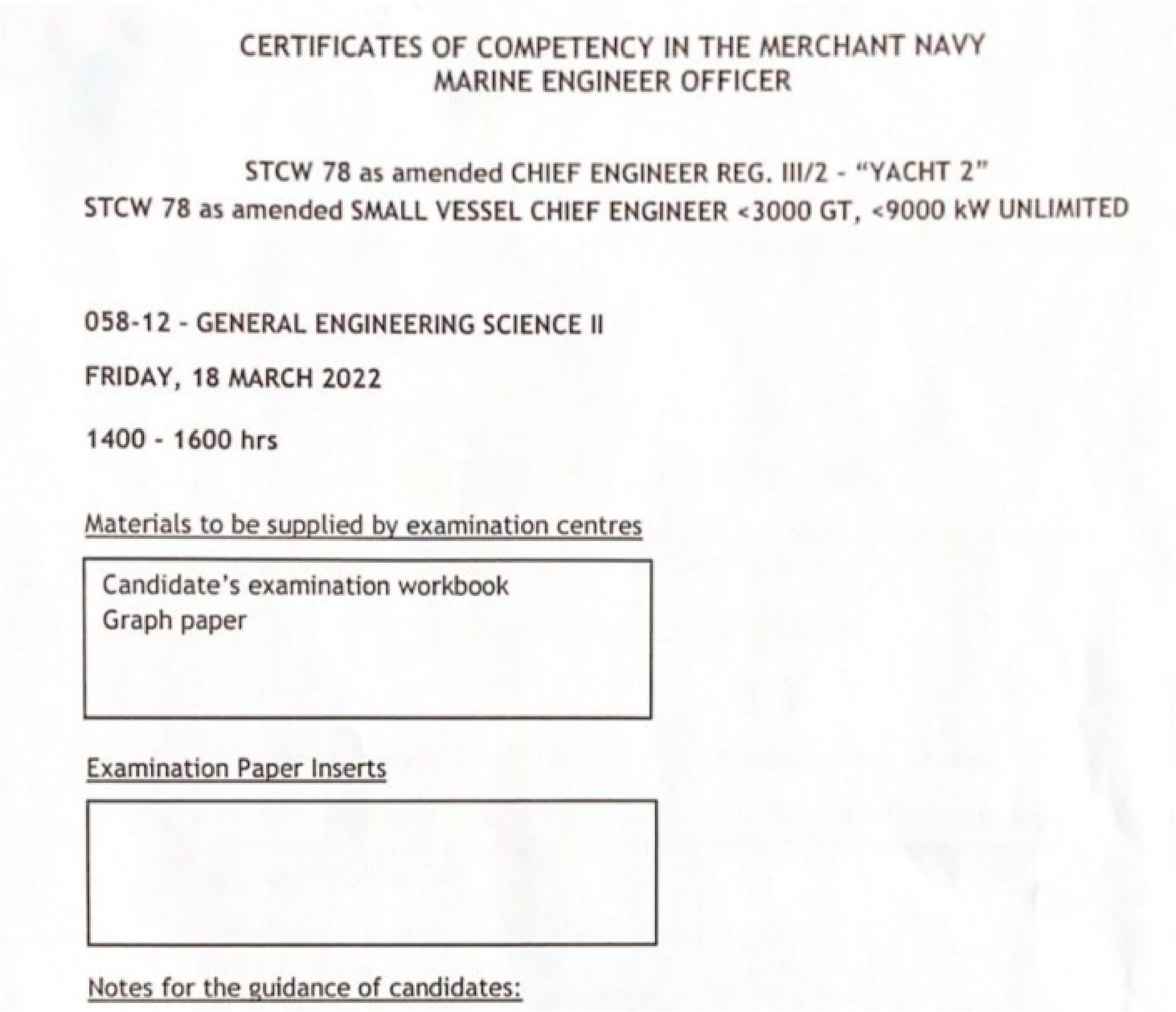


CERTIFICATES OF COMPETENCY IN THE MERCHANT NAVY
MARINE ENGINEER OFFICER

STCW 78 as amended CHIEF ENGINEER REG. III/2 - "YACHT 2"
STCW 78 as amended SMALL VESSEL CHIEF ENGINEER <3000 GT, <9000 kW UNLIMITED

058-12 - GENERAL ENGINEERING SCIENCE II

FRIDAY, 18 MARCH 2022

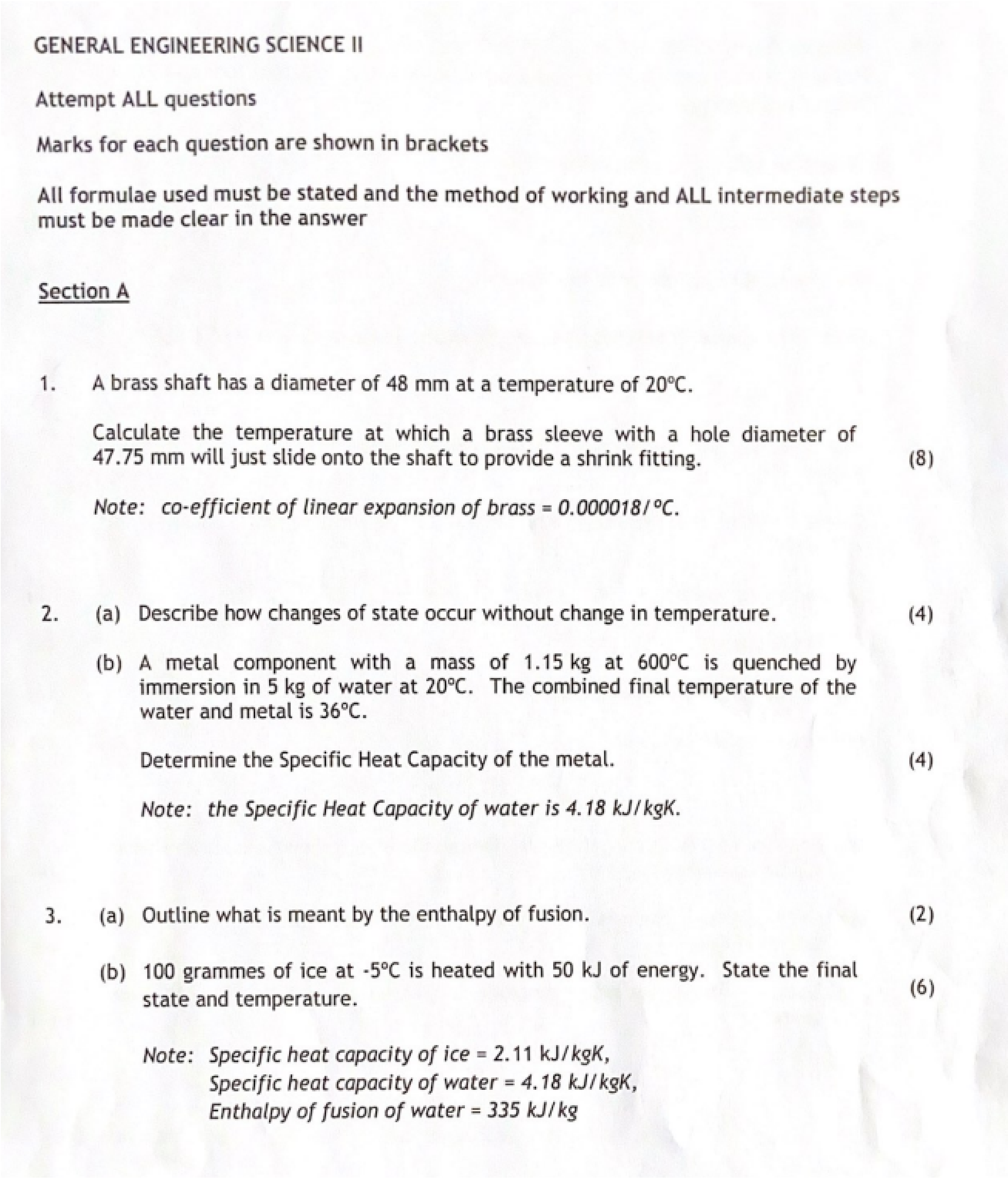
1400 - 1600 hrs

Materials to be supplied by examination centres

Candidate's examination workbook
Graph paper

Examination Paper Inserts

Notes for the guidance of candidates:



GENERAL ENGINEERING SCIENCE II

Attempt ALL questions

Marks for each question are shown in brackets

All formulae used must be stated and the method of working and ALL intermediate steps must be made clear in the answer

Section A

1. A brass shaft has a diameter of 48 mm at a temperature of 20°C.

   Calculate the temperature at which a brass sleeve with a hole diameter of 47.75 mm will just slide onto the shaft to provide a shrink fitting. (8)

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

2. (a) Describe how changes of state occur without change in temperature. (4)

   (b) A metal component with a mass of 1.15 kg at 600°C is quenched by immersion in 5 kg of water at 20°C. The combined final temperature of the water and metal is 36°C.

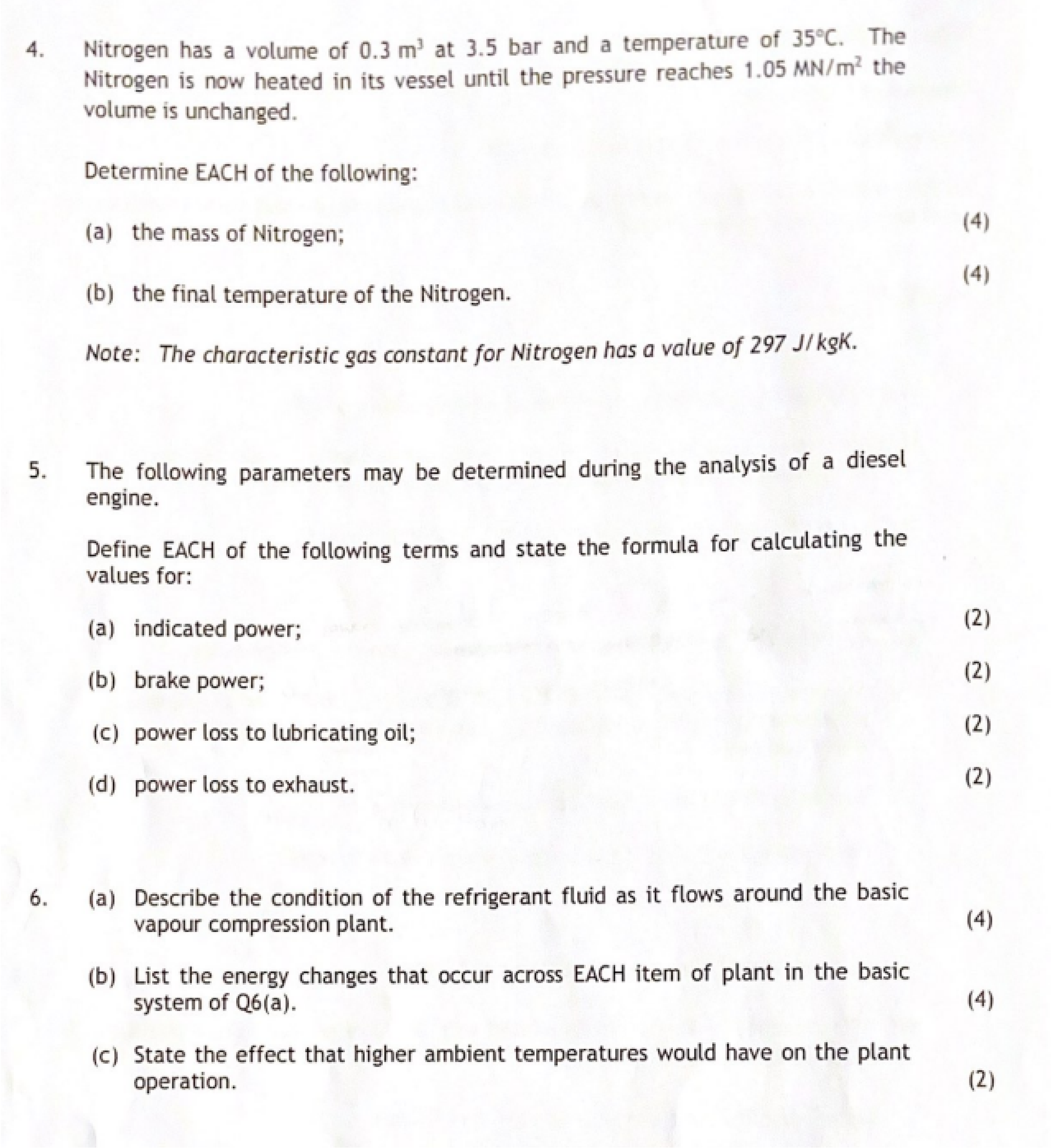
   Determine the Specific Heat Capacity of the metal. (4)

   Note: the Specific Heat Capacity of water is 4.18 kJ/kgK.

3. (a) Outline what is meant by the enthalpy of fusion. (2)

   (b) 100 grammes of ice at -5°C is heated with 50 kJ of energy. State the final state and temperature. (6)

   Note: Specific heat capacity of ice = 2.11 kJ/kgK,
   Specific heat capacity of water = 4.18 kJ/kgK,
   Enthalpy of fusion of water = 335 kJ/kg



4. Nitrogen has a volume of 0.3 m^3 at 3.5 bar and a temperature of 35°C. The Nitrogen is now heated in its vessel until the pressure reaches 1.05 MN/m^2 the volume is unchanged.

Determine EACH of the following:

(a) the mass of Nitrogen; (4)

(b) the final temperature of the Nitrogen. (4)

Note: The characteristic gas constant for Nitrogen has a value of 297 J/kgK.

