GENERAL ENGINEERING SCIENCE II

Attempt ALL questions.

Marks for each question are shown in brackets.

Section A

1. A stainless steel water vessel has a mass of 3 kg and contains 12 kg of water at a temperature of 22°C. A further 15 kg of water at 70°C is added to the vessel.

   Determine the final equilibrium temperature of the vessel and water. **(8)**

   Note: Assume there are no heat losses.
   the specific heat of stainless steel = 0.5 kJ/kgK
   the specific heat of water = 4.18 kJ/kg

   $Q = MC\Delta T$

2. A gas is contained at high pressure in a cylinder. When it is vented to atmosphere through a nozzle, explain what happens to the temperature of the gas released.

   (a) A perfect gas at an initial pressure, temperature and volume of 3.75 bar, 145°C and 280 litres respectively is cooled at constant pressure until its temperature is 10°C. **(2)**

   (b) Determine EACH of the following:

   (i) the initial mass of the gas; **(3)**

   (ii) the final volume in m^3. **(3)**

   Note: R = 0.29 kJ/kgK C = 1.005 kJ/kgK

   $\frac{PV}{t} = MR$

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

   (b) 250 grams of ice at -20°C is heated with 120 kJ of energy. Determine what is the final state and temperature of the resultant. **(6)**

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

   $Q = MC\Delta T$

4. An 8 cylinder, 4 stroke diesel engine has a bore of 350 mm and a stroke of 400 mm.

Indicator cards were taken and each had a mean effective height of 22 mm.

The power of the engine was also tested using a dynamometer which gives a steady state torque reading of 36 kNm at 800 rpm.

Determine EACH of the following:

(a) the brake power; $BP = 2\pi N T$ (3)

(b) the indicated power; $IP = \frac{P_m L A N K}{2}$ (3)

(c) the mechanical efficiency. $\frac{BP}{IP}$ (2)

Note: Indicator spring constant was 80 kN/m²/mm

5. 1.5 kg of Heptane (C_7H_{16}) is completely burned in air. C=12 H=1 O=16

Determine EACH of the following:

(a) the stoichiometric mass of air required; (4)

(b) the mass of carbon dioxide in the exhaust gases. (4)

Note: assume air is 23% oxygen by mass

6. Describe the working principles of a vapour compression refrigeration system.

Include a basic layout diagram and a corresponding pressure vs enthalpy diagram to reference your answer. (10)

Section B

7. The power dissipated in the circuit in FIG Q7 is 7.5 kW.

Determine EACH of the following:

(a) the supply current, I_s; (3)

(b) the current (I_1) flowing in the resistor R_1; (3)

(c) the value of R_2; (2)

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

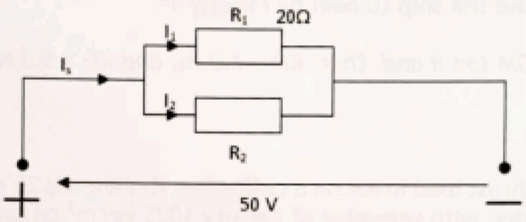


FIG Q7

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

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

Determine the resistance of 1 km of iron wire of 1 mm diameter. (6)

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

9. 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)

10. A conductor of 7.5 mm diameter has an effective length of 400 mm when carrying a current of 20 A at right angles to a magnetic field. The force on the conductor is 20 N.

Determine EACH of the following:

(a) the flux density; (4)

(b) the magnetic flux. (4)

11. A ship has a displacement of 35500 tonne.

Determine the distance a mass of 71 tonnes, already on board, must be moved off the centreline to cause the ship to heel by exactly 1°.

Given $m \times d = \Delta\, GM \tan\theta$ and that KM = 6.2 m, and KG = 5.3 m. (8)

12. (a) Determine the thrust load in MN on a cofferdam (bulkhead) 25 m wide by 26 m deep when flooded with seawater of density 1025 kg/m^3 on one side only. (4)

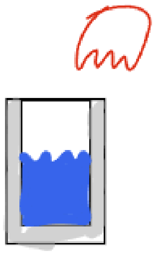
(b) Determine the gauge pressure, in bar, at the lowest point on the bulkhead. (4)

1. A stainless steel water vessel has a mass of 3 kg and contains 12 kg of water at a temperature of 22°C. A further 15 kg of water at 70°C is added to the vessel.

