10/12/21

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. An aluminium vessel has a mass of 3 kg and contains 2 kg of water at a temperature of 12°C. A further 5 kg of water at 40°C is added to the vessel and there are no heat losses.

   Calculate the final temperature of the vessel and water. (8)

   Note: the specific heat of aluminium = 0.95 kJ/kgK
   the specific heat of water = 4.18 kJ/kgK

2. A iron casting has a volume of 0.422 m^3 at 812°C. Its temperature falls to 10°C.

   Calculate EACH of the following:

   (a) the final volume; (4)

   (b) the percentage change in the volume. (4)

   Note: the coefficient of linear expansion of cast iron = 0.000011/°C.

3. A perfect gas at an initial pressure, temperature and volume of 1 bar, 18°C and 35 litres respectively is compressed according to Boyles Law until the volume is 15 litres. Heating then causes an expansion according to Charles Law until the temperature is 160°C.

   Calculate EACH of the following:

   (a) the final pressure; (3)

   (b) the final volume; (3)

   (c) the mass of gas. (3)

   Note: R = 0.29 kJ/kgK

4. (a) In combustion explain what is meant by the Stoichiometric air to fuel ratio. (3)

(b) With reference to internal combustion engines describe the effect of supplying:

(i) inadequate air; (3)

(ii) excess air. (3)

5. A 4 stroke diesel engine is tested over a 24 hour period and uses 18.2 tonnes of fuel. The power of the engine is tested using a dynamometer which gives a steady state torque reading of 48 kNm at 800 rpm. The mechanical efficiency was later found to be 87%.

Calculate EACH of the following:

(a) the brake power; (4)

(b) the indicated specific fuel consumption. (4)

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

6. (a) With the aid of a P-h diagram, 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 refrigeration system of Q6(a). (4)

Section B

7. The circuit shown in Fig Q7 is connected across a 36 V supply. The power dissipated in the network is 540 W.

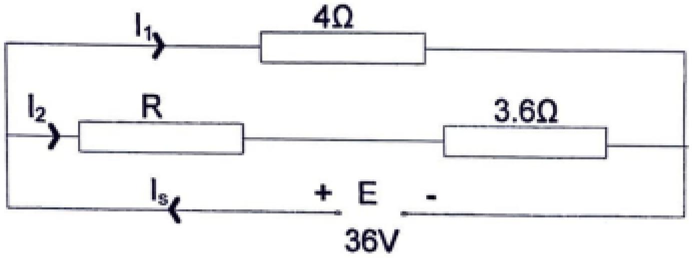


Fig Q7

Calculate EACH of the following:

(a) the value of the unknown resistor R; (5)

(b) the power dissipated by this resistor; (2)

(c) the total energy consumed by the circuit in 2 hours (2)

8. An electric fire operated from a 230 V supply has a heating element comprising of two 25 Ω coils. The coils may be connected in series to give a low setting, or in parallel to give a high setting.

Calculate EACH of the following:

(a) the power output for the low setting; (4)

(b) the power output for the high setting. (4)

9. The circuit in FIG Q9 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)

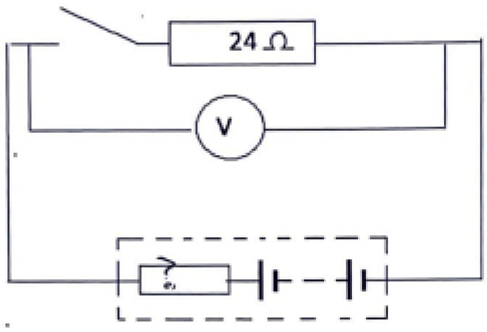


FIG Q9

10. (a) Define the resistivity of a material. (3)

(b) The resistance of 1.9 km of copper wire of 0.5 mm diameter is 170 ohms.

Calculate the resistance of 1 km of iron wire of 1 mm diameter. (5)

Note: the resistivity of iron = 5.9 x resistivity of copper.