5. The following parameters may be determined during the analysis of a diesel engine.

Define EACH of the following terms and state the formula for calculating the values for:

(a) indicated power; (2)

(b) brake power; (2)

(c) power loss to lubricating oil; (2)

(d) power loss to exhaust. (2)

6. (a) Describe the condition of the refrigerant fluid as it flows around the basic vapour compression plant. (4)

(b) List the energy changes that occur across EACH item of plant in the basic system of Q6(a). (4)

(c) State the effect that higher ambient temperatures would have on the plant operation. (2)

Section B

7. (a) Copper is the best known conductor of electricity. State why is it a good conductor of electricity in relation to its structure. (2)

(b) Cables with copper conductors often have PVC insulation. State why is it NOT a good conductor of electricity in relation to its structure. (2)

(c) Outline why conductors have power losses. (2)

(d) Explain how power losses can be determined in conductors. (2)

8. The power dissipated in the circuit in Fig Q8 is 7.5 kW.

Calculate EACH of the following:

(a) the supply current (I_s); (2)

(b) the current (I_1) flowing in the resistor R_1; (2)

(c) the value of R_2; (2)

(d) the energy consumed in the 20 Ω resistor in 5 minutes. (2)

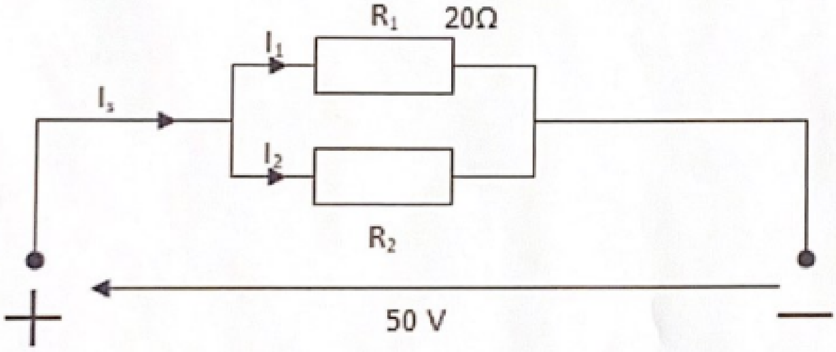
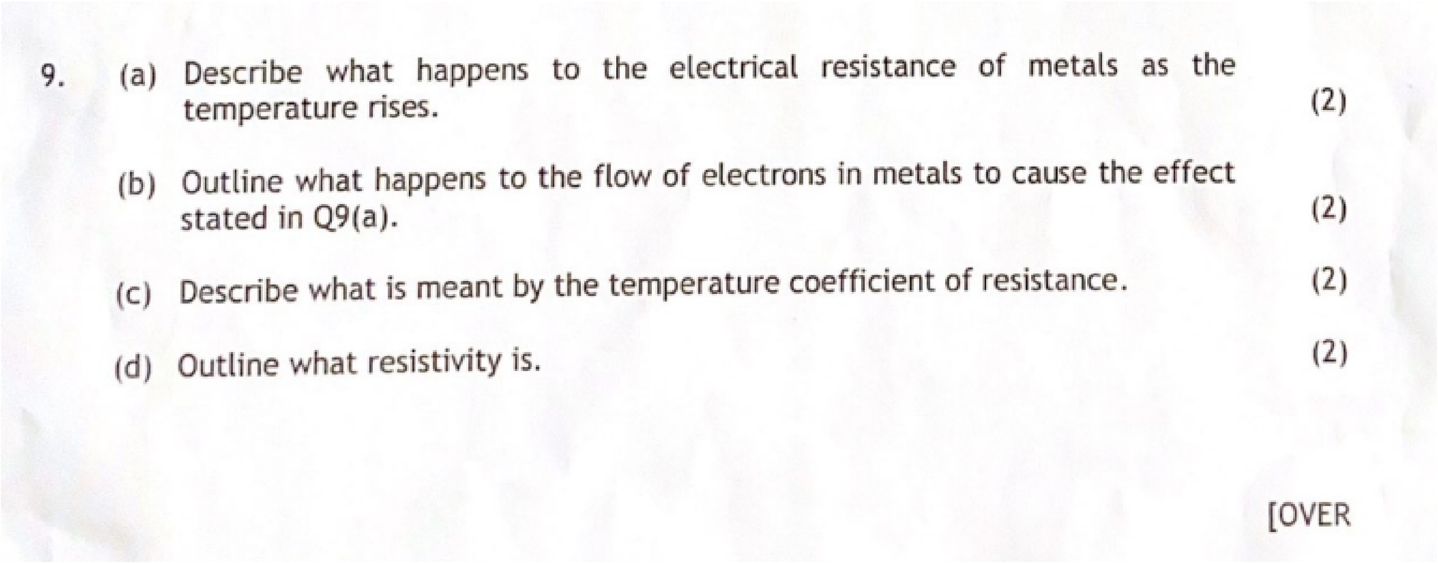


Fig Q8



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(b) Outline what happens to the flow of electrons in metals to cause the effect stated in Q9(a). (2)

(c) Describe what is meant by the temperature coefficient of resistance. (2)

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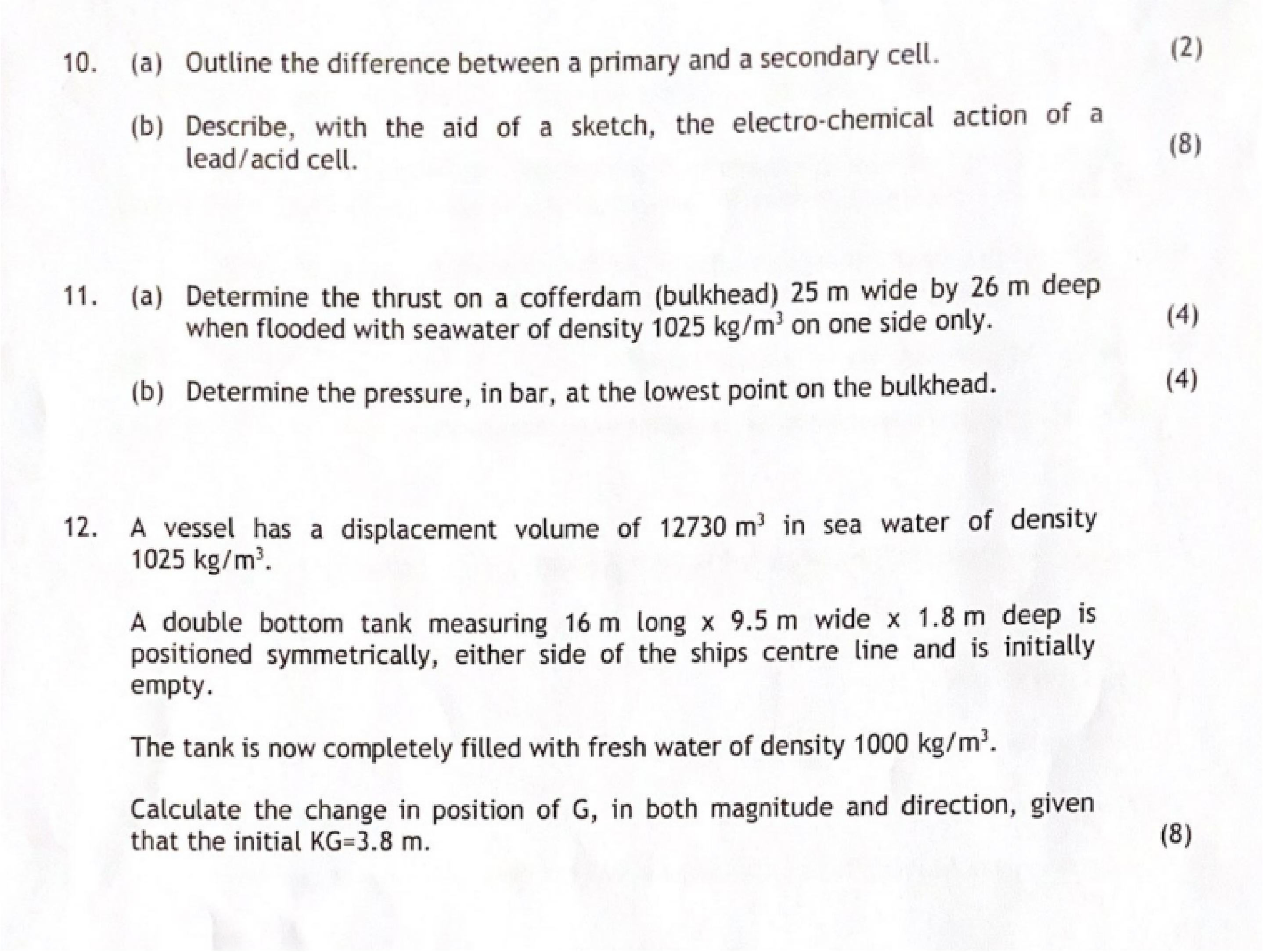