Determine the final equilibrium temperature of the vessel and water. (8)

Note: *Assume there are no heat losses.*
the specific heat of stainless steel = 0.5 kJ/kgK
the specific heat of water = 4.18 kJ/kg

$Q = mc\Delta t$



Heat loss = Heat gain

	initial	Final	Δt	$Q = mc\Delta t$
Water Hot (loss)	$m = 15$, $c = 4180$, $t = 70$	x	$70 - x$	$Q_{HW} = 15 \times 4180(70 - x)$
Water cold gain	$m = 12$, $c = 4180$, $t = 22$	x	$x - 22$	$Q_{CW} = 12 \times 4180(x - 22)$
Stainless gain	$m = 3$, $c = 500$, $t = 22$	x	$x - 22$	$Q_{SS} = 3 \times 500(x - 22)$

$$Q_{loss} = Q_{gain}$$

$$Q_{HW} = Q_{CW} + Q_{SS}$$

$$15 \times 4180(70 - x) = 12 \times 4180(x - 22) + 3 \times 500(x - 22)$$

$$4389000 - 62700x = 50160x - 1103520 + 1500x - 33000$$

$$4472160 = 114360x$$

$$\boxed{39.106^\circ C}$$ Final temp

2. A gas is contained at high pressure in a cylinder. When it is vented to atmosphere through a nozzle, explain what happens to the temperature of the gas released. (2)

(a) A perfect gas at an initial pressure, temperature and volume of 3.75 bar, 145°C and 280 litres respectively is cooled at constant pressure until its temperature is 10°C.

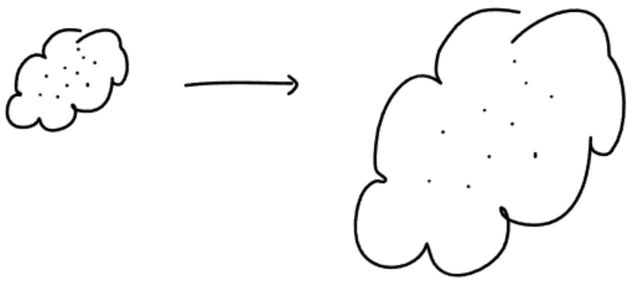
(b) Determine EACH of the following:

(i) the initial mass of the gas; (3)

(ii) the final volume in m^3. (3)

Note: R = 0.29 kJ/kgK C = 1.005 kJ/kgK

2)



the gas expands quickly, this is an adiabatic expansion process, so heat is not transferred to the environment. The temperature of the gas that escapes will decrease, as the gas expands, the number of vibrations per cubic volume will decrease.

b i)

$P_1 = 3.75$ bar $= 375{,}000$ (Pa) $\quad P_2 = 3.75$ bar $= 375{,}000$ (Pa)

$V_1 = 280$ litre $= 0.28\ m^3 \quad V_2 = x$

$T_1 = 145°C = 418$ K $\quad T_2 = 10°C = 283$

$$P_1 V_1 = m R t$$

$$375{,}000 \times 0.28 = x(290)(418)$$

$$\frac{105000}{121220} = x$$

$$\boxed{0.866193 \text{ kg}}$$

b ii)

$$\frac{P_1 V_1}{t_1} = \frac{P_2 V_2}{t_2}$$

$P_1 = 3.75$ bar $= 375{,}000\,(Pa)$ $P_2 = 3.75$ bar $= 375{,}000\,(Pa)$

$V_1 = 280$ litre $= 0.28\ m^3$ $V_2 = x$

$T_1 = 145^\circ C = 418\ K$ $T_2 = 10^\circ C = 283$

$$\frac{0.28}{418} = \frac{x}{283}$$

$0.189564\ m^3$

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

(b) 250 grams of ice at -20°C is heated with 120 kJ of energy. Determine what is the final state and temperature of the resultant. (6)

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

a)

b)

ice -20°C	① heat ice → Specific	ice 0°C	② melt ice → Latent	water 0°C	③ heat water → Specific	water x°C

①
$Q = mc\Delta t$
$Q =$
$m = 0.25$ kg
$c = 2110$ J/kgK
$\Delta t = 20$

②
$Q = mc$
$Q =$
$m = 0.25$ kg
$c = 335{,}000$ J/kg

③
$Q = mc\Delta t$
$Q =$
$m = 0.25$ kg
$c = 4180$ J/kgK
$\Delta t = x$

$Q_1 = 0.25 \times 2110 \times 20$

$= 10{,}550$ J

$Q_2 = 0.25 \times 335{,}000$

$83{,}750$ J

$Q_3 = 120{,}000 - Q_1 - Q_2$

$120{,}000 - 83750 - 10{,}550$

$25{,}700$ J

$Q = mc\Delta t$

$25{,}700 = 0.25(4180)x$

$24.5933°C$ = Final temp liquid (state)

4. An 8 cylinder, 4 stroke diesel engine has a bore of 350 mm and a stroke of 400 mm.

Indicator cards were taken and each had a mean effective height of 22 mm.

The power of the engine was also tested using a dynamometer which gives a steady state torque reading of 36 kNm at 800 rpm.

