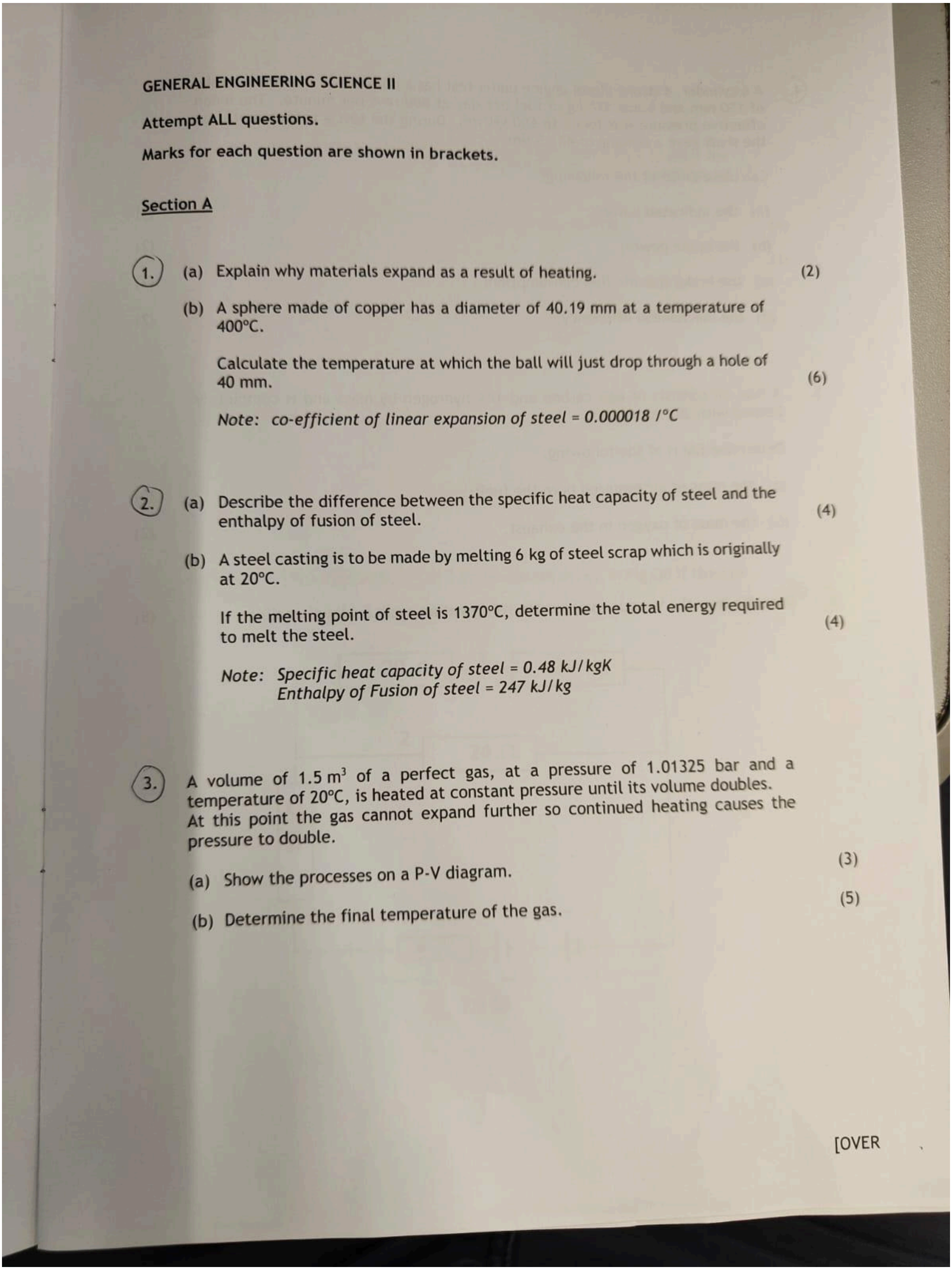

GENERAL ENGINEERING SCIENCE II

Attempt ALL questions.

Marks for each question are shown in brackets.

Section A

1. (a) Explain why materials expand as a result of heating. (2)

(b) A sphere made of copper has a diameter of 40.19 mm at a temperature of 400°C.

Calculate the temperature at which the ball will just drop through a hole of 40 mm. (6)

Note: co-efficient of linear expansion of steel = 0.000018 /°C

2. (a) Describe the difference between the specific heat capacity of steel and the enthalpy of fusion of steel. (4)

(b) A steel casting is to be made by melting 6 kg of steel scrap which is originally at 20°C.

If the melting point of steel is 1370°C, determine the total energy required to melt the steel. (4)

Note: Specific heat capacity of steel = 0.48 kJ/kgK
Enthalpy of Fusion of steel = 247 kJ/kg

3. A volume of 1.5 m^3 of a perfect gas, at a pressure of 1.01325 bar and a temperature of 20°C, is heated at constant pressure until its volume doubles. At this point the gas cannot expand further so continued heating causes the pressure to double.

(a) Show the processes on a P-V diagram. (3)

(b) Determine the final temperature of the gas. (5)

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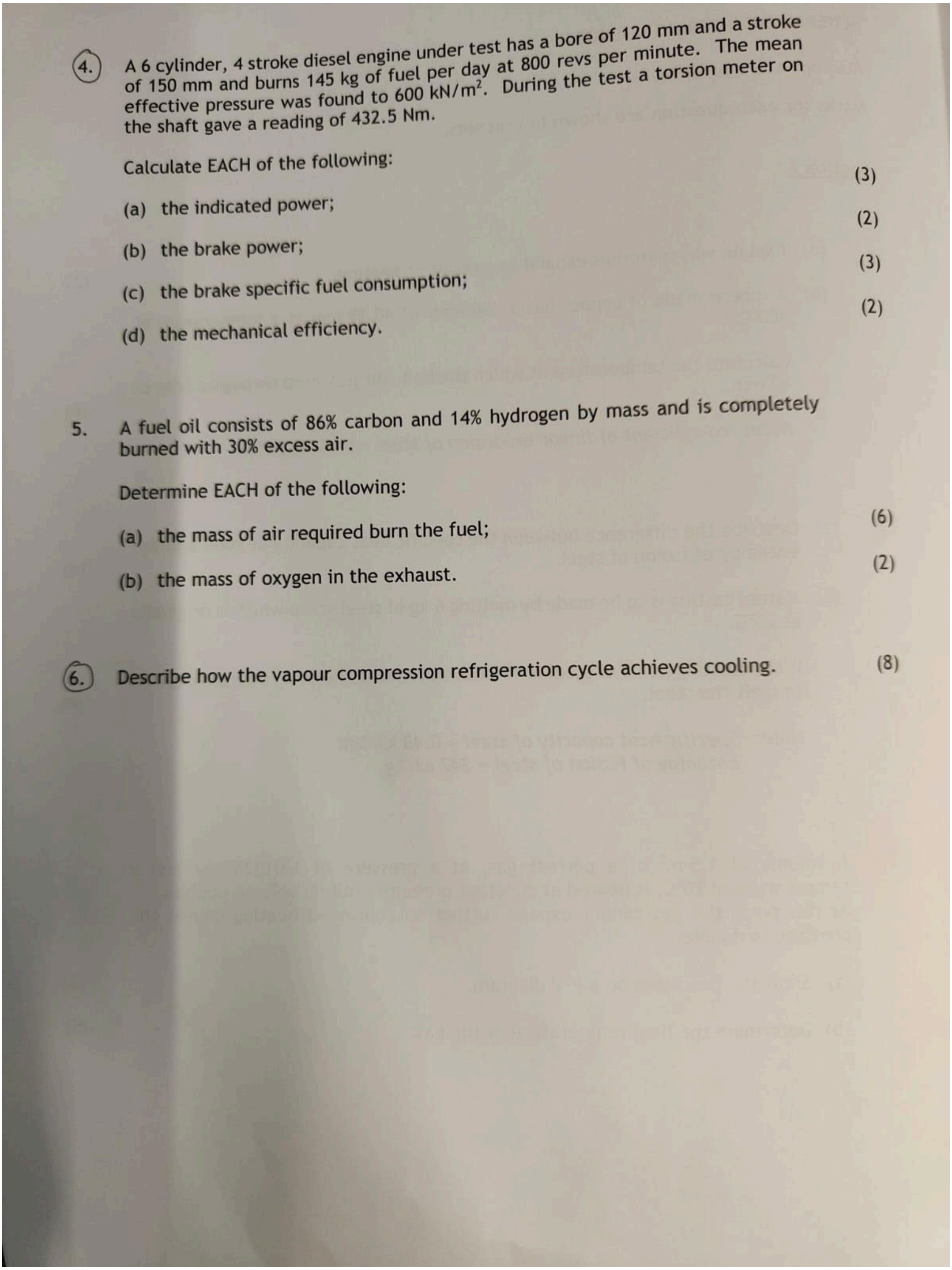