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(b) Describe, with the aid of a sketch, the electro-chemical action of a lead/acid cell. (8)

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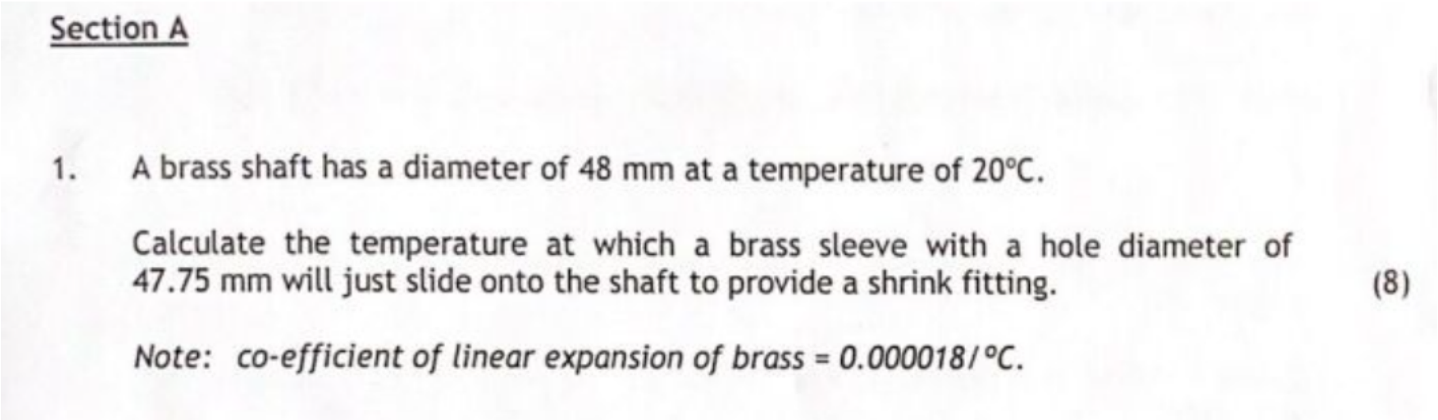
(b) Determine the pressure, in bar, at the lowest point on the bulkhead. (4)

12. A vessel has a displacement volume of 12730 m^3 in sea water of density 1025 kg/m^3.

A double bottom tank measuring 16 m long x 9.5 m wide x 1.8 m deep is positioned symmetrically, either side of the ships centre line and is initially empty.

The tank is now completely filled with fresh water of density 1000 kg/m^3.

Calculate the change in position of G, in both magnitude and direction, given that the initial KG=3.8 m. (8)



Section A

1. A brass shaft has a diameter of 48 mm at a temperature of 20°C.

   Calculate the temperature at which a brass sleeve with a hole diameter of 47.75 mm will just slide onto the shaft to provide a shrink fitting. (8)

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

diameter + expansion = New diameter

$$D + D \alpha \Delta t$$

$$47.75 + 47.75 \times 0.000018 \, \Delta t = 48$$

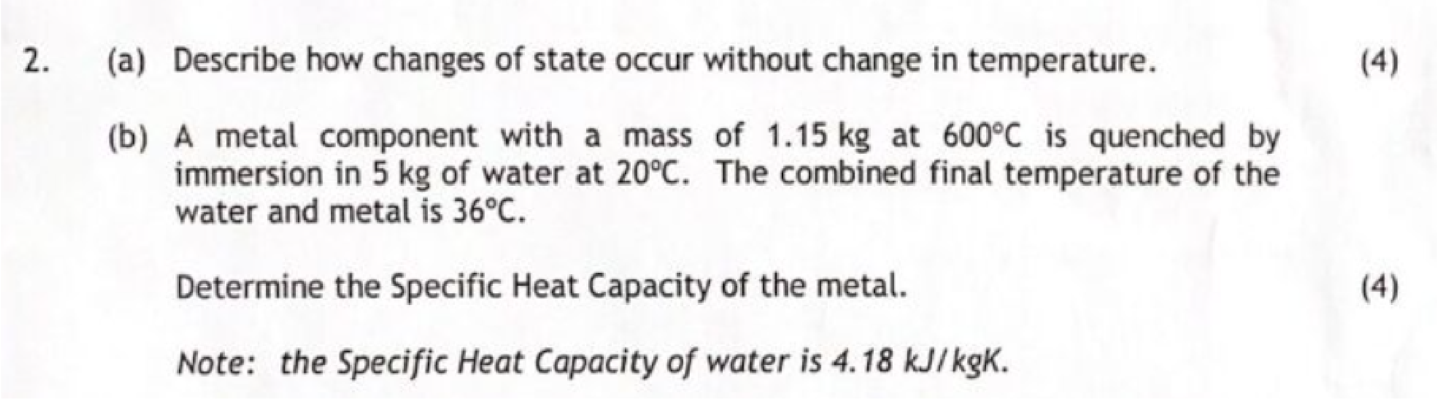
$$\Delta t = \frac{0.25}{47.75 \times 0.000018}$$

$$\Delta t = 290.866783$$

Final temp = starting temp + Δt

$$20 + 290.867$$

$$= \underline{310.867°C}$$



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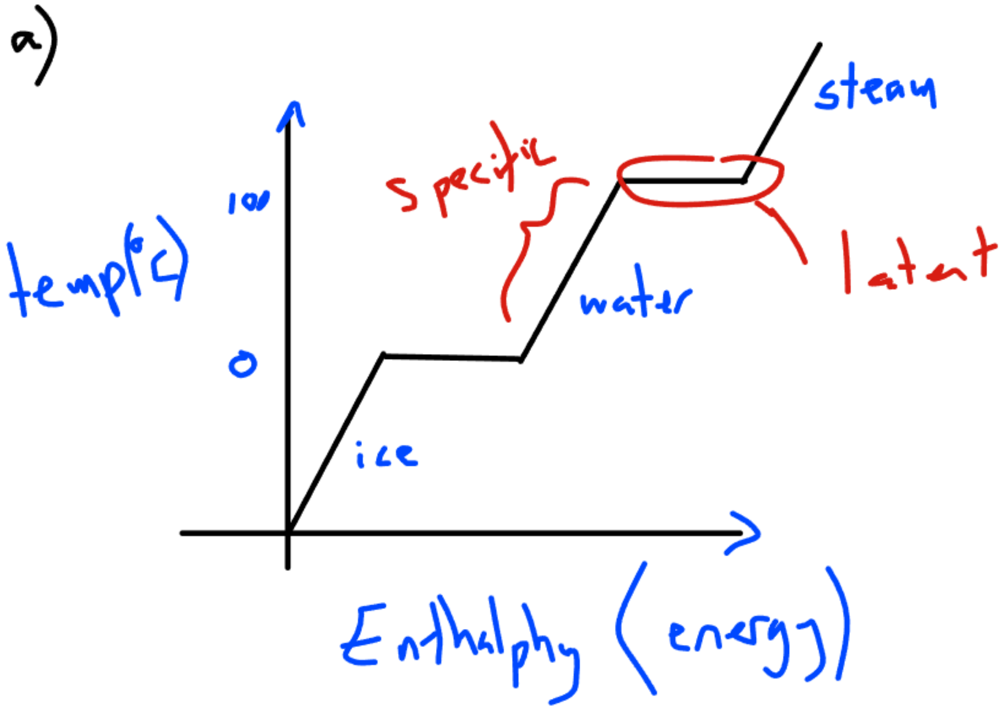
Note: the Specific Heat Capacity of water is 4.18 kJ/kgK.

a)



State changes occur between states such as solid, liquid gas, this inbetween stage is called a phase change, or a state change.