11. A rectangular river dam is 30 m wide and is flooded to its top edge, on one side only, with water of density 1005 kg/m^3.

Calculate EACH of the following:

(a) the height of the dam, if the thrust under the flooded condition is 30MN; (5)

(b) the pressure at a point 2.24 m above the base of the dam. (4)

12. A ship has a displacement volume of 3440 m^3 in sea water.

Calculate the mass, m, which when loaded on the centre line at a Kg of 4.8 m will cause a change of + 0.25 m in the position of the ship's centre of gravity. (8)

Note: KG = 3.5 m and density of sea water = 1025 kg/m^3

Section A

1. An aluminium vessel has a mass of 3 kg and contains 2 kg of water at a temperature of 12°C. A further 5 kg of water at 40°C is added to the vessel and there are no heat losses.

   Calculate the final temperature of the vessel and water. (8)

   Note: the specific heat of aluminium = 0.95 kJ/kgK
   the specific heat of water = 4.18 kJ/kgK

loss = Gain

$Q_{water\ hot} = Q_{water\ cold} + Q_{Alu}$

Name	Start	Final	Δt	$Q = mc\Delta t$
Water hot loss	$m = 5$ $c = 4180$ $t = 40$	$t = x$	$40 - x$	$Q_{water\ hot} = 5 \times 4180(40 - x)$
Water cold gain	$m = 2$ $c = 4180$ $t = 12$	$t = x$	$x - 12$	$Q_{water\ cold} = 2 \times 4180(x - 12)$
Alu gain	$m = 3$ $c = 950$ $t = 12$	$t = x$	$x - 12$	$Q_{Alu} = 3 \times 950(x - 12)$

$$Q_{water\ hot} = Q_{water\ cold} + Q_{Alu}$$

$$5 \times 4180(40 - x) = 2 \times 4180(x - 12) + 3 \times 950(x - 12)$$

$$836{,}000 - 20{,}900x = 8360x - 100{,}320 + 2850x - 34{,}200$$

$$970{,}520 = 32110x$$

$$30.22485 = x$$

30.225°C Final temp

2. A iron casting has a volume of 0.422 m^3 at 812°C. Its temperature falls to 10°C.

Calculate EACH of the following:

(a) the final volume; (4)

(b) the percentage change in the volume. (4)

Note: the coefficient of linear expansion of cast iron = 0.000011/°C.

a) Vol + expansion = New Vol

$V + V\,3\alpha\,\Delta t$

$0.422 - 0.422 \times 3(0.000011)\,802 = 0.410831348\ m^3$

b) $\frac{\text{New} - \text{old}}{\text{old}} \times 100$

$\frac{0.410831348 - 0.422}{0.422} \times 100 = 2.6466\%$ Decrease

3. A perfect gas at an initial pressure, temperature and volume of 1 bar, 18°C and 35 litres respectively is compressed according to Boyles Law until the volume is 15 litres. Heating then causes an expansion according to Charles Law until the temperature is 160°C.

Calculate EACH of the following:

(a) the final pressure; (3)

(b) the final volume; (3)

(c) the mass of gas. (3)

Note: R = 0.29 kJ/kgK

$$\frac{P_1V_1}{T_1} = \frac{P_2V_2}{T_2} = \frac{P_3V_3}{T_3}$$

$P_1 = 1bar = 100,000 (P_a)$ $P_2 = x$ $P_3 = x$

$V_1 = 35L = 0.035 m^3$ $V_2 = 0.015$ $V_3 = y$

$T_1 = 18°C = 291 K$ $T_2 = 291$ $T_3 = 160°C = 433 K$

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

$100,000 \times 0.035 = x(0.015)$

$\frac{100,000 \times 0.035}{0.015} = 233,333.333 (P_a)$ Final Pressure

b) $\frac{P_2V_2}{T_2} = \frac{P_3V_3}{T_3}$

$\frac{0.015}{291} = \frac{y}{433}$

$0.02231958763 m^3 = V_3$ Final vol

c) $Pv = mRT$

$100{,}000 \times 0.035 = x \times 290 \times 291$

$$\frac{100{,}000 \times 0.035}{290 \times 291} = x$$

0.041474 Kg mass of gas

4. (a) In combustion explain what is meant by the Stoichiometric air to fuel ratio. (3)

