GENERAL ENGINEERING SCIENCE II

Attempt ALL questions

Marks for each question are shown in brackets.

Section A

1. A steel shaft has a diameter of 48 mm.

(a) Calculate the temperature at which a brass sleeve with a hole diameter of 47.75 mm, at a temperature of 20°C will just slide onto the shaft to provide a shrink fitting. (4)

(b) When the combined shaft and sleeve are in use they may be subjected to a temperature rise. If the temperature rose to that determined in Q1(a), explain with reasons whether the sleeve becomes loose or not. (2)

Note: coefficient of linear expansion of brass = 0.000018/°C

2. 5 kg of Argon gas occupied a fixed volume of 300 litres at a temperature of 20°C. It was accidentally heated until its temperature was 200°C.

Calculate EACH of the following:

(a) the amount of heat was transferred to the gas; (3)

(b) the final pressure of the gas. (5)

Note: $R = 0.209\ kJ/kgK$ $Cv = 0.315\ kJ/kgK$

3. (a) Explain the form in which useful energy is stored in liquid fuels such as diesel. (2)

(b) Describe the difference between temperature and heat transfer. State what condition is required for Heat. (3)

(c) State the fixed points on the Celsius scale and describe how this relates to the Kelvin scale. Describe are the unit intervals determined. (3)

4. A 4 cylinder, 2 stroke diesel engine, has a bore of 120 mm and a stroke of 150 mm and runs at 800 revs per minute. Under test, the mean effective pressure was found to be 600 kN/m^2. During the test a torsion meter on the shaft gave a reading of 576 Nm.

Calculate EACH of the following:

(a) the brake power; (3)

(b) the indicated power; (3)

(c) the mechanical efficiency. (2)

5. (a) Sketch the plant diagram of a basic vapour compression refrigeration system discussing condenser sub-cooling and evaporator superheating. (4)

(b) Describe the basic functions of the FOUR key components of a vapour compression refrigeration system with reference to your diagram in Q5(a). (4)

(c) If the refrigeration system described in Q5(a) has a water cooled condenser, describe the effect of a higher cooling water inlet temperature if the flow rate remains the same. (2)

6. At point 1 of a cyclic process 0.2 m^3 of air at 1.01325 bar and 20°C occupies a cylinder at bottom dead centre. Assume that losses are negligible.

(a) At top dead centre, point 2, the gas has been compressed to one tenth of its original volume at point 1. Calculate the pressure assuming no temperature rise. (2)

(b) At top dead centre there is a heat addition of 60 kJ which causes an expansion at constant pressure to point 3. Calculate the volume as a result of this expansion. (6)

(c) The cycle continues with an expansion from point 3 back to bottom dead centre, point 4, calculate the final pressure at point 4 if the temperature remains constant in this process. (2)

Note: $R=0.287kJ/kgK$, $C_p = 1.005kJ/kgK$

Section B

7. (a) Explain the main differences in the atomic structure of materials which determines whether the material may be a good conductor or an insulator. (2)

(b) State examples of processes using electric current being used for EACH of the following:

(i) its magnetic effect; (2)

(ii) chemical effect; (2)

(iii) its heating effect. (2)

8. (a) Explain how the resistance of metals varies with temperature. Briefly explain why this occurs. (4)

(b) State an example of where this changing property is used. (2)

(c) Determine the total resistance of the circuit shown in FIG Q8. (4)

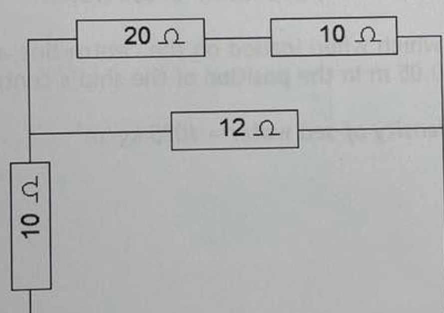


Fig Q8

9. (a) Define the resistivity of a material. (2)

(b) The resistance of 4.5 km of aluminium wire of 3 mm diameter is 420 ohms.