It happens because the molecules are absorbing energy in order to change shape, going from ice to water, the H2O molecules change shape, and this requires energy, so even though we need to put more energy into the system, the temperature doesn't increase.

Temperature is a measure of how fast the particles are vibrating, so during these latent-heat phase changes, the particles don't vibrate any faster, but use that energy to change their shape.

3)

Heat lost by metal = heat gained by Water

Name	start	Final	Δt	$Q = mc\Delta t$
metal (loss)	$m = 1.15$ $c = x$ $t = 600$	$t = 36$	$\Delta t = 564$	$Q_{metal} = 1.15(x)564$
water (gain)	$m = 5$ $c = 4180$ $t = 20$	$t = 36$	$\Delta t = 16$	$Q_{water} = 5 \times 4180 \times 16$

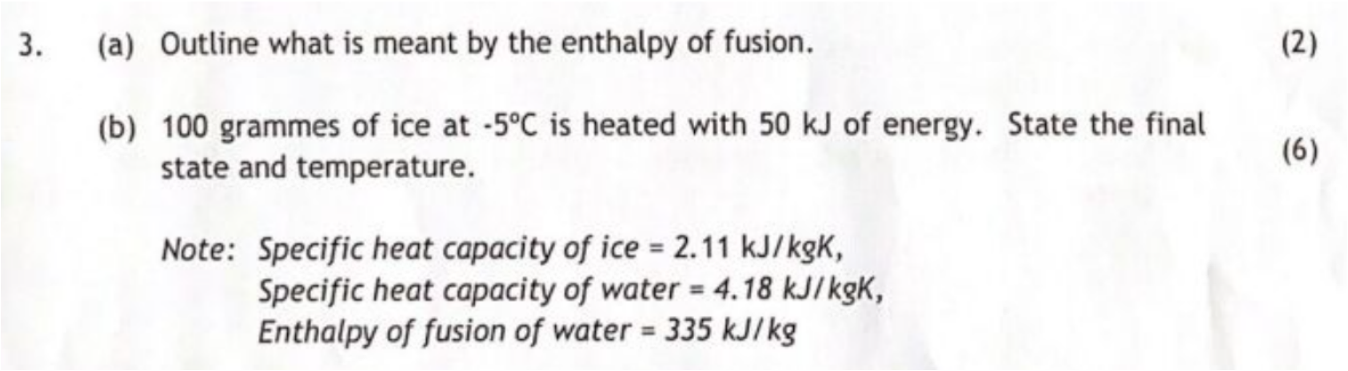
Heat lost by metal = heat gained by Water

$$Q_{metal} = Q_{water}$$

$$1.15(x)564 = 5 \times 4180 \times 16$$

$$x = \frac{5 \times 4180 \times 16}{1.15 \times 564}$$

$$x = 515.572 \text{ J/kg k}$$



3. (a) Outline what is meant by the enthalpy of fusion. (2)

(b) 100 grammes of ice at -5°C is heated with 50 kJ of energy. State the final state and temperature. (6)

Note: *Specific heat capacity of ice = 2.11 kJ/kgK,*
Specific heat capacity of water = 4.18 kJ/kgK,
Enthalpy of fusion of water = 335 kJ/kg

3a) enthalpy of fusion is the amount of energy required to bring about a phase transition from a solid to a liquid or vice versa, for 1 kg of the material

Units = J/kg

Formula $Q = mL$

b) $\underset{-5^\circ}{\text{ice}} \xrightarrow[\text{heat}]{①} \underset{0^\circ C}{\text{ice}} \xrightarrow[\text{melt}]{②} \underset{0^\circ C}{\text{water}} \xrightarrow[\text{heat}]{③} \underset{z^\circ C}{\text{water}}$

① heat the ice

$Q = mc\,\Delta t$

$= 0.1 \times 2110 \times 5$

$= 1055\ J$

② melt ice

$Q = mL$

$Q = 0.1 \times 335{,}000$

$= 33{,}500\ J$

③

$50{,}000 - 33500 - 1055 = 15445\ J$

$Q = mc\,\Delta t$

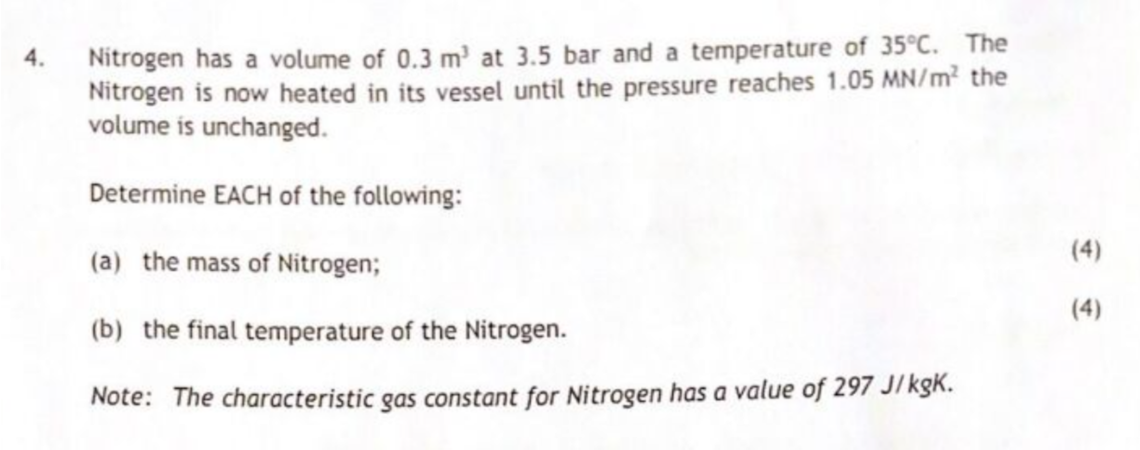
$15{,}445 = 0.1 \times 4180\ \Delta t$

$\frac{15445}{418} = \Delta t$

$36.9497 = \Delta t$

Final temp of water (liquid)

$\underline{\underline{36.9498^\circ C}}$



4. Nitrogen has a volume of 0.3 m³ at 3.5 bar and a temperature of 35°C. The Nitrogen is now heated in its vessel until the pressure reaches 1.05 MN/m² the volume is unchanged.

Determine EACH of the following:

(a) the mass of Nitrogen; (4)

(b) the final temperature of the Nitrogen. (4)

Note: The characteristic gas constant for Nitrogen has a value of 297 J/kgK.