Determine EACH of the following:

(a) the brake power; $BP = 2\pi NT$ (3)

(b) the indicated power; $IP = \frac{P_m L A N k}{2}$ (3)

(c) the mechanical efficiency. $\frac{BP}{IP}$ (2)

Note: Indicator spring constant was 80 kN/m²/mm

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

$IP = x p l a n$

$Eff = \frac{BP}{IP} \times 100$

$BP = T 2 \pi N$

a) $BP = 36000 \times 2\pi \times 13.333 = 3{,}015{,}928.9$ Watts

$N = \frac{800 \text{ Rev}}{1 \text{ min}} = 13.333$ Rev/sec

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

$x = 8$

$p = 1{,}760{,}000$

$L = 0.4m$

$a = \left(\frac{350}{2000}\right)^2 \pi = 0.0962112 7 m^2$

$n = \frac{13.333}{2} = 6.6666$

$Imp = \frac{A \phi}{L}$ (A = mean height)

$\phi = 80\ kN/m^2/mm$ (N/m² = pascal)

ϕ 80,000 Pa/mm

$Imp = 22 \times 80{,}000$

$1{,}760{,}000\ N/m^2$

17.6 bar

$IP = 8 \times 1{,}760{,}000 \times 0.4 \times 0.09621127 \times 6.6666$ (x, p, L, a, n)

$IP = 3{,}612{,}412.67$ Watts

c) $eff = \frac{BP}{IP} \times 100$

$\frac{3{,}015{,}928.9}{3{,}612{,}412.67} \times 100$

83.488%

4\. An 8 cylinder, 4 stroke diesel engine has a bore of 350 mm and a stroke of 400 mm.

Indicator cards were taken and each had a mean effective height of 22 mm.

The power of the engine was also tested using a dynamometer which gives a steady state torque reading of 36 kNm at 800 rpm.

Determine EACH of the following:

(a) the brake power; $BP = 2\pi NT$ (3)

(b) the indicated power; $IP = \frac{P_m LANK}{2}$ (3)

(c) the mechanical efficiency. $\frac{BP}{IP}$ (2)

Note: Indicator spring constant was 80 kN/m²/mm

5. 1.5 kg of Heptane (C_7H_{16}) is completely burned in air. C=12 H=1 O=16

Determine EACH of the following:

(a) the stoichiometric mass of air required; (4)

(b) the mass of carbon dioxide in the exhaust gases. (4)

Note: assume air is 23% oxygen by mass

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

5 c)

Carbon

$C_7 = 12 \times 7 = 84$

$\frac{84}{100} \times 1.5 = 1.26$ kg

Hydrogen

$H_{16} = 1 \times 16 = 16$

$\frac{16}{100} \times 1.5 = 0.24$ kg

total

100

Burn Carbon

$C + O_2 = CO_2$

mols = $\frac{mass}{RAM}$

$\frac{1.26}{12} = \frac{x}{32}$

3.36 kg of Oxygen is Required to burn Carbon

Burn Hydrogen

$H_2 + O = H_2O$

$\frac{0.24}{2} = \frac{x}{16}$

1.92 kg of Oxygen required to burn Hydrogen

1.5 kg of Heptane (C_7H_{16}) is completely burned in air. C=12 H=1 O=16

Determine EACH of the following:

(a) the stoichiometric mass of air required; (4)

(b) the mass of carbon dioxide in the exhaust gases. (4)

Note: assume air is 23% oxygen by mass

Stoich oxygen = 3.36 kg + 1.92 kg = 5.28 kg

stoich air @ 23% oxy = $\frac{5.28}{0.23}$

= **22.9565 kg** stoich air

6. Describe the working principles of a vapour compression refrigeration system.

Include a basic layout diagram and a corresponding pressure vs enthalpy diagram to reference your answer. (10)

7. The power dissipated in the circuit in FIG Q7 is 7.5 kW.

Determine EACH of the following:

(a) the supply current, I_s; (3)

(b) the current (I_1) flowing in the resistor R_1; (3)

(c) the value of R_2; (2)

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

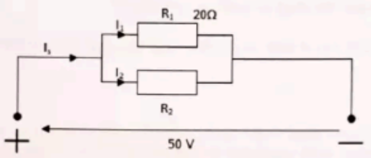


FIG Q7

$\frac{V}{I \times R}$ $\frac{P}{V \times I}$

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

7a) $P = IV$

$7500 = x\ 50$

$\frac{7500}{50} = x$

$\boxed{150\text{ Amps}}$

b) Amps through R_1

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

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

c) R_2

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

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

d) $P = IV$

$P = 2.5 \times 50$

$= 125\text{ watts} = 0.125\text{ kwatts}$

$125\ \frac{J}{S}$ $\times 60 \times 5$

$0.125 \times \frac{1}{12}$

$\boxed{37{,}500\ J}$ or $\boxed{0.01041666\ \text{kwh}}$

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

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

Determine the resistance of 1 km of iron wire of 1 mm diameter. (6)