Calculate the resistance of 1 km of copper wire of 1.5 mm diameter. (6)

Note: the resistivity of copper = 0.65 x resistivity of Aluminium.

10. A battery consists of four cells in series each having an e.m.f. of 1.5 V and an internal resistance of 0.6 Ω.

Calculate EACH of the following:

(a) the current flowing if connected to a device of 7.6 Ω resistance; (6)

(b) the terminal voltage. (2)

11. An electrical conductor which has an effective length of 200 mm and a diameter of 9.5 mm carries a current of 35 A at right angles to a magnetic field. The force on the conductor is 22 N.

Calculate EACH of the following using appropriate S.I. units:

(a) the flux density; (3)

(b) the magnetic flux. (5)

12. A vessel has a displacement volume of 5450 m^3 in sea water.

Calculate the mass, m, which when loaded on the centre line at a Kg of 3.8 m will cause a change of +0.05 m in the position of the ship's centre of gravity. (8)

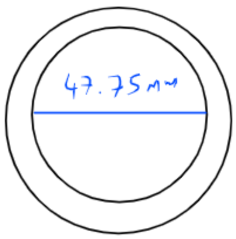
Note: KG = 3.2 m and density of sea water = 1025 kg/m^3

1. A steel shaft has a diameter of 48 mm.

(a) Calculate the temperature at which a brass sleeve with a hole diameter of 47.75 mm, at a temperature of 20°C will just slide onto the shaft to provide a shrink fitting. (4)

(b) When the combined shaft and sleeve are in use they may be subjected to a temperature rise. If the temperature rose to that determined in Q1(a), explain with reasons whether the sleeve becomes loose or not. (2)

Note: coefficient of linear expansion of brass = 0.000018/°C



liner expansion

$D + D\alpha\Delta t = \text{New } D$

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

$47.75 \times 0.000018\,\Delta t = 0.25$

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

$\Delta t = 290.9447384$

Find temp $290.94 + 20 = 310.94°C$

b) It would not become loose, as the diameter of the shaft to which it is attached will also expand

2. 5 kg of Argon gas occupied a fixed volume of 300 litres at a temperature of 20°C.
It was accidentally heated until its temperature was 200°C.
Calculate EACH of the following:
(a) the amount of heat was transferred to the gas; (3)
(b) the final pressure of the gas. (5)
Note: R = 0.209 kJ/kgK Cv = 0.315 kJ/kgK

a) $Q = mc\Delta t$

$Q = 5 \times 315 \times 180$

$Q = 283500\text{J}$

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

$Pv = mRt$

$P(0.3) = 5 \times 209 \times 293$

$P = \frac{5 \times 209 \times 293}{0.3}$

$P = 1{,}020{,}616.667 \text{ Pa}$

$P_1 = 1{,}020{,}616.667$ $P_2 = x$

$T_1 = 20 + 273 = 293$ $T_2 = 200 + 273 = 473$

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

$\frac{1{,}020{,}616.667}{293} = \frac{x}{473}$

$x = 1{,}647{,}616.667 \text{ (Pa)}$

Final pressure 16.476 bar

3. (a) Explain the form in which useful energy is stored in liquid fuels such as diesel. (2)
(b) Describe the difference between temperature and heat transfer. State what condition is required for Heat. (3)
(c) State the fixed points on the Celsius scale and describe how this relates to the Kelvin scale. Describe are the unit intervals determined. (3)

a) Energy is stored in liquid fuels such as diesel in the form of un oxidized carbon and hydrogen. Once these elements are oxidized (burnt) they release energy in the oxidation process.

b) Temperature is a measure of how fast the atoms of a material are vibrating. You can sense it with your hands or a thermometer. It doesn't matter about the size of the object, you can have 1kg of a material at 20°C or 1000kg at 20°C, they have the same temperature.