$P_v = m r t$

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

a) $P = 3.5\,\text{bar} = 350{,}000\ (\text{Pa})$

$v = 0.3$

$m = x$

$R = 297$

$t = 35°C + 273 = 308°K$

$$\frac{350{,}000 \times 0.3}{297 \times 308} = x$$

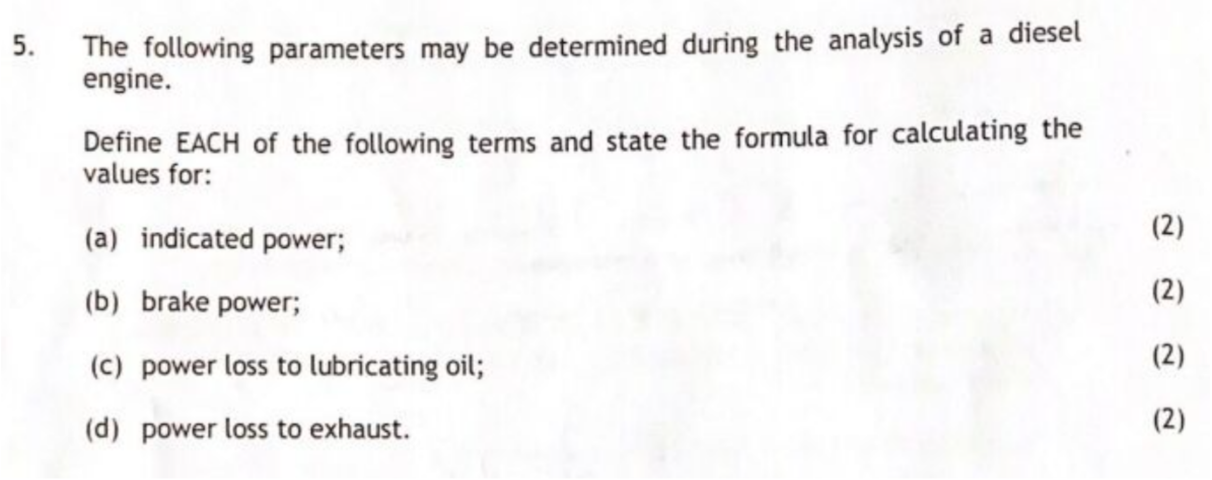
$$\boxed{1.1478\ \text{kg}}$$

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

$$\frac{350{,}000}{308} = \frac{1.05\times10^6}{x}$$

$$x = \frac{1.05\times10^6}{\left(\frac{350{,}000}{308}\right)}$$

$$\boxed{\begin{array}{l} x = 924\ \text{K} \\ \text{or } 651\ °C \end{array}}$$



5. The following parameters may be determined during the analysis of a diesel engine.

Define EACH of the following terms and state the formula for calculating the values for:

(a) indicated power; (2)

(b) brake power; (2)

(c) power loss to lubricating oil; (2)

(d) power loss to exhaust. (2)

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

Indicated power (units usually Watts) is the theoretical power of the engine based on
x - number of cylinders
p - indicated mean effective pressure
l - length of stroke
a - cross sectional area of piston
n - number of power strokes/effective strokes per second

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

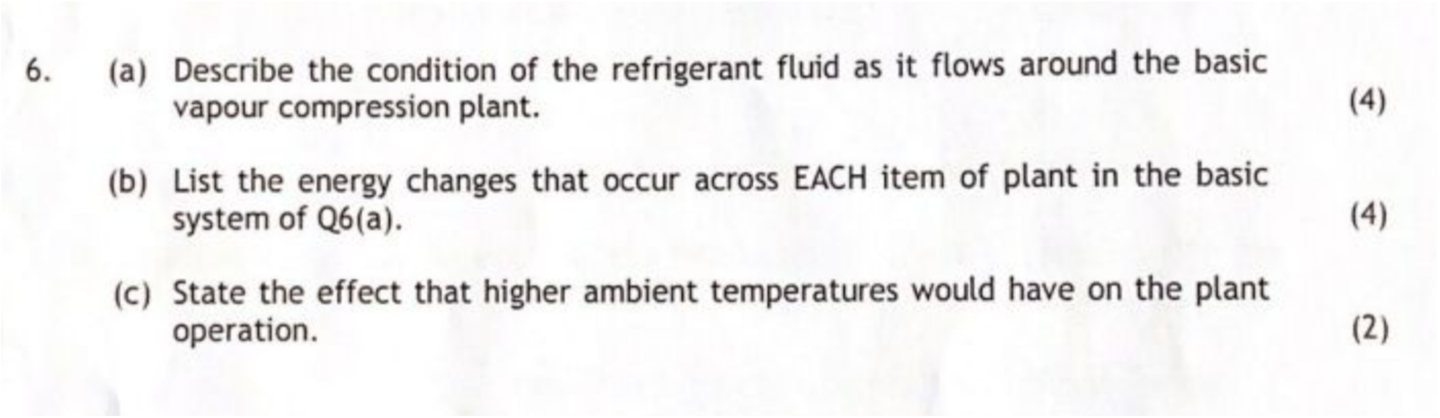
Break power is the ACTUAL power of the engine, the torque is measured off the main camshaft, multiplied by 2pi, and the number of revolutions per second.
The units are usually given in Watts.

c) Power loss $\dot{Q} = \dot{m}\,c\,\Delta t$

Power loss due to lubricating oil, as the oil is cycled out of the engine to be filtered and then put back in, it loses heat, this can equate to a power loss of the engine. The calculation multiplies mass flow rate of the oil by the heat capacity, and the temperature differential. (units Watts)

d) Power loss $\dot{Q} = \dot{m}\,c\,\Delta t$

Power loss due to exhaust gas is similar to that of power loss due to lubricating oil. Power loss occurs due to heat leaving the engine in the form of the exhaust gas
Again we multiply the mass flow rate of the exhaust gas by the heat capacity of the gases in the exhaust flume, and the temperature differential



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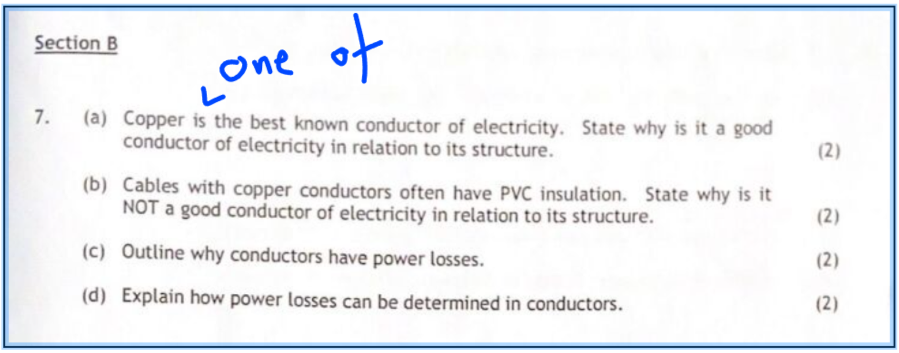

Section B

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(b) Cables with copper conductors often have PVC insulation. State why is it NOT a good conductor of electricity in relation to its structure. (2)

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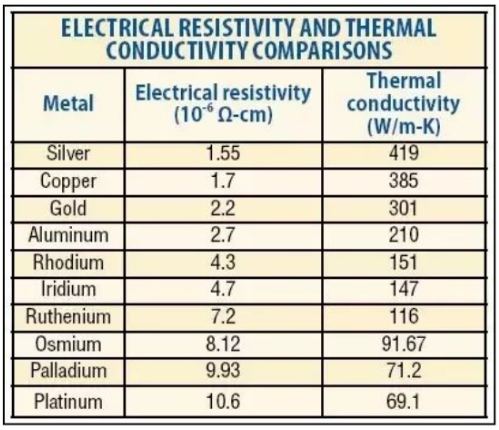


ELECTRICAL RESISTIVITY AND THERMAL CONDUCTIVITY COMPARISONS

Metal	Electrical resistivity (10^{-6} Ω-cm)	Thermal conductivity (W/m-K)
Silver	1.55	419
Copper	1.7	385
Gold	2.2	301
Aluminum	2.7	210
Rhodium	4.3	151
Iridium	4.7	147
Ruthenium	7.2	116
Osmium	8.12	91.67
Palladium	9.93	71.2
Platinum	10.6	69.1

a) Copper is one of the best conductors of electricity due to its Giant lattice structure, and the presence of valence electrons.