(b) With reference to internal combustion engines describe the effect of supplying:

(i) inadequate air; (3)

(ii) excess air. (3)

a)
Stoichiometric air to fuel ratio
Stoichiometric air means the minimum amount of air required to bring about complete combustion of a given amount of fuel. This is usually done in a lab, as in an internal combustion engine we usually add excess air in order to ensure complete combustion.

bi) inadequate air would lead to incomplete combustion of the fuel, this will lead to the production of carbon monoxide, a toxic and deadly gas. It will also lead to unburnt fuel being released in the exhaust, increasing environmental damage, this will also lead to increased running costs and decreased efficiency of the engine.

bii) excess air is usually what we aim for, usually about 15 to 25% excess air is added to the stoichiometric ratio in order to ensure there is enough oxygen in the fuel air mix. This is to ensure that all the fuel molecules can find oxygen molecules in order to combust during the engine's cycle. As the cycle is fast, we add a bit of extra oxygen to ensure combustion. Too much would decrease overall efficiency, there a an optimum amount of excess air for best results.

Excess air reduces the carbon monoxide produced, reduces unburnt fuel being released through the exhaust, and increases efficiency.

5. A 4 stroke diesel engine is tested over a 24 hour period and uses 18.2 tonnes of fuel. The power of the engine is tested using a dynamometer which gives a steady state torque reading of 48 kNm at 800 rpm. The mechanical efficiency was later found to be 87%.

Calculate EACH of the following:

(a) the brake power; (4)

(b) the indicated specific fuel consumption. (4)

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

$$Imep = \frac{A\phi}{L} \qquad IP = \times plan \qquad BP = T2\pi N$$

$$Eff = \frac{BP}{IP} \qquad Isfc = \frac{kg}{kwh} = \frac{\dot{m}}{IP}$$

a) $BP = 48{,}000 \times 2\pi \left(\frac{800}{60}\right)$

4,021,238.597 watts

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

$$0.87 = \frac{4,021,238.597}{x}$$

$$x = \frac{4,021,238.597}{0.87}$$

$$x = 4,622,113.3 = IP$$

$$Isfc = \frac{\left(\frac{18200}{24}\right) kg/h}{4,622,113 \ kw} = 0.164066 \ kg/kwh$$

6. (a) With the aid of a P-h diagram, 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 refrigeration system of Q6(a). (4)

Section B

7. The circuit shown in Fig Q7 is connected across a 36 V supply. The power dissipated in the network is 540 W.

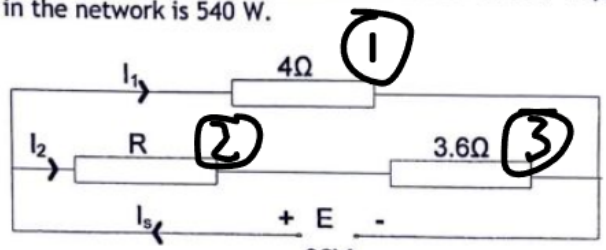


Fig Q7

Calculate EACH of the following:

(a) the value of the unknown resistor R; (5)

(b) the power dissipated by this resistor; (2)

(c) the total energy consumed by the circuit in 2 hours (2)

a) $P = IV$

$540 = I \times 36$

$\frac{540}{36} = I = 15$ Amps

Find I_1

$V = 36$

I

$R = 4$

$I = \frac{36}{4} = 9$

$I_2 = 15 - 9 = 6$ Amps

Voltage drop over R_3 (3.6 Ω)