Heat transfer is the transfer of heat energy. This is a quantity of energy measured in Joules (temperature is usually measured in Kelvin or Celsius). This energy can be transferred to an object and raise its TEMPERATURE. The amount of heat energy in a system is dependent upon its mass.

C) The 2 fixed points on the Celsius Scale are 100°C which is the boiling point of water, and 0°C which is the freezing point of water. The space in between is divided into 100 equal sized segments, each of these is called a degree Celsius. The step length for a degree Celsius is the same for one Kelvin. The Kelvin Scales goes down to approx. -273°C which is absolute zero. This is the temperature at which atoms stop vibrating.

4. A 4 cylinder, 2 stroke diesel engine, has a bore of 120 mm and a stroke of 150 mm and runs at 800 revs per minute. Under test, the mean effective pressure was found to be 600 kN/m². During the test a torsion meter on the shaft gave a reading of 576 Nm.

Calculate EACH of the following:

(a) the brake power; (3)

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(c) the mechanical efficiency. (2)

$IP = x\, plan$ $\qquad BP = T 2\pi n$ $\qquad Eff = \frac{BP}{IP}$

a) $BP = 576 \times 2\pi \times 13.333$

$n = 800\ rev/min \div 60 = 13.3333$

$BP = 48254.86$ Watts

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

$x = 4$

$p = 600{,}000\ (Pa)$

$L = 150\ mm = 0.15\ m$

$a =$

bore $= 120\ mm = 0.12$

area $= \pi r^2 = \pi (0.06)^2 = 0.0113097 3355\ m^2$

$d = 0.12\ m$

$r = 0.06\ m$

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

$IP = 4 \times 600{,}000 \times 0.15 \times 0.0113097 3355 \times 13.3333$

$IP = 54286.72$ Watts

c) $Eff = \frac{BP}{IP} = \frac{48254.86}{54286.72}$

$= 0.888944$

88.894%

5. (a) Sketch the plant diagram of a basic vapour compression refrigeration system discussing condenser sub-cooling and evaporator superheating. (4)

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6. At point 1 of a cyclic process 0.2 m^3 of air at 1.01325 bar and 20°C occupies a cylinder at bottom dead centre. Assume that losses are negligible.

(a) At top dead centre, point 2, the gas has been compressed to one tenth of its original volume at point 1. Calculate the pressure assuming no temperature rise. (2)

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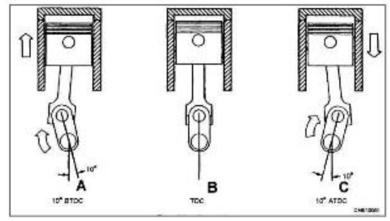
(c) The cycle continues with an expansion from point 3 back to bottom dead centre, point 4, calculate the final pressure at point 4 if the temperature remains constant in this process. (2)

Note: $R=0.287kJ/kgK$, $C_p = 1.005kJ/kgK$



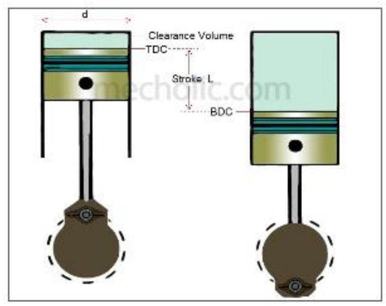
Point 1 (BDC) Point 2 (TDC)

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

$P_1 = 101{,}325$ (Pa) $P_2 = x = 1013250$

$V_1 = 0.2$ (m^3) $V_2 = 0.02\ m^3$

$T_1 = 20^\circ C = 293\ K$ $T_2 = 293$



a) $P_1 V_1 = P_2 V_2$

$101{,}325 \times 0.2 = 0.02\,x$

$$\frac{101\,325 \times 0.2}{0.02} = 1{,}013{,}250$$

$P_2 = 1013250$ (Pa)

b) (TDC)

$Q = mc\Delta t$

$Q = 60{,}000J$

$m = ?$

$c = 718$

$\Delta t = x$

$Pv = mRt$

We dont know the mass of the gas, we can find this from the inital conditions.