4. A 6 cylinder, 4 stroke diesel engine under test has a bore of 120 mm and a stroke of 150 mm and burns 145 kg of fuel per day at 800 revs per minute. The mean effective pressure was found to 600 kN/m^2. During the test a torsion meter on the shaft gave a reading of 432.5 Nm.

Calculate EACH of the following:

(a) the indicated power; (3)

(b) the brake power; (2)

(c) the brake specific fuel consumption; (3)

(d) the mechanical efficiency. (2)

5. A fuel oil consists of 86% carbon and 14% hydrogen by mass and is completely burned with 30% excess air.

Determine EACH of the following:

(a) the mass of air required burn the fuel; (6)

(b) the mass of oxygen in the exhaust. (2)

6. Describe how the vapour compression refrigeration cycle achieves cooling. (8)

Section B

7. The circuit in Fig Q7 has a voltmeter as shown. When the switch is open the reading on the voltmeter is 30 V, when the switch is closed the voltage drops to 26.67 V.

(a) Explain the reason for the change in the voltmeter readings. (4)

(b) Determine the resistance of the cell. (4)

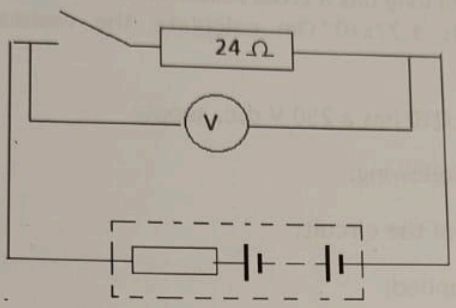


Fig Q7

8. Determine the current at points 1, 2 & 3 in the circuit shown in Fig Q8 if the cell e.m.f. is 32 V. (8)

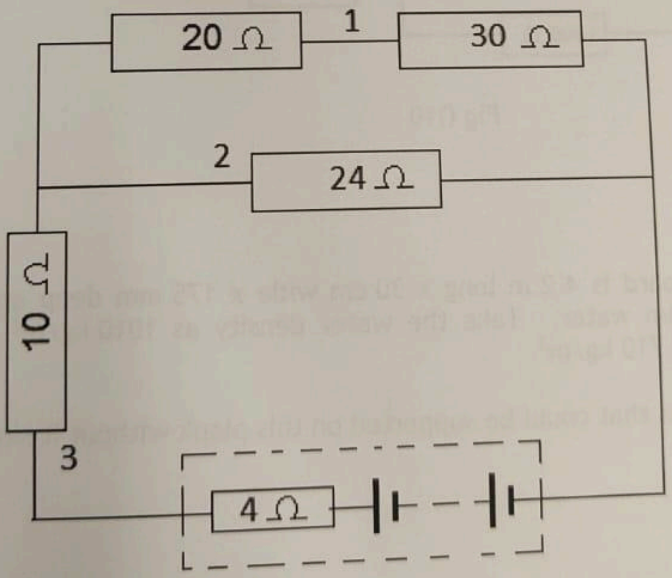


Fig Q8

[OVER

(2)

9. (a) State Lenz's Law.

(b) A conductor with an effective length of 250 mm creates a magnetic flux 480 μWb when carrying a current of 45 A at right angles to a magnetic field. The force on the conductor is 48 N.

Determine the diameter of the conductor. (6)

10. (a) A copper conductor 80 m long has a cross sectional area of 2.5 mm^2. If the resistivity of copper is $1.77 \times 10^{-8}\,\Omega m$ calculate the resistance of the conductor. (2)

(b) The circuit shown in Fig Q10 has a 250 V d.c. supply.

Determine EACH of the following:

(i) the total resistance of the circuit; (2)

(ii) the total current supplied; (1)

(iii) the volt drop across the 800 Ω resister. (3)

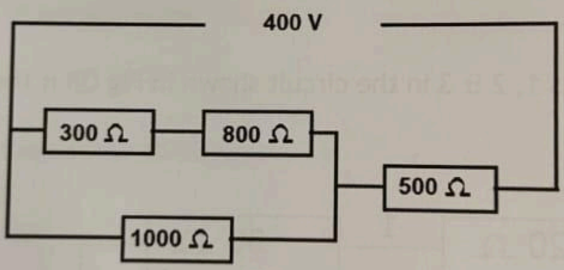
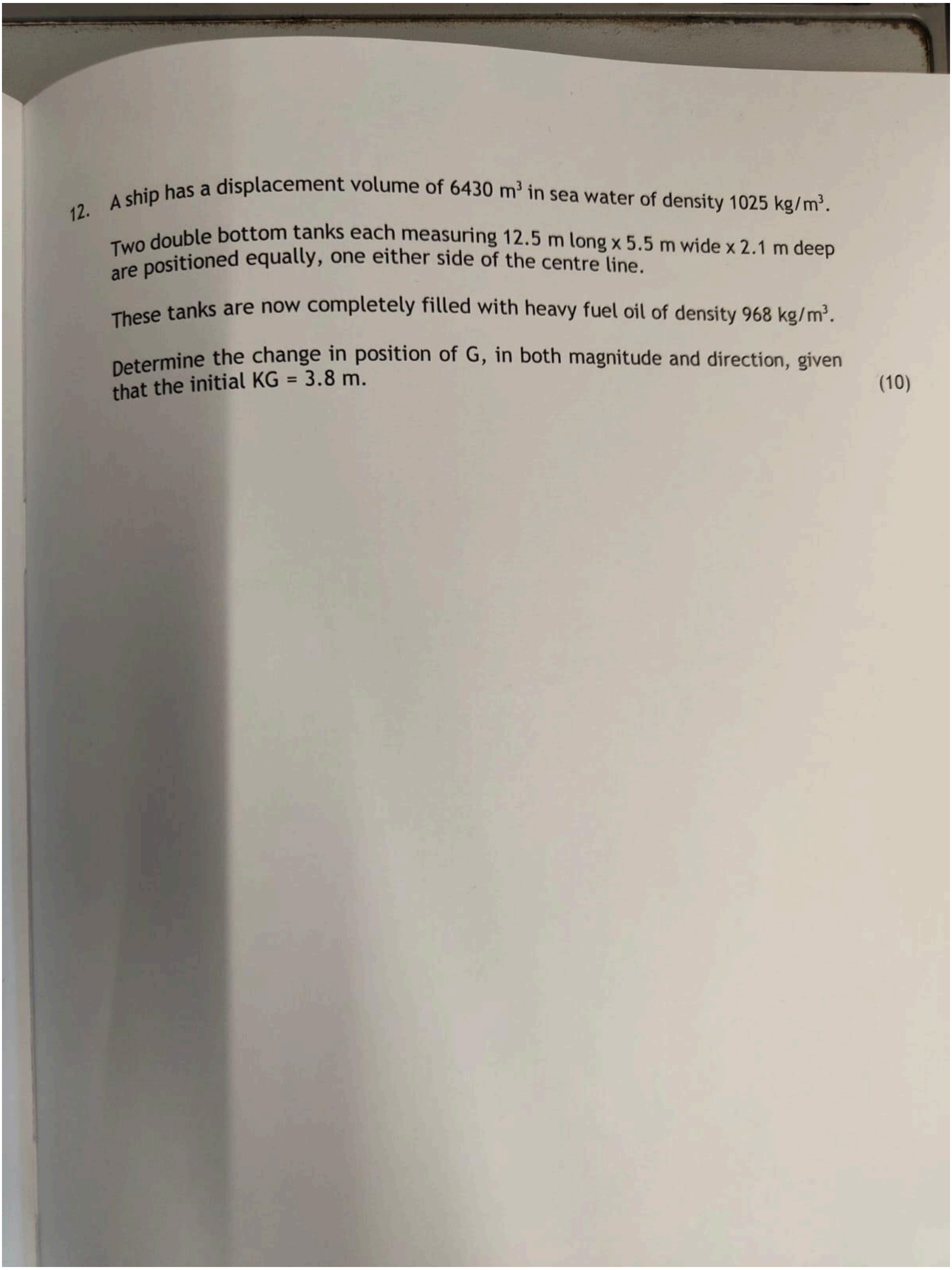