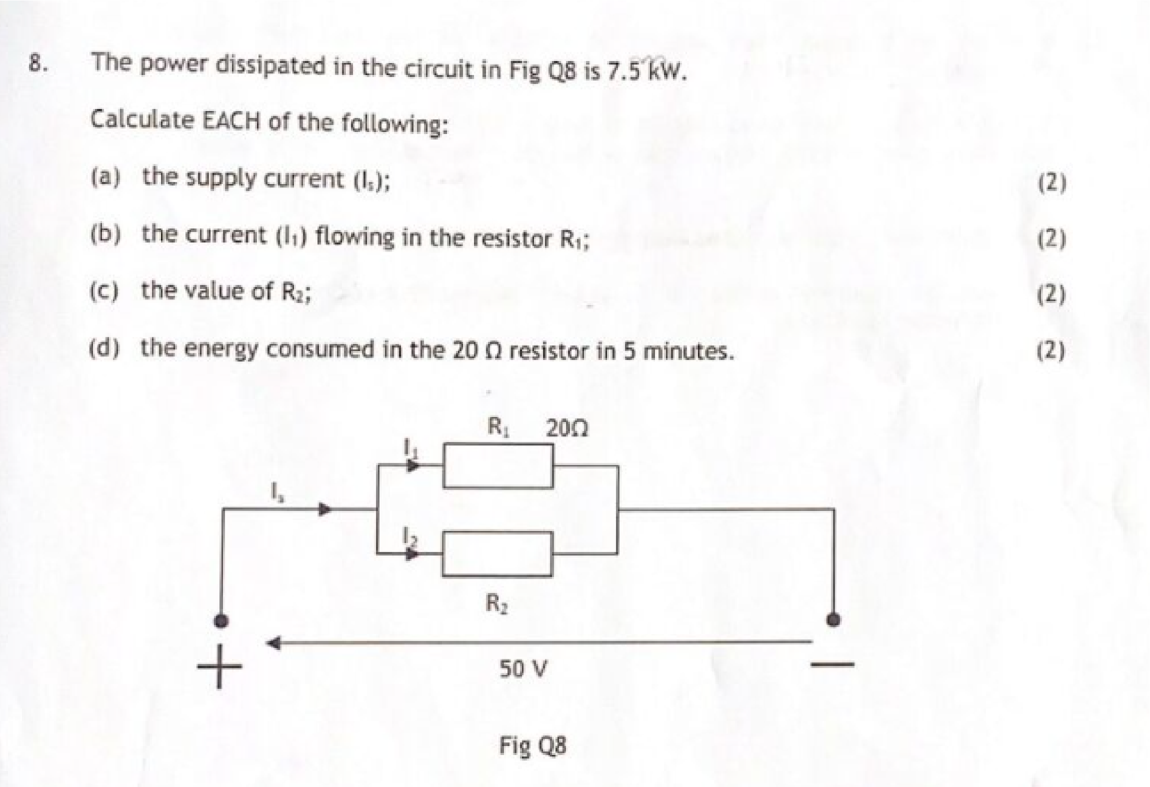
This makes a copper wire essentially a very long and large molecule, allowing electrons to "flow" along it.

b) PVC is not a good conductor of electricity because it doesn't have a giant lattice structure, and doesn't have valence electrons.

PVC has long molecules, but they are not connected to each other, they are isolated, so even if electrons could flow across each molecule, they find it hard to jump to the next. You can build a charge on an insulator, that's static electricity (it doesn't flow)

c) Conductors have power losses due to internal resistance, this is usually lost as heat!

d) Power losses can be calculated using the formula P=IV if the current and the voltage drop over the conductor is known. If they are not known they can be calculated using Ohm's law.



8. The power dissipated in the circuit in Fig Q8 is 7.5 kW.

Calculate EACH of the following:

(a) the supply current (I_s); (2)

(b) the current (I_1) flowing in the resistor R_1; (2)

(c) the value of R_2; (2)

(d) the energy consumed in the 20 Ω resistor in 5 minutes. (2)

Fig Q8

a) $P = IV$

$7500 = I \times 50$

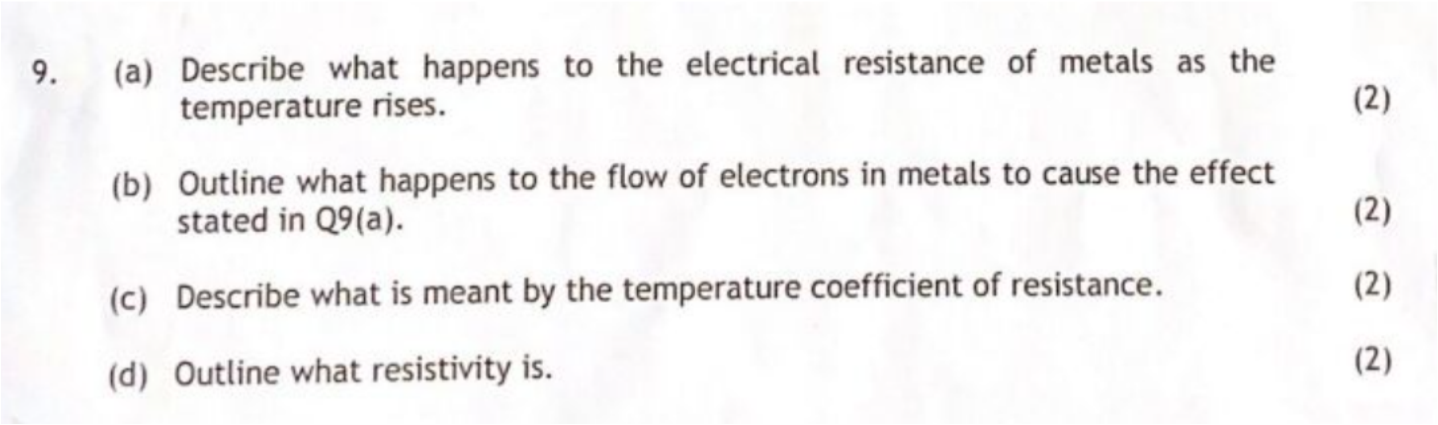
$\frac{7500}{50} = 150$ Amps $= I_s$

b)

$I = \frac{V}{R} > \frac{50}{20} = 2.5$ Amps

c) Amps through R_2 $150 - 2.5 = 147.5$ Amps

$\frac{V}{I} = R$ $\frac{50}{147.5} = 0.33898\ \Omega$



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(b) Outline what happens to the flow of electrons in metals to cause the effect stated in Q9(a). (2)

(c) Describe what is meant by the temperature coefficient of resistance. (2)

(d) Outline what resistivity is. (2)

a) electrical resistance increases as temperature increases.

b)This is due to higher internal resistance, and that is due to the atoms vibrating faster. At higher temperatures its harder for the electrons to pass through the metal.

