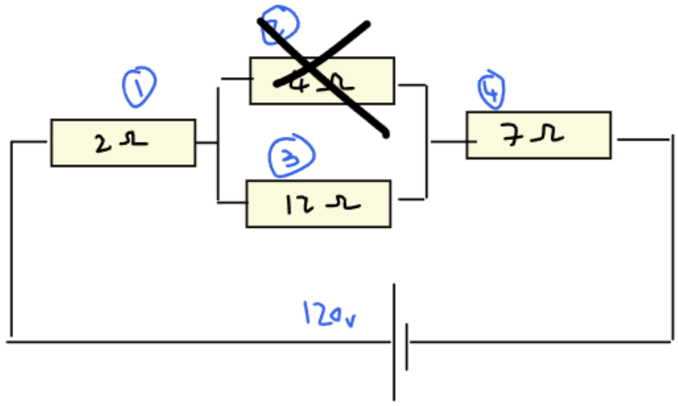
$R = 12$

$I = \frac{V}{R} = \frac{120}{12} = 10$

a) 12Ω

b) 10 Amps

d)



$R_s = 2 + 12 + 7 = 21\ \Omega$

$V = 120$

I

$R = 21$

$I = \frac{V}{R} = \frac{120}{21} = 5.714285$ Amps

8. (a) List FOUR means by which electricity may be produced. (2)

(b) State the THREE main effects of an electric current. (3)

(c) State TWO practical examples of EACH effect in Q8(b). (3)

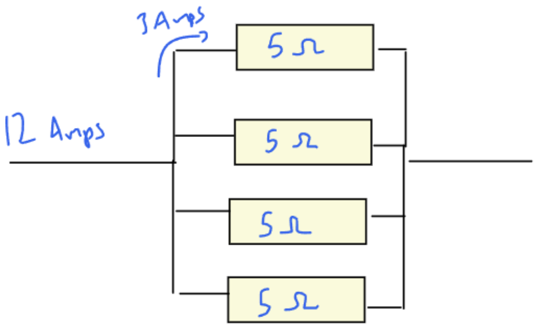
9. A lighting system is fed from a d.c. supply. Four lights are connected in parallel with a supply current of 12 A and line current of 3 A. The lamps have a resistance of 5 Ω each.

Calculate EACH of the following:

(a) the power dissipated by each lamp; (3)

(b) the total power consumed by the circuit if the total resistance of the cables was 0.6 Ω; (3)

(c) the supply voltage. (2)



$$\frac{1}{R_p} = \frac{1}{5} + \frac{1}{5} + \frac{1}{5} + \frac{1}{5}$$

$$R_T = \frac{5}{4} = 1.25\ \Omega$$

Circuit

V = 15 Volts
I = 12 Amps
R = 1.25 Ω

V
I R

$V = I \times R$

$V = 12 \times 1.25 = 15$ Volts

Check for each bulb

V
I = 3
R = 5

V
I R

$V = 3 \times 5$

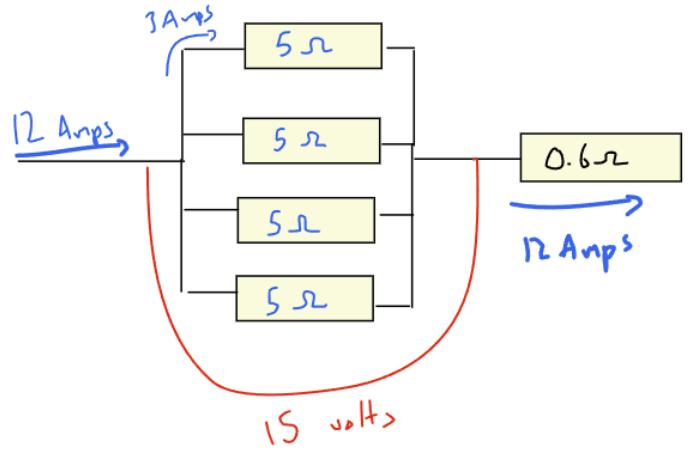
$V = 15$ volts

a) Power each lamp

$P = IV$

$P = 3 \times 15 = 45$ watts

b)



P.d. across cables

V = 7.2

I = 12

R = 0.6

$V = I \times R$

$V = 7.2$ v

Power for lamps

$45 \times 4 = 180$ watts

Power for cables

$P = IV$

12×7.2

86.4 watts

total

180 + 86.4 = **266.4 watts**

c) Supply voltage = 15 + 7.2 = **22.2 volts**

10. A conductor with an effective length of 500 mm and a diameter of 12.5 mm is carrying a current of 45 A at right angles to a magnetic field. The force on the conductor is 7 N.