Fig Q10

11. A solid wooden board is 4.2 m long x 30 cm wide x 175 mm deep and floats horizontally in calm water. Take the water density as 1010 kg/m^3 and the density of wood as 710 kg/m^3.

Determine the mass that could be supported on this plank without it sinking. (8)

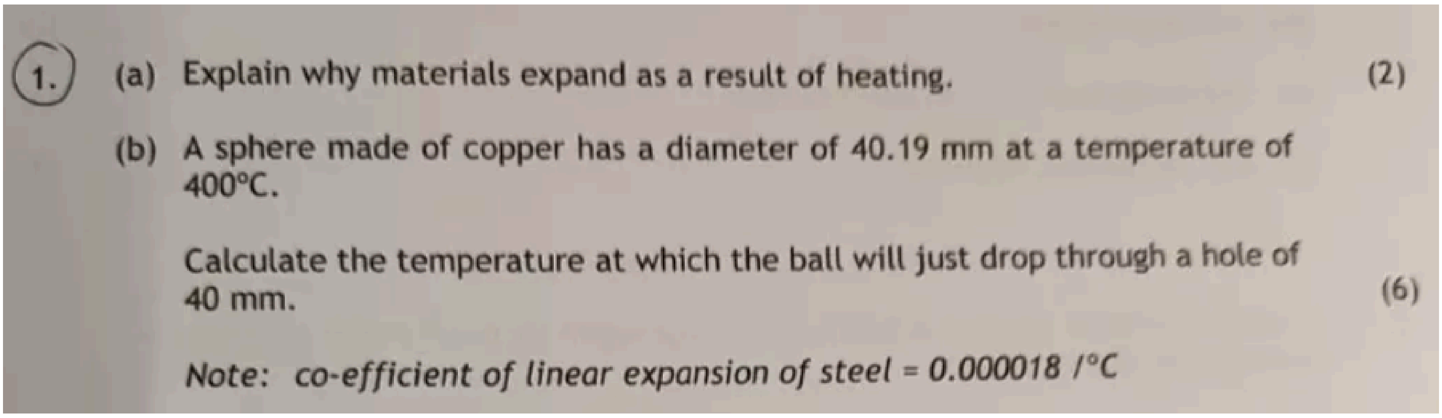


12. A ship has a displacement volume of 6430 m^3 in sea water of density 1025 kg/m^3.

Two double bottom tanks each measuring 12.5 m long x 5.5 m wide x 2.1 m deep are positioned equally, one either side of the centre line.

These tanks are now completely filled with heavy fuel oil of density 968 kg/m^3.

Determine the change in position of G, in both magnitude and direction, given that the initial KG = 3.8 m. (10)



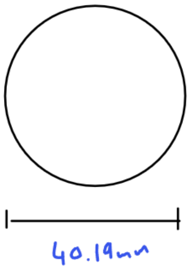
1. (a) Explain why materials expand as a result of heating. (2)

(b) A sphere made of copper has a diameter of 40.19 mm at a temperature of 400°C.

Calculate the temperature at which the ball will just drop through a hole of 40 mm. (6)

Note: co-efficient of linear expansion of steel = 0.000018 /°C

a) Temperature is a measure of the vibration of the atoms of a material, as this increases the atoms vibrate more, and take up more space as they move around, resulting in an expanding of the overall material.



$$\text{Dia} + \underbrace{\text{expansion}} = \text{New dia}$$

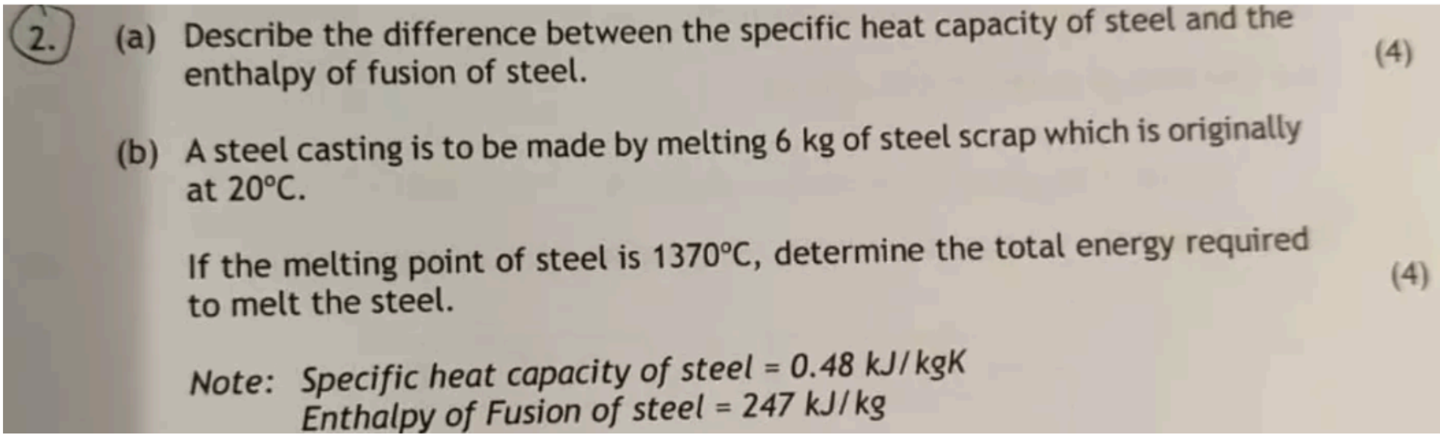
$$40.19 + D\alpha\Delta t = 40$$

$$40.19 \times 0.000018\,\Delta t = -0.19$$

$$\Delta t = \frac{-0.19}{40.19 \times 0.000018}$$

$$\Delta t = -262.64$$

$$\text{Final temp} = 400 - 262.64 = \boxed{137.36\,°C}$$



2. (a) Describe the difference between the specific heat capacity of steel and the enthalpy of fusion of steel. (4)

(b) A steel casting is to be made by melting 6 kg of steel scrap which is originally at 20°C.

If the melting point of steel is 1370°C, determine the total energy required to melt the steel. (4)

Note: Specific heat capacity of steel = 0.48 kJ/kgK
Enthalpy of Fusion of steel = 247 kJ/kg

specific heat capacity is the amount of energy in joules required to raise the temperature of 1kg of steel by 1°C.