$V =$

$I = 6$

$R = 3.6$

$V = I \times R$

$V = 6 \times 3.6$

$V_3 = 21.6$

Voltage drop over R_2

$36 - 21.6 = 14.4$ volts

Find R_2

$V = 14.4$

$I = 6$

$R =$

$R = \frac{V}{R} = \frac{14.4}{6} = 2.4\ \Omega$

2.4 Ω

b) $P = IV$

$P = 6 \times 14.4 = 86.4$ watts

c) 540 watts $= 540\ \frac{J}{sec} \times 2 \times 3600 = 3{,}888{,}000\ J$

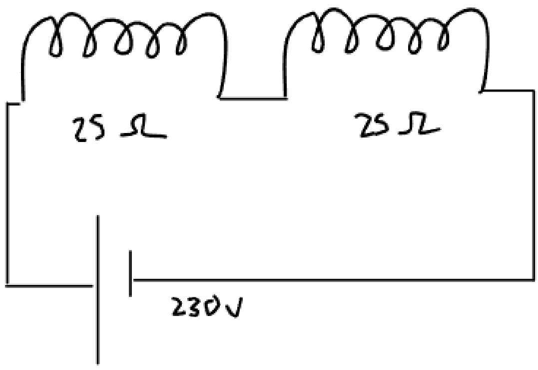
8. An electric fire operated from a 230 V supply has a heating element comprising of two 25 Ω coils. The coils may be connected in series to give a low setting, or in parallel to give a high setting.

Calculate EACH of the following:

(a) the power output for the low setting; (4)

(b) the power output for the high setting. (4)

a)



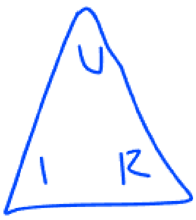
Resistance Series $= R_1 + R_2$

$25 + 25 = 50\,\Omega$

$V = 230$

$I = 4.6$

$R = 50$



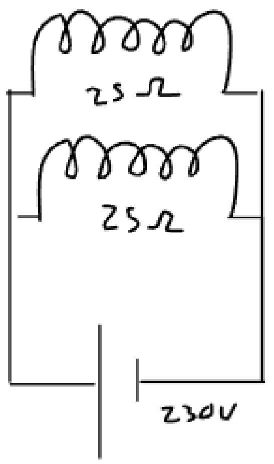
$I = \frac{V}{R} = \frac{230}{50}$

$I = 4.6$ Amps

$P = IV$

$P = 4.6 \times 230 = 1058$ watts

b)



Resistance in Parallel

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

$$\frac{1}{R_T} = \frac{1}{25} + \frac{1}{25}$$

$$R_T = 12.5\ \Omega$$

V = 230

I

R = 12.5

$$I = \frac{V}{R} = \frac{230}{12.5}$$

I = 18.4 Amps

P = IV

= 18.4 × 230 = 4232 watts

9. The circuit in FIG Q9 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)

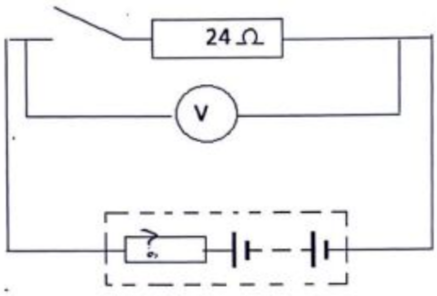
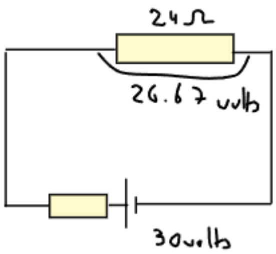


FIG Q9

a) While the switch is open, the circuit is not complete, the voltmeter is showing 30 volts, this is the EMF of the battery. When the switch is closed, the circuit is complete, and the voltmeter shows 26.67volts, which is a drop of 3.33 volts, this is the terminal voltage, or the voltage of the battery under load. We can deduce that the voltage drop of 3.33 volts is caused by the voltage drop over the internal resistance.

b)



Find current

$V = 26.67$

I

$R = 24$

$I = \frac{V}{R} = \frac{26.67}{24}$

$I = 1.11125$ Amps

Find Res of internal Resistor

$Emf - Ir = \text{terminal voltage}$

$30 - (1.11125)r = 26.67$

$\frac{30 - 26.67}{1.11125} = r$

$\boxed{2.9966\,\Omega}$ = Res of cell

10. (a) Define the resistivity of a material. (3)

(b) The resistance of 1.9 km of copper wire of 0.5 mm diameter is 170 ohms.