Calculate EACH of the following:

(a) the flux density; (4)

(b) the magnetic flux. (4)

a) $F = BIL \sin\theta$

$F = 7$ N

$B = x$

$I = 45$ A

$L = 0.5$ m

$7 = x(45 \times 0.5)$

$0.31111 = x$

0.31111 Tesla

b) $B = \frac{\phi}{A}$

$B = 0.311111$ T

ϕ

$A = \left(\frac{12.5}{2000}\right)^2 \pi = 1.227184 \times 10^{-4}$ m^2

$BA = \phi$

$0.311111 \times 1.227184 \times 10^{-4} = \phi$

3.8179×10^{-5} Wb

101%

11. A section of a water retaining wall with a gate at the bottom is shown in Fig Q11. The gate is 0.7 m wide and is hinged at point A.

Determine EACH of the following:

(a) the thrust force on the gate when the water level is 3.2 m; (4)

(b) the minimum force, F, required at the bottom of the gate to keep the gate closed if the thrust force acts at a point 0.02 m below the gate centroid. (4)

Note: density of water is 1020 kg/m³

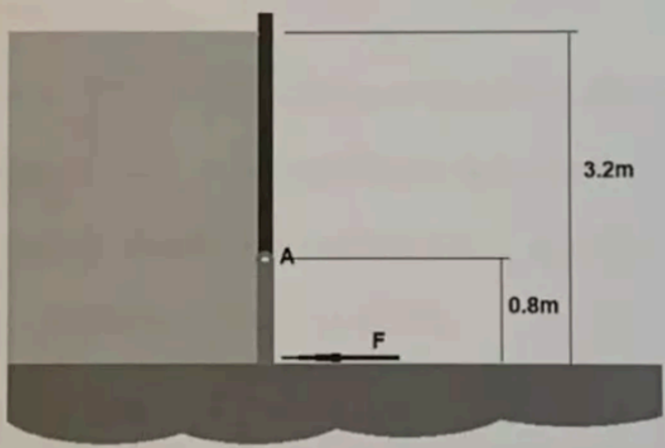


Fig Q11

a) $F = \rho g A \bar{h}$

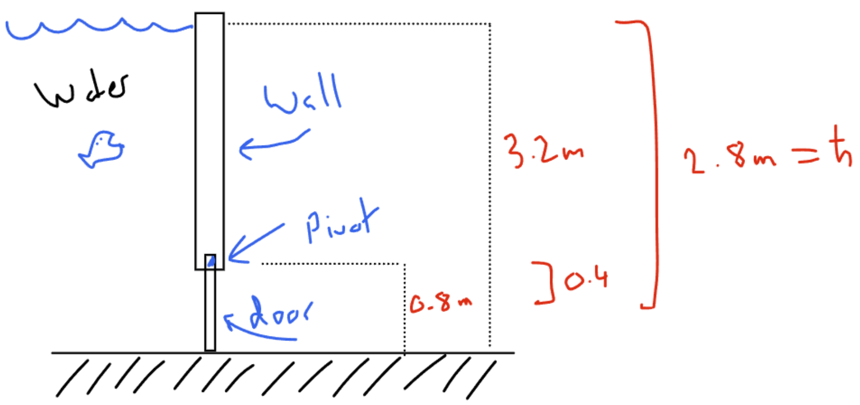
$\rho = 1020$

$g = 9.81$

$A = 0.8 \times 0.7 = 0.56 m^2$

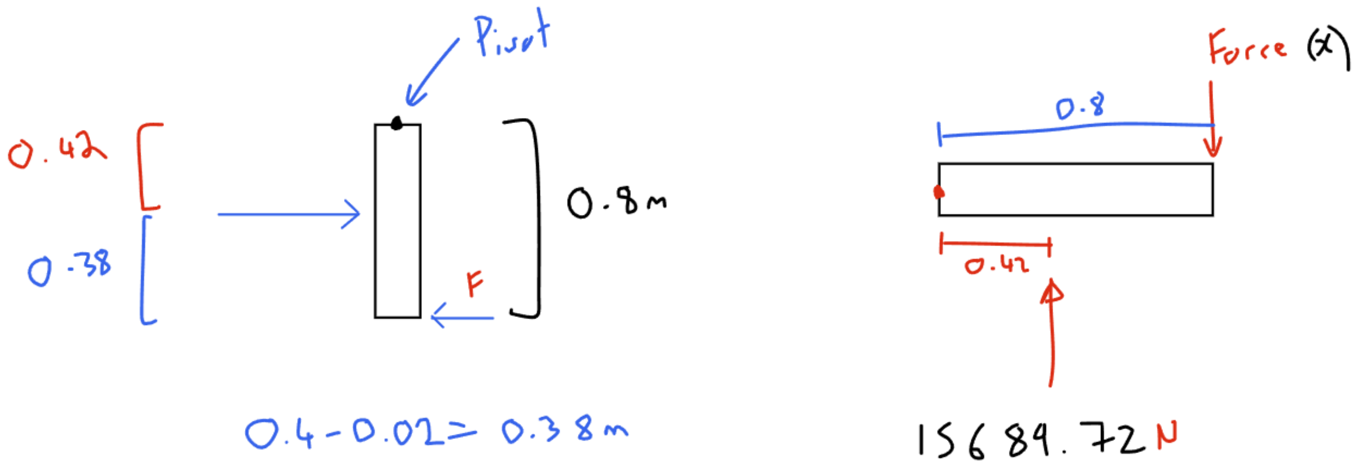
$\bar{h} = 2.8$

took me a while to understand this question because of the bad diagram, and had to do it twice