Enthalpy of fusion of a material is the amount of energy required to bring about a phase change from a solid to a liquid of steel.

The formulas are different

$$Q_{spec} = m \, \textcircled{c} \, \Delta t \leftarrow \text{specific heat capacity}$$

$$Q_{fusion} = m \, \textcircled{L} \leftarrow \text{Ethlpy of fusion}$$

Specific heat capacity occurs while steel is in its solid form, changes of temperature are sensible (can be sensed, measured) it also has a comparably low value of 480J/KgK. Specific heat capacity is a measure of how temperature conductive a material is, the lower the value, the more conductive. Copper is lower than steel and is therefore more conductive. Water has a higher specific heat content than steel, so it's better for holding on to heat energy.

Enthalpy of fusion is changing the state from a solid to a liquid or vice versa, its a very high value in comparison to specific heat, it has a value of 247,000 J/kg (omg!) As the energy is injected into the system, it spreads out over all the steel atoms. Such a high amount of energy is required in comparison to the specific heat capacity as this heat actually changes the layout of the substance. In the case of steel, breaking its giant lattice structure, and turning it into a liquid, that requires a LOT of energy!

Specific heat is just making the atoms/molecules vibrate faster b)

this is a 2 step problem, first we must heat the steel to melting point, then we must melt the steel

heat steel

$Q = mc\Delta t$

$Q =$

$m = 6\text{kg}$

$c = 480$

$\Delta t = (1370 - 20) = 1350$

$Q = 6 \times 480 \times 1350$

$Q = 3,888,000 \text{ J}$

melt steel

$Q = mL$

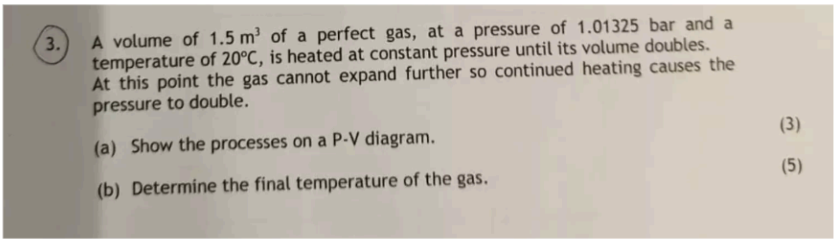
$m = 6$

$L = 247,000$

$Q = 6 \times 247000$

$= 1,482,000 \text{ J}$

$\boxed{\text{total} = 5370000 \text{J} \quad 5.37 \text{ MJ}}$



3. A volume of 1.5 m³ of a perfect gas, at a pressure of 1.01325 bar and a temperature of 20°C, is heated at constant pressure until its volume doubles. At this point the gas cannot expand further so continued heating causes the pressure to double.

(a) Show the processes on a P-V diagram. (3)

(b) Determine the final temperature of the gas. (5)

b) $$\frac{P_1 V_1}{T_1} = \frac{P_2 V_2}{T_2} = \frac{P_3 V_3}{T_3}$$

$P_1 = 1.01325$ bar
$101{,}325$ (Pa)

$V_1 = 1.5 m^3$

$T_1 = 20°C \overset{+273}{=} 293 K$

$P_2 = 101{,}325$ (Pa)

$V_2 = 3 m^3$

$T_2 = x = 586$

$P_3 = 202650$ (Pa)

$V_3 = 3 m^2$

$T_3 = y$

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

$$\frac{1.5}{293} = \frac{3}{x}$$

$x = 586$ K

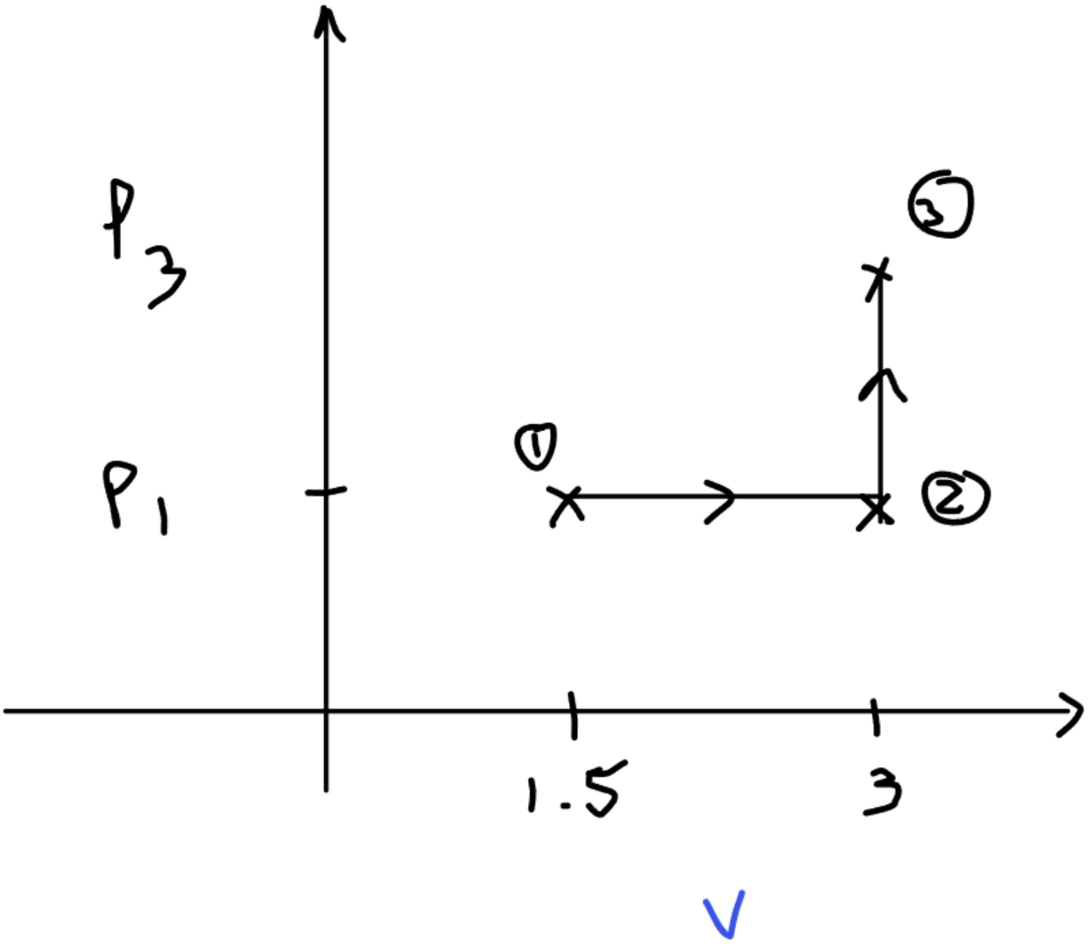
$$\frac{P_2 \cancel{V_2}}{T_2} = \frac{P_3 \cancel{V_3}}{T_3}$$

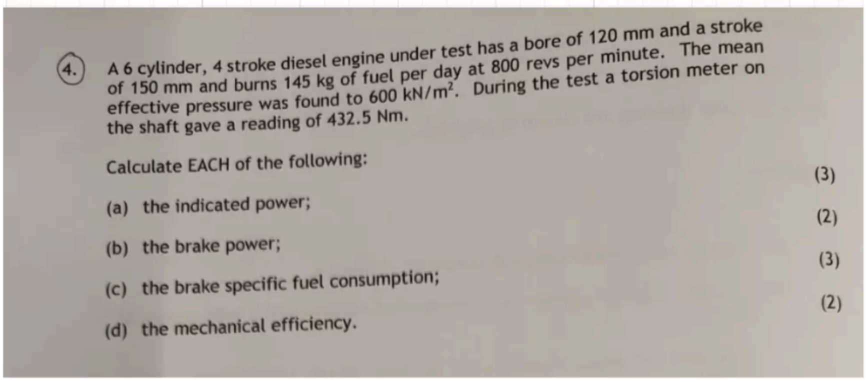
$$\frac{101325}{586} = \frac{202650}{y}$$

$y = 1172$ K

$\boxed{\text{Final temp } 1172 k}$

a)





④ A 6 cylinder, 4 stroke diesel engine under test has a bore of 120 mm and a stroke of 150 mm and burns 145 kg of fuel per day at 800 revs per minute. The mean effective pressure was found to 600 kN/m². During the test a torsion meter on the shaft gave a reading of 432.5 Nm.