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

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

Copper

$R = 170\,\Omega$

$\rho = x = 1.756811 \times 10^{-8}\,\Omega m$ $\xrightarrow{\times 5.9}$

$L = 1900\,m$

$A = \left(\frac{0.5}{2000}\right)^2 \pi = 1.9634 \times 10^{-7}\,m$

$170 = \frac{x(1900)}{1.9634 \times 10^{-7}}$

$\frac{170 \times 1.9634 \times 10^{-7}}{(1900)} = x$

$1.7568 \times 10^{-8}\,\Omega m$

Iron

R

$\rho = 1.03651889 \times 10^{-7}\,\Omega m$

$L = 1000\,m$

$A = \left(\frac{1}{2000}\right)^2 \pi = 7.85398 \times 10^{-7}\,m^2$

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

$R = \frac{1.03651889 \times 10^{-7} \times 1000}{7.85398 \times 10^{-7}}$

$R = 131.9737\,\Omega$

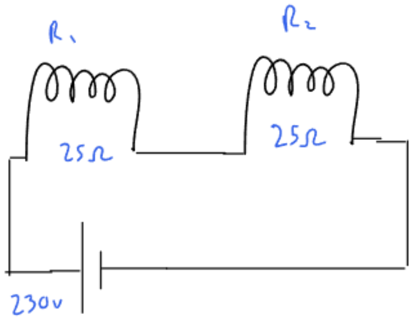
9. An electric fire operated from a 230 V supply has a heating element comprising of two 25 Ω coils. The coils may be connected in series to give a low setting, or in parallel to give a high setting.

Calculate EACH of the following:

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

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

a)



Res

$R_T = R_1 + R_2$

$R_T = 25 + 25 = 50\,\Omega$

Current

V = 230v
I = 4.6 Amps
R = 50 Ω

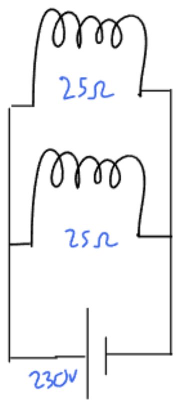
$I = \frac{V}{R} = \frac{230}{50} = 4.6$ Amps

$P = IV$

$P = 4.6 \times 230$

1058 watts

b)



Res

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

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

$R_T = 12.5\,\Omega$

Amps

V = 230v
I = 18.4 Amps
R = 12.5

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

$P = IV$

18.4×230

4232 Watts

10. A conductor of 7.5 mm diameter has an effective length of 400 mm when carrying a current of 20 A at right angles to a magnetic field. The force on the conductor is 20 N.

Determine EACH of the following:

(a) the flux density; (4)

(b) the magnetic flux. (4)

a) $F = BIL \sin\theta$

$F = 20\ N$

$B = x$

$I = 20\ A$

$L = 0.4\ m$

$20 = x(20)(0.4)$

2.5 Tesla $= x$

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

$BA = \phi$

$A = \left(\frac{7.5}{2000}\right)^2 \pi = 4.41786 \times 10^{-5}\ m^2$

$2.5 \times 4.41786 \times 10^{-5} = \phi$

1.104466×10^{-4} wb

11. A ship has a displacement of 35500 tonne.

Determine the distance a mass of 71 tonnes, already on board, must be moved off the centreline to cause the ship to heel by exactly 1°.

Given m x d = Δ GM tan θ and that KM = 6.2 m, and KG = 5.3 m. (8)

11)

$$md = \Delta \, GM \tan\theta$$

$m = 71 \text{ t}$

$d = x$

$\Delta = 35{,}500 \text{ t}$

$GM = KM - KG = 6.2 - 5.3 = 0.9 \text{ m}$

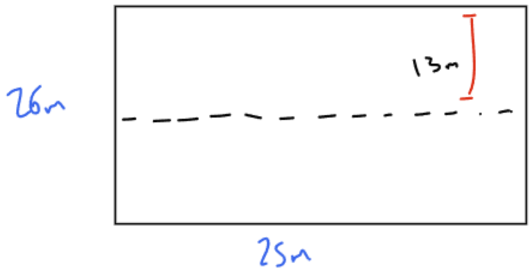
$\tan\theta = \tan(1)$

$$71x = 35{,}500 \times (0.9)(\tan 1)$$

$$\boxed{x = 7.85478 \text{ m}}$$

12. (a) Determine the thrust load in MN on a cofferdam (bulkhead) 25 m wide by 26 m deep when flooded with seawater of density 1025 kg/m^3 on one side only. (4)

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



$P = \rho g h$

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

a) $F = 1025 \times 9.81 \times (26 \times 25) \times 13$

84.967 MN

b) $P = \rho g h$

$P = 1025 \times 9.81 \times 26$

$2{,}61{,}436.5$ (Pa)

2.6144 bar