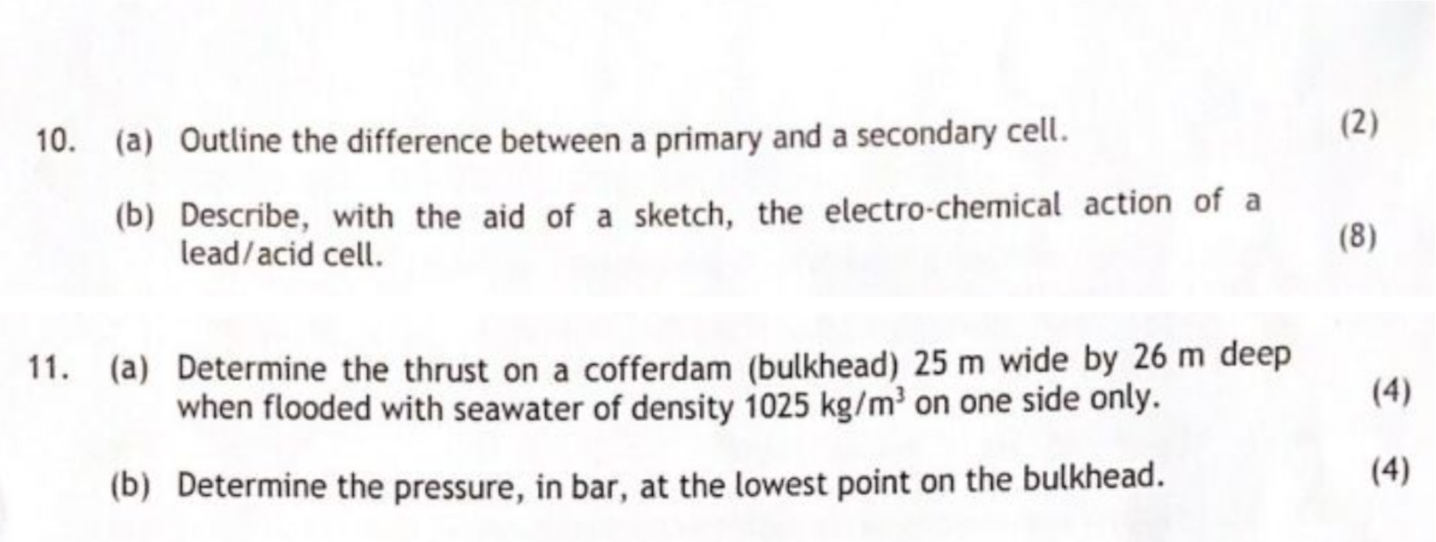
c) Temperature coefficient of resistance is a measure of resistance of a material that will change by a certain amount for every degree change in temperature.

d) resistivity is the inherent resistance of a material measured in Ohm-metres. It can be found by passing a known current through a known size of a material with the formula:

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

$$\frac{RA}{L} = \rho$$

Where the resistivity is given by rho, the total resistance of the material is given by R in ohms, and A is the cross sectional area, and L is the length.



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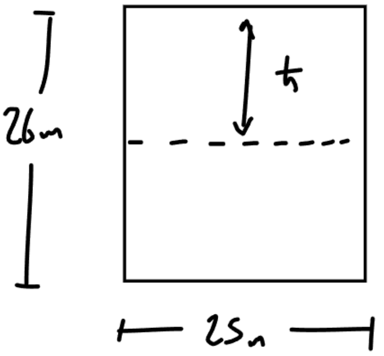
(b) Determine the pressure, in bar, at the lowest point on the bulkhead. (4)

a)

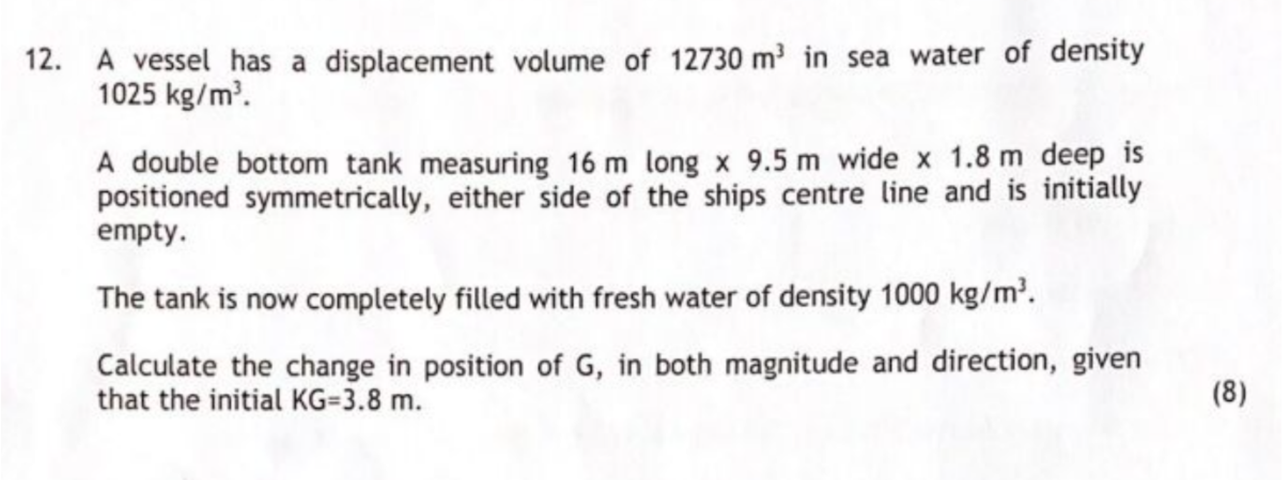


$F = \rho g A \bar{h}$

$= 1025 \times 9.81 \times 25 \times 26 \times 13$

84,966,862.5 N

b) $P = \rho g h = 1025 \times 9.81 \times 26 = 261,436.5$ (Pa)



12. A vessel has a displacement volume of 12730 m³ in sea water of density 1025 kg/m³.

A double bottom tank measuring 16 m long x 9.5 m wide x 1.8 m deep is positioned symmetrically, either side of the ships centre line and is initially empty.

The tank is now completely filled with fresh water of density 1000 kg/m³.

Calculate the change in position of G, in both magnitude and direction, given that the initial KG=3.8 m. (8)

Ship mass = vol x density

12730 x 1025

load mass = 16 x 9.5 x 1.8 x 1000 =

Assume tank is on bottom of ship? It doesnt say...

$$kg = \frac{1.8}{2} = 0.9$$

taking moments about K

Name	Mass t	~~Force~~	Dis	Moment	Dir
ship	13,048.25		3.8	49583.35	C
load	273.6		0.9	246.24	C
ship+load	13321.85		x	$13321.85x$	A

sum of anticlockwise moments = sum of clockwise moments

$$13321.85x = 49583.35 + 246.24$$

$$x = 3.74044$$

change $3.8 - 3.74 = 0.05956$m $\underline{\underline{\text{down}}}$