Calculate EACH of the following:

(a) the indicated power; (3)

(b) the brake power; (2)

(c) the brake specific fuel consumption; (3)

(d) the mechanical efficiency. (2)

$\text{Imep} = \frac{A\phi}{L}$ $\quad IP = x\,p\,l\,a\,n$ $\quad BP = T2\pi N$

$\text{Eff} = \frac{BP}{IP} \times 100$ $\quad \text{Bsfc} = \text{kg}/\text{kwh} = \frac{\text{Fuel Consump}}{BP} \quad \frac{\text{kg}/\text{h}}{\text{kw}}$

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

IP

$x = 6$

$p = 600\ kN/m^2 = 600{,}000\ (Pa)$

$l = 150\ mm = 0.15\ m$

a

$n = 800\ Rev/min \xrightarrow{\div 60} = 13.333\ Rev/sec \xrightarrow{\div 2} \overset{(4\ stroke)}{6.66666}$

$d = 120\ mm$

$a = \left(\frac{120}{2000}\right)^2 \pi = 0.01130473355\ m^2$

$$\begin{array}{cccccccccc} IP = & x & & p & & l & & a & & n \\ IP = & 6 & \times & 600{,}000 & \times & 0.15 & \times & 0.01130473355 & \times & 6.6666 \end{array}$$

$= 40{,}715.04$ Watts

b) $BP = T 2 \pi N$

$= 432.5 \times 2\pi \times 13.3333$

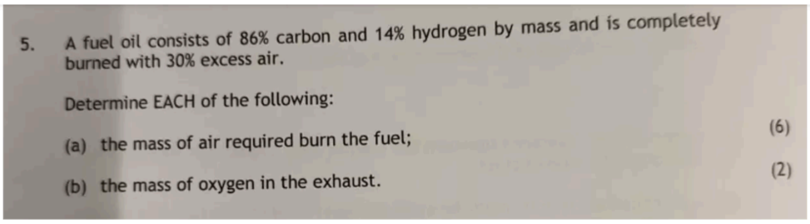
$= 36233.034$ Watts

c) $Bsfc = kg/kwh = \frac{\text{Fuel Consump}}{BP}\ \frac{kg/h}{kw}$

Fuel consumption $= 145\ kg / 24 = 6.041666\ kg/h$

$Bsfc = \frac{6.041666\ kg/h}{36.233\ kw} = 0.16674486\ kg/kwh$

d $Eff = \frac{BP}{IP} = \frac{36233.034}{40{,}715.04} \times 100 = 88.991768\ \%$



5. A fuel oil consists of 86% carbon and 14% hydrogen by mass and is completely burned with 30% excess air.

Determine EACH of the following:

(a) the mass of air required burn the fuel; (6)

(b) the mass of oxygen in the exhaust. (2)

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

as the question does state the mass of the fuel to be burnt, we will assume 1Kg.

Carbon

1 kg × 0.86 = 0.86 kg

Burn Carbon

$C + O_2 = CO_2$

mols = mass / RAM

$\frac{0.86}{12} = \frac{x}{32}$

2.293333 kg of oxygen Req to burn Carbon

Hydrogen

1 kg × 0.14 = 0.14 kg

Burn Hydrogen

$H_2 + O = H_2O$

$\frac{0.14}{2} = \frac{x}{16}$

1.12 kg of oxygen Req to burn Hydrogen

a) Stoich oxygen = 2.293333 + 1.12

= 3.413333 kg

Stoich Air @ 23%

$x \times 0.23 = 3.413333$

$x = 14.84057971$ kg

include excess @ 30%

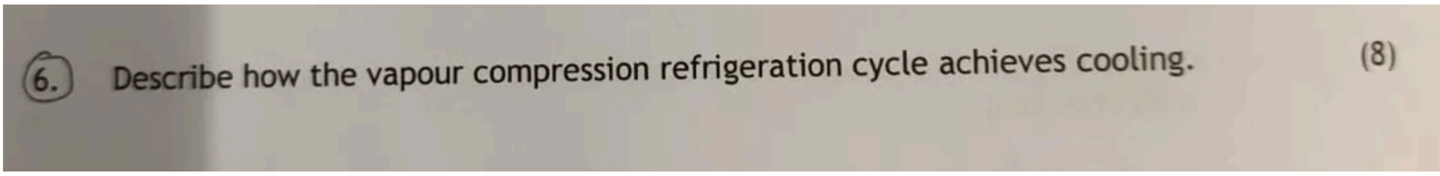
14.84057971 × 1.3

$= \boxed{19.2928 \text{ kg Air per kg of fuel}}$

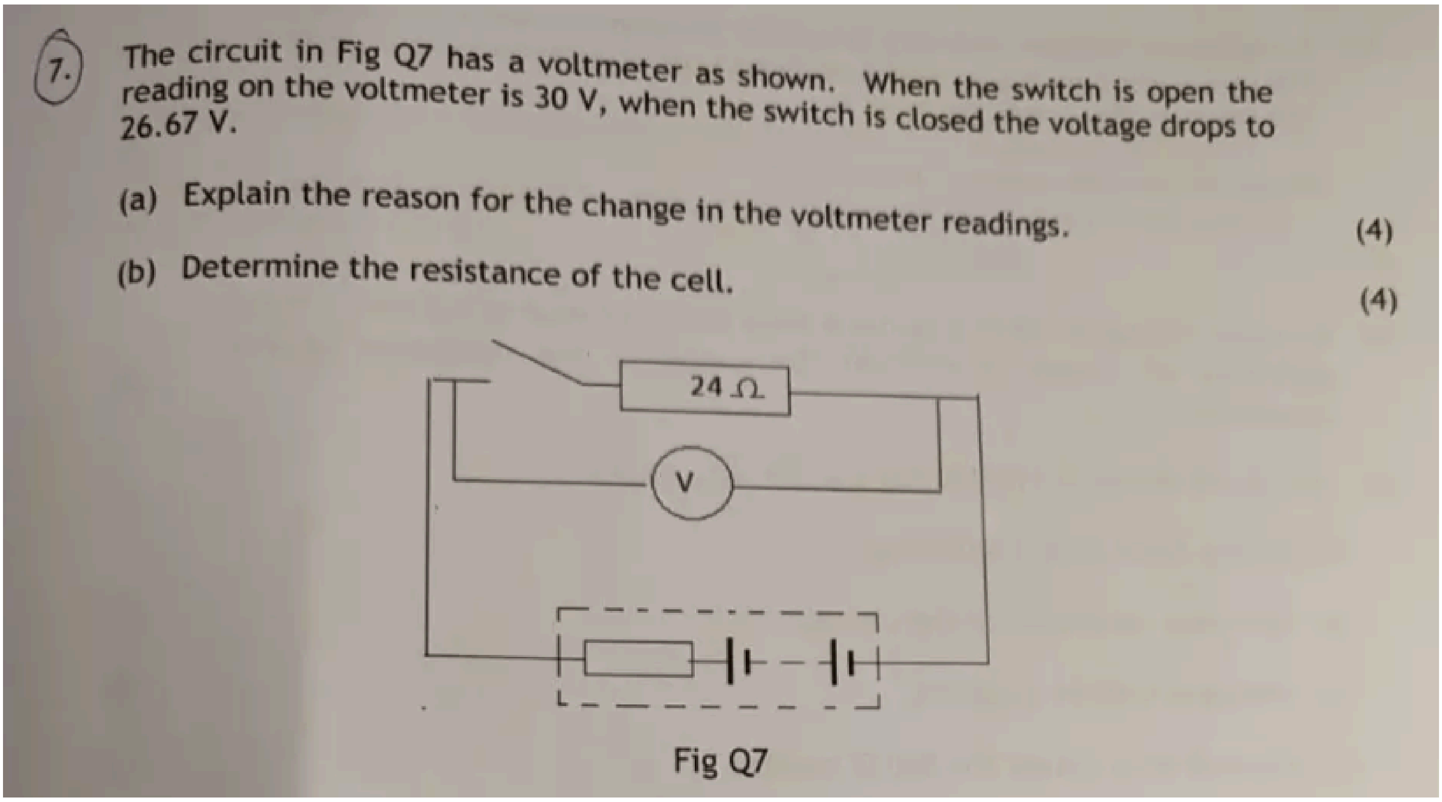
b) Oxygen intake − oxygen burnt = oxygen in exhaust