$P = 1013250$

$V = 0.02$

$m = x$

$R = 287$

$t = 293k$

$1013250 \times 0.02 = x \times 287 \times 293$

mass = 0.2409889287 kg

$Q = mc\Delta t$

$60{,}000 = 0.240988927 \times 1005 \times \Delta t$

$\frac{60{,}000}{(0.240988927 \times 1005)} = \Delta t$

$247.73 = \Delta t$

Find temp = initial $+\Delta t$

$293 + 247.73$

$= 540.7354\ K$

calc Volume $P_2 = P_3$

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

$\frac{0.02}{293} = \frac{x}{540.7354}$

$0.03691m^3 = V_3$

6. At point 1 of a cyclic process 0.2 m^3 of air at 1.01325 bar and 20°C occupies a cylinder at bottom dead centre. Assume that losses are negligible.

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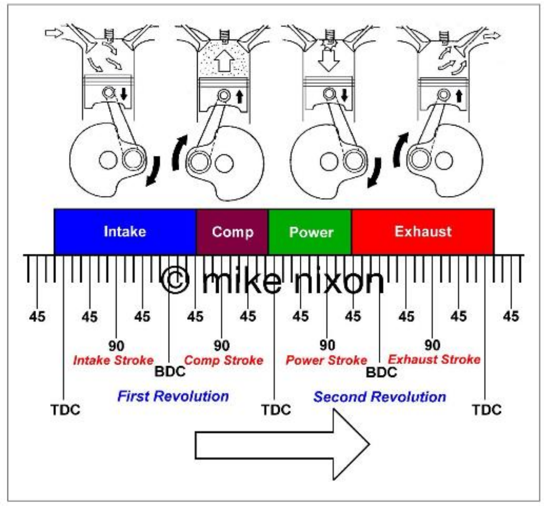

(BDC)

$$\frac{P_3 V_3}{\cancel{T_3}} = \frac{P_4 V_4}{\cancel{T_4}}$$

$P_3 = 1013250 (Pa)$ $P_4 = x$

$V_3 = 0.03691$ $V_4 = 0.2$

to get these volumes we need to look over the previous steps, V4 is BDC (bottom dead centre) so we know its volume, and is the same as V1

$$1013250 \times 0.03691 = x \times 0.2$$

$$P_4 = 186,995.29 \ (Pa)$$

Section B

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(b) State examples of processes using electric current being used for EACH of the following:

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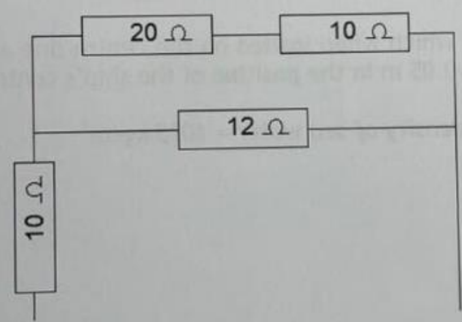
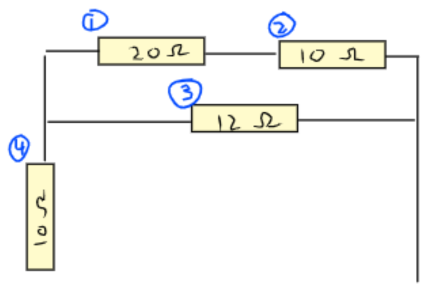


Fig Q8

a) Resisitivity of a material is due to hte internal resisitance. This is casued by the atoms vibrating in the material and obstructing the path of the electrons as they flow through tht ematerial. When the matieral is at a higher temeprature the atoms vibrate more, and this causes more obstruction, hence higher resisitance (in most cases) in a few materials such as carbon the opposite is true, where an increase in temperature LOWERS the internal resistance of a material.