$F = 1020 \times 9.81 \times 0.56 \times 2.8 = 15689.72$ N

b) Use centroids on door



taking moments about A

sum of clockwise moments = sum of anticlockwise moments

$$F \times d = F \times d$$

$$x(0.8) = 15689.72 \times 0.42$$

$$x = \boxed{8237.103\ N}$$

minimum force required to keep door closed

12. A ship, initially upright, has a mass, M, of 8000 tonnes, KM is 8.6 m and KG is 8 m. During bad weather a piece of deck cargo was lost overboard which had a KG of 10 m and was 8 m from the centreline, this resulted in a list of 3°.

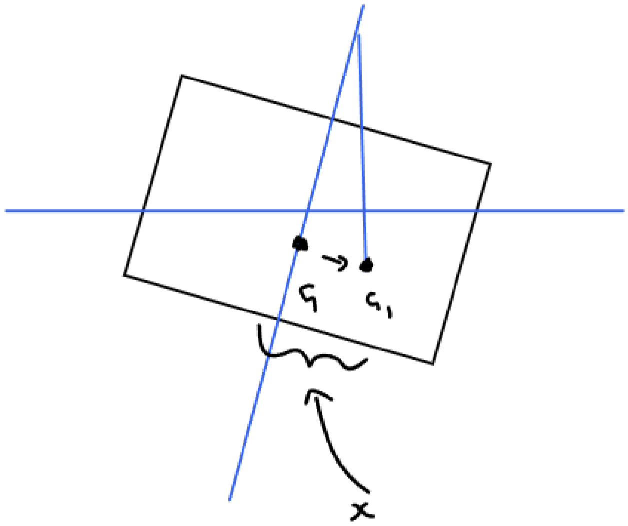
Determine EACH of the following:

(a) the mass of cargo lost overboard; (5)

(b) the new KG of the vessel after the loss of cargo; (4)

(c) the new GM after the loss of cargo. (1)

a) $\tan\theta = \dfrac{GG_1}{GM}$



$\tan 3 = \dfrac{x}{0.6}$

$0.03144466\,m = x$

shift of centre of gravity

Ship loaded = 8000

unloaded = 8000 − load

8000 − x

now ship is in equilibrium
Sum of anticlockwise moments = sum of anticlockwise moments

$$F \times D = F \times d$$

$$(M - \text{load})\, D = \text{load} \times \text{distance}$$

$$(8000 - x)\, 0.0314466 = x(8)$$

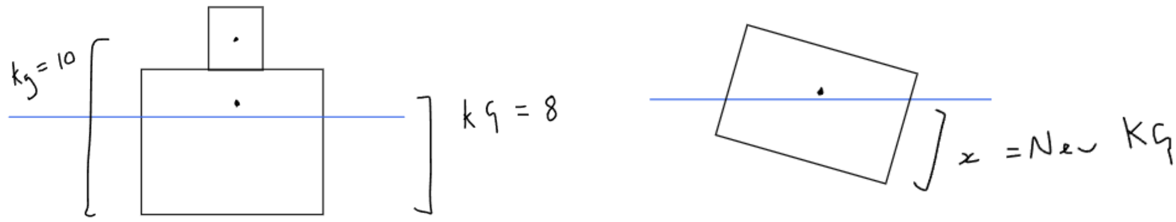
$$251.557 - 0.0314466x = 8x$$

$$251.557 = 8.0314446\, x$$

$$\frac{251.557}{8.031444} = x$$

mass of load → $31.3215\ t = x$

b)



Name	Mass (t)	Force	distance	Moment	Dir
Ship	7968.68		x	$7968.68x$	C
load	31.321		10	313.21	C
Ship + load	8000		8	64000	A

taking moments about K

sum of clockwise moments = sum of anticlockwise moments

$$7968.68x + 313.21 = 64000$$

$$x = \frac{64000 - 313.21}{7968.68}$$

New $KG = x = $ **7.99214 m**

c) New $GM = KM - KG$

$8.6 - 7.99214 = 0.60786\text{ m}$

assuming meta centre is unchanged (for 1 mark)