19.2928 × 0.23

4.4373333 − 3.413333 = $\boxed{1.024 \text{ kg}}$



6. Describe how the vapour compression refrigeration cycle achieves cooling. (8)



7. The circuit in Fig Q7 has a voltmeter as shown. When the switch is open the reading on the voltmeter is 30 V, when the switch is closed the voltage drops to 26.67 V.

(a) Explain the reason for the change in the voltmeter readings. (4)

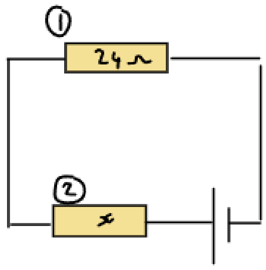
(b) Determine the resistance of the cell. (4)

Fig Q7

a) When the switch is open, the circuit is not complete. The 30v reading on the voltmeter is showing the emf of the battery.

When the switch is closed the battery is now under load, and the new potential difference across the terminals is 26.67Volts, showing a 3.33 voltage drop due to the internal resistance of the battery.

b)



Circuit

$V = 30$

I

$R = x + 24\Omega$

$I = \frac{V}{R} = \frac{30}{x+24}$

emf − IR = terminal voltage

$30 - IR = 26.67\ v$

$I_x = 3.33$

$I = \frac{3.33}{x}$

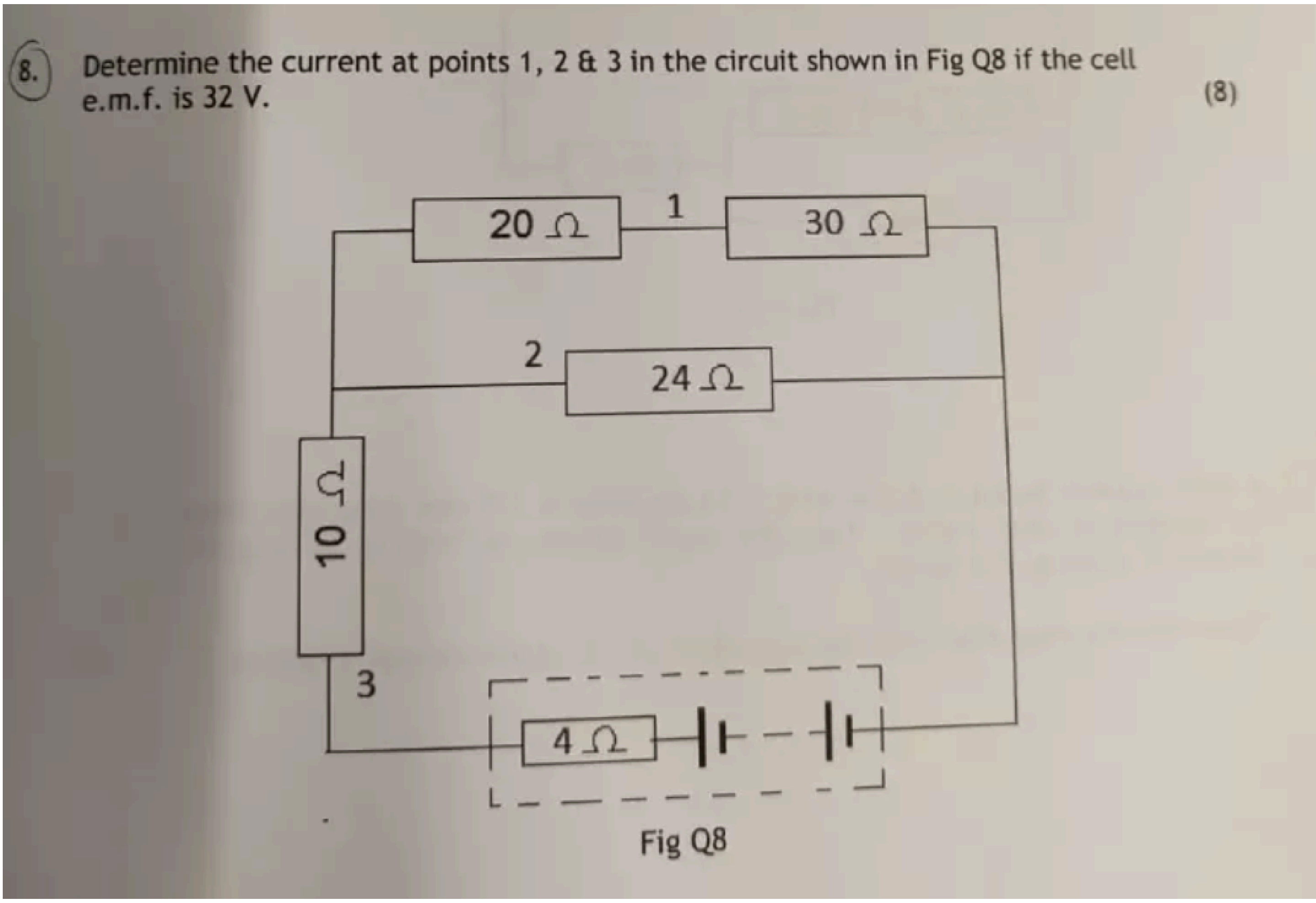
$$\frac{30}{x+24} = \frac{3.33}{x}$$

$$30x = 3.33(x+24)$$

$$30x = 3.33x + 79.92$$

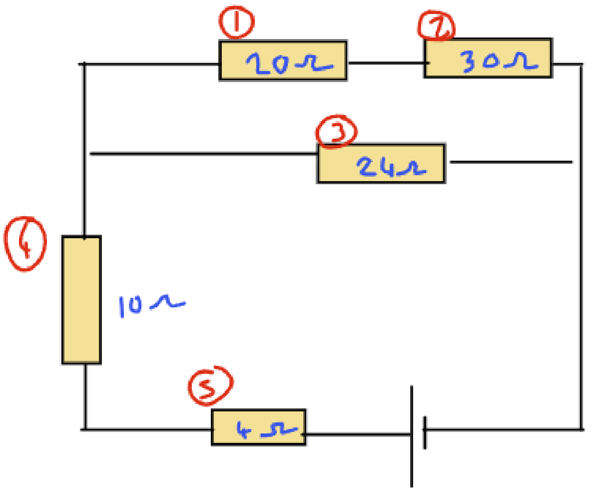
$$26.67x = 79.92$$

b) $\boxed{x = 2.9966\ \Omega}$



8. Determine the current at points 1, 2 & 3 in the circuit shown in Fig Q8 if the cell e.m.f. is 32 V. (8)

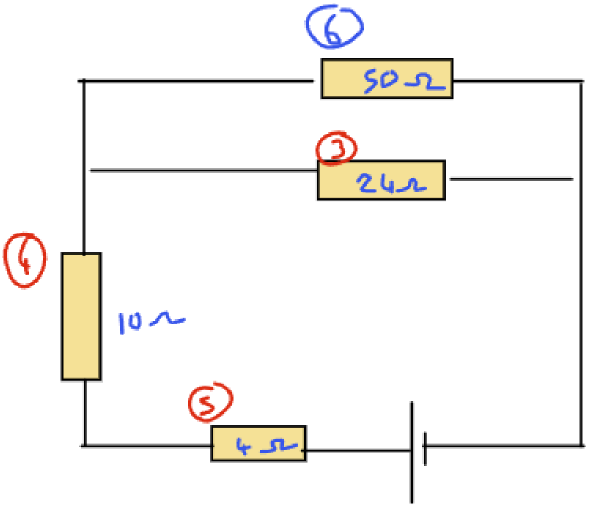
Fig Q8



RES in series R1 and R2

$$R_T = R_1 + R_2$$

$$20 + 30 = 50\,\Omega$$

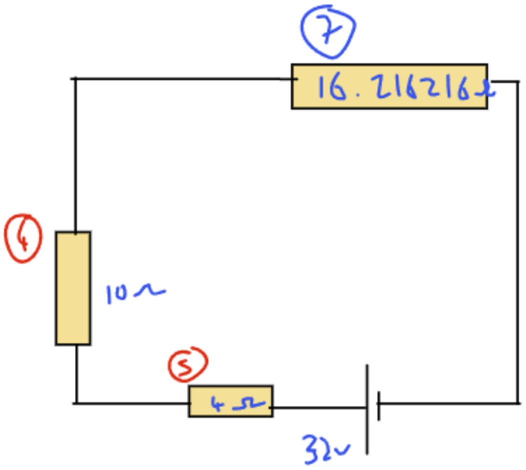


RES over parrallel section R6 R3

$$\frac{1}{R_T} = \frac{1}{R_6} + \frac{1}{R_3}$$

$$\frac{1}{R_T} = \frac{1}{50} + \frac{1}{24}$$

$$R_T = 16.216216\,\Omega$$



RES over series section R5 R4 R7

$$R_T = 4 + 10 + 16.216216$$

$$= 30.216216\,\Omega$$

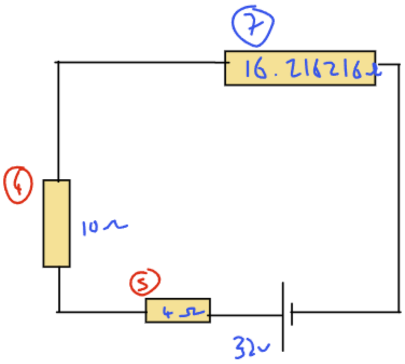
$I = \frac{V}{R}$

Circuit

$V = 32$