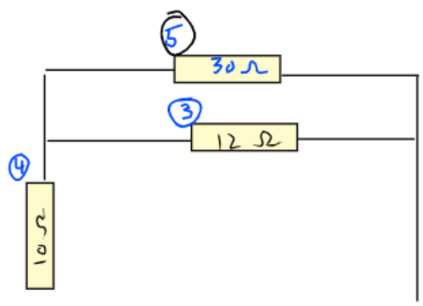
b) a thermistor takes advantage of this effect, and can be made to increase in resistance, or decrease in resistance when temperature increases. This can be used in heat applications such digital thermometers, ovens and fridges.



Res over series section ① + ②

$R_T = R_1 + R_2$

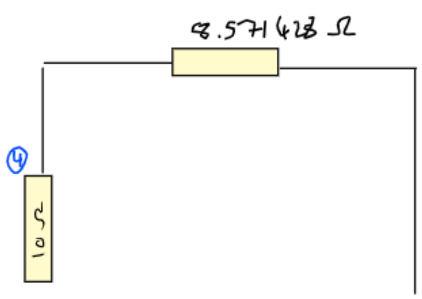
$R_T = 20 + 10 = 30\ \Omega$



Res over parallel section ⑤ + ③

$$\frac{1}{R_T} = \frac{1}{30} + \frac{1}{12}$$

$R_T = 8.571428\ \Omega$



total Resistivity = $18.571428\ \Omega$

9. (a) Define the resistivity of a material. (2)

(b) The resistance of 4.5 km of aluminium wire of 3 mm diameter is 420 ohms.

Calculate the resistance of 1 km of copper wire of 1.5 mm diameter. (6)

Note: the resistivity of copper = 0.65 x resistivity of Aluminium.

Alu

b) $R = \dfrac{\rho \times L}{A}$

$R = 420$

$\rho = x$

$L = 4500$

$A = (0.0015)^2 \pi$

$420 = \dfrac{x \times 4500}{(0.0015)^2 \pi}$

$\dfrac{420 (0.0015)^2 \pi}{4500} = x$

$6.597344 \times 10^{-7} = x = \rho$

Copper

$0.65 \times 6.597344 \times 10^{-7} = \rho_{copper}$

$L = 1000$

$A = (0.00075)^2 \pi$

$R = \dfrac{0.65 \times 6.597344 \times 10^{-7} \times 1000}{(0.00075)^2 \pi} = 242.6667\ \Omega$

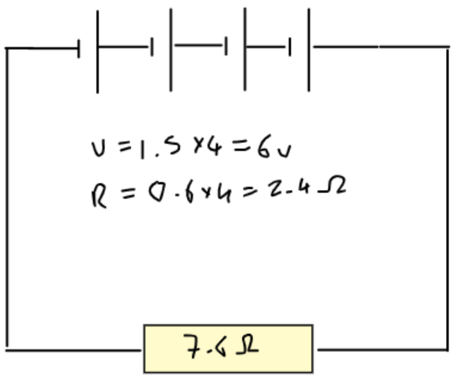
10. A battery consists of four cells in series each having an e.m.f. of 1.5 V and an internal resistance of 0.6 Ω.

Calculate EACH of the following:

(a) the current flowing if connected to a device of 7.6 Ω resistance; (6)

(b) the terminal voltage. (2)

a)



Resistance Series Section

$R_T = 2.4 + 7.6 = 10\,\Omega$

$I = \frac{V}{R} = \frac{6}{10} = 0.6$ Amps

b) Emf − Ir = terminal voltage.

$6 - (0.6 \times 2.4)$

$6 - 1.44 = 4.56$ Volts.

11. An electrical conductor which has an effective length of 200 mm and a diameter of 9.5 mm carries a current of 35 A at right angles to a magnetic field. The force on the conductor is 22 N.