Calculate the resistance of 1 km of iron wire of 1 mm diameter. (5)

Note: the resistivity of iron = 5.9 x resistivity of copper.

a)

$$R = \frac{\rho l}{A} \qquad \frac{AR}{l} = \rho$$

The Resistivity of a material is the intrinsic resistance of a material, measured in ohm metres. It can be found by measuring the voltage drop for a known amperage across a material, this will find the resistance, and then knowing the cross sectional area, and the length of the material we can calculate the resistance using the formula above.

b) copper

$R = 170$

$\rho = x$

$l = 1900$

$A = \pi\left(\frac{0.0005}{2}\right)^2$

$$\frac{\pi\left(\frac{0.0005}{2}\right)^2 \times 170}{1900} = \rho$$

$$1.75681168 \times 10^{-8} = \rho$$

iron

$R = y$

$\rho = 5.9x = 1.03651089 \times 10^{-7}$

$l = 1000$

$A = \pi\left(\frac{0.001}{2}\right)^2$

$$R = \frac{\rho L}{A} = \frac{1.03651089 \times 10^{-7} \times 1000}{\pi\left(\frac{0.001}{2}\right)^2}$$

$$\boxed{R = 131.97\ \Omega}$$

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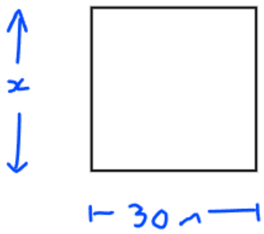
11. A rectangular river dam is 30 m wide and is flooded to its top edge, on one side only, with water of density 1005 kg/m^3.

Calculate EACH of the following:

(a) the height of the dam, if the thrust under the flooded condition is 30MN; (5)

(b) the pressure at a point 2.24 m above the base of the dam. (4)

a)



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

$F = 1005 \times 9.81 \times (30x)\left(\frac{x}{2}\right) = 30 \times 10^6$

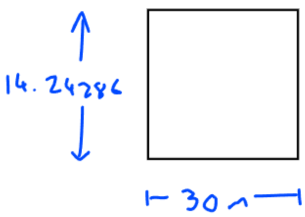
$1005 \times 9.81 \times 15x^2 = 30 \times 10^6$

$x = \sqrt{\frac{30 \times 10^6}{1005 \times 9.81 \times 15}}$

$x = 14.24286$ m

height of Dam

b)



$P = \rho g h$

$h = 14.2428 - 2.24 = 14.0028$ m

$P = 1005 \times 9.81 \times 14.0028$

$138{,}054.3$ (Pa)

1.38 bar

12. A ship has a displacement volume of 3440 m^3 in sea water.

Calculate the mass, m, which when loaded on the centre line at a Kg of 4.8 m will cause a change of + 0.25 m in the position of the ship's centre of gravity. (8)

Note: KG = 3.5 m and density of sea water = 1025 kg/m^3

ship mass = vol × density

3440 × 1025

3526 t

taking moments about K

Name	Mass (t)	Force	distance	Moment	Dir
Ship	3526		3.5	12341	C
load	x		4.8	$4.8x$	C
Ship + load	$3526 + x$		3.75	$3.75(3526 + x)$	A

sum of clockwise moments = sum of anticlockwise moments

$$12341 + 4.8x = 3.75(3526 + x)$$

$$12341 + 4.8x = 13222.5 + 3.75x$$

$$1.05x = 881.5$$

$$x = 839.5238$$

load = 839.52 t