$I = 1.059033989$ Amps

$R = 30.216216$



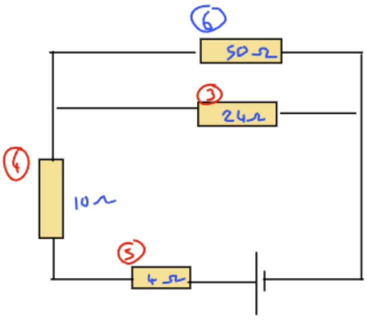
I really need voltage drop over R7, but I am going to do the other components just to check

$V = I \times R$

⑤	④	⑦
$V = 4.23614v$	$V = 10.59034v$	$V = 17.1735v$
$I = 1.059034$	$I = 1.059034$	$I = 1.059034$
$R = 4$	$R = 10$	$R = 16.216216$

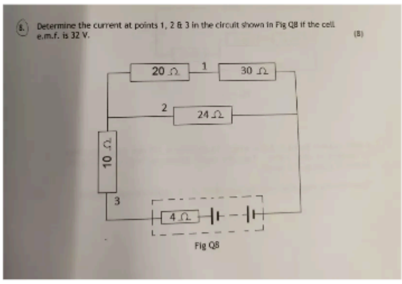
total volt is 31.99, so all good

how is current split over parrallel section R6 and R3?



③	⑥
$V = 17.1735$	$V = 17.1735$
$I = 0.7155625$ Amp	$I = 0.34347$ Amps
$R = 24$	$R = 50$

$$I = \frac{V}{R} = 0.7155625$$



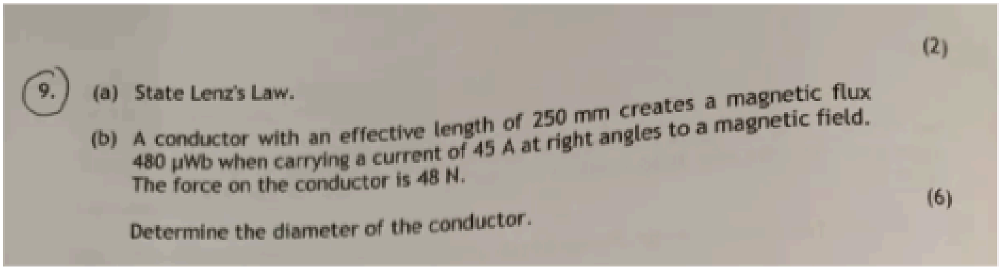
⑧ Determine the current at points 1, 2 & 3 in the circuit shown in Fig Q8 if the cell e.m.f. is 32 V. (8)

Fig Q8

Point 1 = 0.34347 Amps

2 = 0.7155625 Amp

3 = 1.059033989 Amps



9\. (a) State Lenz's Law. (2)

(b) A conductor with an effective length of 250 mm creates a magnetic flux 480 μWb when carrying a current of 45 A at right angles to a magnetic field. The force on the conductor is 48 N.

Determine the diameter of the conductor. (6)

$F = BIl\,\cancel{\sin\theta}$

$F = 48\ N$

$B = x$

$I = 45$

$L = 0.25$

$\frac{F}{IL} = B$

$\frac{48}{45 \times 0.25}$

$4.26667\ (T)$

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

$B = 4.2667\ T$

$\phi = 480 \times 10^{-6}\ Wb$

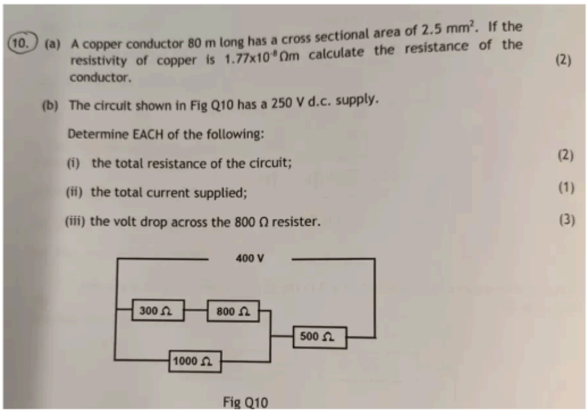
$A = \frac{\phi}{B} = \frac{480 \times 10^{-6}}{4.26666}$

$A = 1.125 \times 10^{-4}\ m^2$

$\cancel{\pi}\, r^{\cancel{2}} = \sqrt{\frac{1.125 \times 10^{-4}}{\pi}}$

$r = 5.984134 \times 10^{-3}\ m$

$\boxed{d = 0.0119683\ m}$



⑩ (a) A copper conductor 80 m long has a cross sectional area of 2.5 mm^2. If the resistivity of copper is 1.77x10^{-8} Ωm calculate the resistance of the conductor. (2)

(b) The circuit shown in Fig Q10 has a 250 V d.c. supply.