Calculate EACH of the following using appropriate S.I. units:

(a) the flux density; (3)

(b) the magnetic flux. (5)

$F = BIL \sin\theta$ $B = \frac{\phi}{A}$

a)

L = 0.2 m
I = 35 A
F = 22 N
B = x

$22 = x \times 35 \times 0.2$

$\frac{22}{35 \times 0.2} = x = 3.142857$ Tesla

b) $BA = \phi$

$A = (0.00475)^2 \pi = 7.088 \times 10^{-5}$

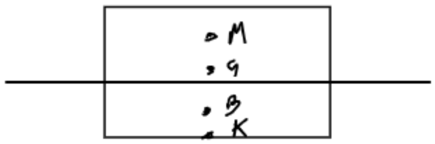
$3.142857 \times 7.088 \times 10^{-5} = \phi$

$\phi = 2.227726 \times 10^{-4}$ wb

12. A vessel has a displacement volume of 5450 m^3 in sea water.

Calculate the mass, m, which when loaded on the centre line at a Kg of 3.8 m will cause a change of +0.05 m in the position of the ship's centre of gravity. (8)

Note: KG = 3.2 m and density of sea water = 1025 kg/m^3

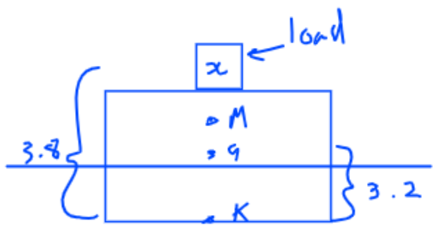


M G B K

Mass = Vol x density

Mass = 5450 x 1025 = 5,586,250 kg

5586.25 tonnes

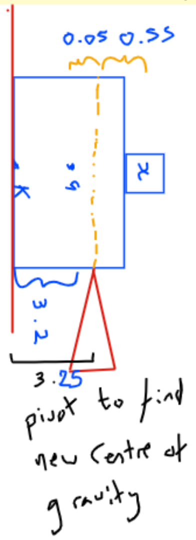


Distance from old G to new G = 0.05

Distance from load to new G = 3.8 − 3.25 = 0.55

taking moments about ~~Left side~~ Pivot

as clockwise moments must equal to anticlockwise moments, and we KNOW the new centre of ravity, we can make this easier (quicker anyway), and take moments about the new centre of gravity



Name	Mass (t)	Force (kN)	distance (m)	Moments (kNm)	Direction
Ship	5586.25	54801.1125	0.05	2740.06	A
load	x	9.81 x	0.55	5.3955 x	C

Sum of anticlockwise moments = Sum of clockwise moments

$2740.06 = 5.3955x$

$507.84\,t = x$

load = 507.84 t

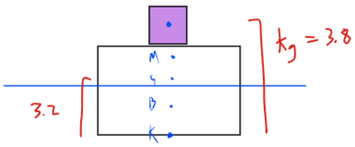
Alternate method

12. A vessel has a displacement volume of 5450 m^3 in sea water.

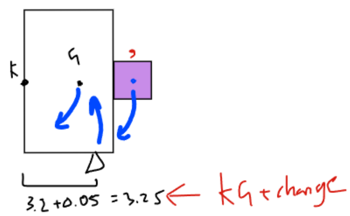
Calculate the mass, m, which when loaded on the centre line at a Kg of 3.8 m will cause a change of +0.05 m in the position of the ship's centre of gravity. (8)

Note: KG = 3.2 m and density of sea water = 1025 kg/m³

g = load centre gravity
G = ship " "



taking moments about K



Ship = density × vol
(1025 × 5450) ÷ 1000
5 586.25 t

Sum of the downwards forces = sum of upwards forces

Name	mass	Force	distance	Moment	Dir A/C
Ship	5586.25		3.2	17876	C
load	x		3.8	$3.8x$	C
Fulcrum	(5586.25 + x)		3.25	3.25 (5586.25 + x)	A

Sum of the clockwise moments = sum of the anticlockwise moments

$$17876 + 3.8x = 3.25(5586.25 + x)$$

$$17876 + 3.8x = 18155.3125 + 3.25x$$

$$0.55x = 279.3125$$

$$x = \frac{279.3}{0.55}$$

$$x = 507.8409\ t$$