Determine EACH of the following:

(i) the total resistance of the circuit; (2)

(ii) the total current supplied; (1)

(iii) the volt drop across the 800 Ω resister. (3)

Fig Q10

a)

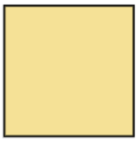
$$R = \frac{\rho L}{A}$$

$$R = \frac{1.77 \times 10^{-8} \times 80}{2.5 \times 10^{-6}}$$

$$= 0.5664\ \Omega$$

Convert mm^2 to m^2

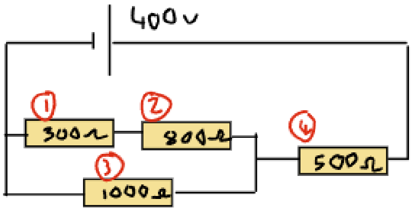
$$2.5\ \text{mm}^2 \xrightarrow{\div 1,000,000} 2.5 \times 10^{-6}\ \text{m}^2$$



$$1\text{m}^2 = 1,000,000\ \text{mm}^2$$

÷1,000,000

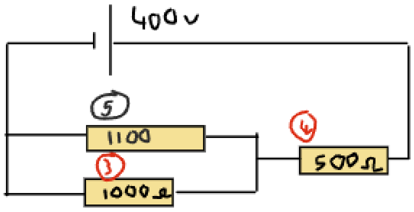
bi)



Res Series R_1 R_2

$R_T = R_1 + R_2$

$300 + 800 = 1100\ \Omega$

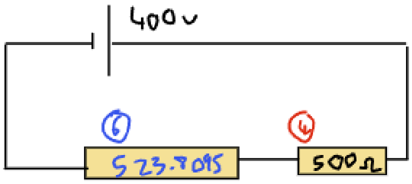


Res Parrallel R_3 R_5

$$\frac{1}{R_T} = \frac{1}{R_3} + \frac{1}{R_5}$$

$$\frac{1}{R_T} = \frac{1}{1000} + \frac{1}{1100}$$

$R_T = 523.8095\ \Omega$



Res in Series $R_6 + R_4$

$R_T = R_6 + R_4$

$R_T = 523.8095 + 500$

$1023.8095\ \Omega$

$$\boxed{\text{bi) Circuit Res } 1023.8095\ \Omega}$$

Circuit info

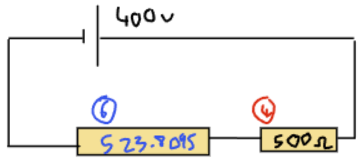
$I = \frac{V}{R}$

$V = 400\text{v}$

$$\boxed{\text{bii) } I = \frac{400}{1023.8} = 0.39069768 \text{ Amp}}$$

$R = 1023.8095$

voltage drop over R4 and R6



④

U = 195.3188

I = 0.39069768 Amp

R = 500

⑥

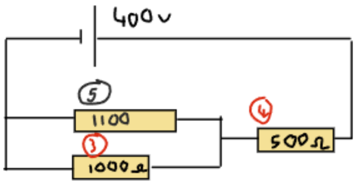
U = 204.651156 v

I = 0.39069768 Amp

R = 523.8095

V = I x R

current split over R5 and R3



⑤

V = 204.651156 v

I = 0.1860465 A

R = 1100

③

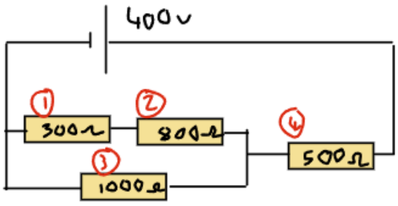
V = 204.651156 v

I = 0.20465156 A

R = 1000

$I = \frac{V}{R}$

Voltage drop over R1 and R2



①

V = 55.81395

I = 0.1860465 A

R = 300

②

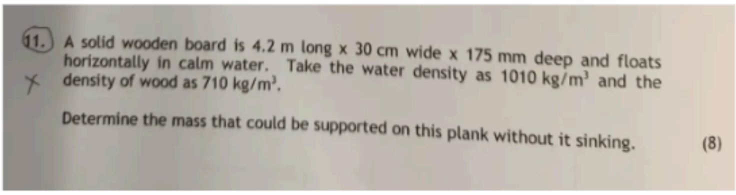
V = 148.837 v

I = 0.1860465 A

R = 800

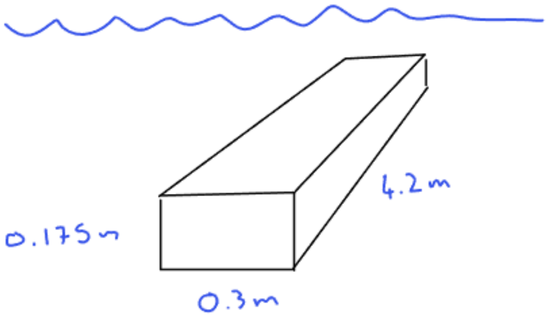
V = I x R

biii) voltage drop = 148.837 v



11. A solid wooden board is 4.2 m long x 30 cm wide x 175 mm deep and floats horizontally in calm water. Take the water density as 1010 kg/m³ and the density of wood as 710 kg/m³.

Determine the mass that could be supported on this plank without it sinking. (8)



volume of wood = volume of water displaced

$0.175 \times 0.3 \times 4.2 = 0.2205\ m^3$

mass of water displaced

$m = 1010 \times 0.2205$

$m = 222.705\ kg$

mass of wood

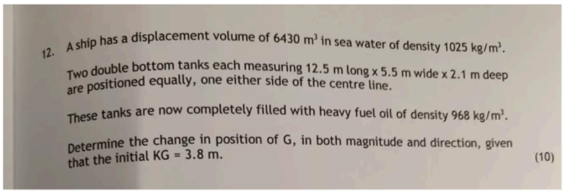
$m = 710 \times 0.2205$

$= 156.555\ kg$

mass of water displaced - mass of wood = extra load

$222.705 - 156.555 = \underline{\underline{66.15\ kg}}$

$\boxed{\text{maximum load} = 66.15\ kg}$



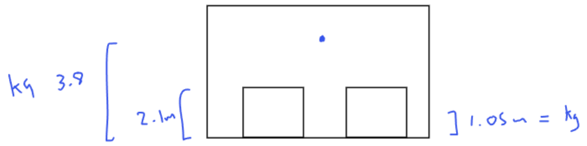
12. A ship has a displacement volume of 6430 m³ in sea water of density 1025 kg/m³.

Two double bottom tanks each measuring 12.5 m long x 5.5 m wide x 2.1 m deep are positioned equally, one either side of the centre line.

These tanks are now completely filled with heavy fuel oil of density 968 kg/m³.

Determine the change in position of G, in both magnitude and direction, given that the initial KG = 3.8 m. (10)

Name	Mass (t)	~~Force~~	Dist(m)	Moment(tm)	Dir A/C
Ship	6590.75		3.8	25044.85	C
load	279.51		1.05	293.4855	C
Ship +load	6870.26		x	6870.26x	A



sum of clockwise moments = sum of anticlockwise moments

$25044.85 + 293.4855 = 6870.26x$

$\underline{3.6881189}\ m = \text{New kg}$

$\underline{\text{Ship mass}}$ vol x density

$6430 \times 1.025 = 6590.75\ (t)$

$\underline{\text{load mass}}$ vol x density

$2 \times (2.1 \times 12.5 \times 5.5) \times 0.968 = 279.51\ t$

$\text{Change} = 3.8 - 3.6981189$

$\boxed{0.11188\ m}$ down $\underline{\underline{\text{Keelwards}}}$