CERTIFICATES OF COMPETENCY IN THE MERCHANT NAVY
MARINE ENGINEER OFFICER

STCW 78 as amended SMALL VESSEL CHIEF ENGINEER <3000 GT, <9000 kW UNLIMITED

058-12 - GENERAL ENGINEERING SCIENCE II

FRIDAY, 15 MARCH 2024

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:

1. Examinations administered by SQA on behalf of the Maritime & Coastguard Agency.
2. Candidates are required to obtain 50% of the total marks allocated to this paper to gain a pass **AND** also obtain a minimum 40% in Sections A and B of the paper.
3. Non-programmable calculators may be used.
4. All formulae used must be stated and the method of working and ALL intermediate steps must be made clear in the answer.

Maritime & Coastguard Agency

SQA

GENERAL ENGINEERING SCIENCE II

Attempt ALL questions.

Marks for each question are shown in brackets.

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

2. (a) State Charles's Law for a perfect gas. (2)

   (b) A perfect gas at a pressure of 2.4 bar and temperature 44°C is heated until the volume is 60 litres with temperature of 194°C at constant pressure.

   Calculate EACH of the following:

   (i) the original volume of the gas in m^3; (4)

   (ii) the mass of gas. (2)

   Note: for the gas R = 0.29 kJ/kgK

3. With regard to the performance of a diesel engine, define EACH of the following terms, stating the formula for calculating the values of such:

   (a) indicated power; (2)

   (b) brake power; (2)

   (c) brake specific fuel consumption; (2)

   (d) power loss to exhaust. (2)

4. (a) State TWO important thermodynamic properties of refrigerants, explaining their importance. (4)

(b) State the condition of the refrigerant, at the FOUR key points in a simple refrigeration circuit. (4)

5. Butane (C_4H_{10}) is completely burned in 25% excess air by mass.

Calculate EACH of the following:

(a) the mass of carbon dioxide in the exhaust gases per kg of fuel; (5)

(b) the mass of nitrogen in the exhaust gases per kg of fuel. (5)

6. (a) Explain what is meant by EACH of the following terms:

(i) specific heat capacity; (2)

(ii) specific enthalpy of evaporation. (2)

(b) 10 kg of liquid at 20°C has 1950 kJ of heat transferred to it raising its temperature to 85°C.

Determine the specific heat capacity. (4)

Section B

7. A conductor of 12.5 mm diameter carries a current of 30 A when it is at right angles to a magnetic field. The conductor has an effective length of 600 mm in the magnetic field and experiences a force of 28 N.

Determine EACH of the following:

(a) the flux density; (4)

(b) the magnetic flux. (4)

8. An electric heater operated from a 230 V supply has a heating element comprising of two 30 Ω coils. The coils may be connected in series or in parallel to give different outputs.

Determine EACH of the following:

(a) the power output for the series connection; (4)

(b) the power output for the parallel connection. (4)

9. (a) Name TWO sources of electricity; (2)

(b) Explain what happens to the electrical resistance of most metals as the temperature rises. Briefly explain why this occurs. (3)

(c) Explain what characteristic of the atomic structure of insulators makes them bad conductors of electricity, give two examples. (3)

10. The circuit shown in Fig Q10 has a 250 V d.c. supply.

Determine EACH of the following:

(a) the total resistance of the circuit; (3)

(b) the total current supplied; (1)

(c) the volt drop across the 800Ω resister. (4)

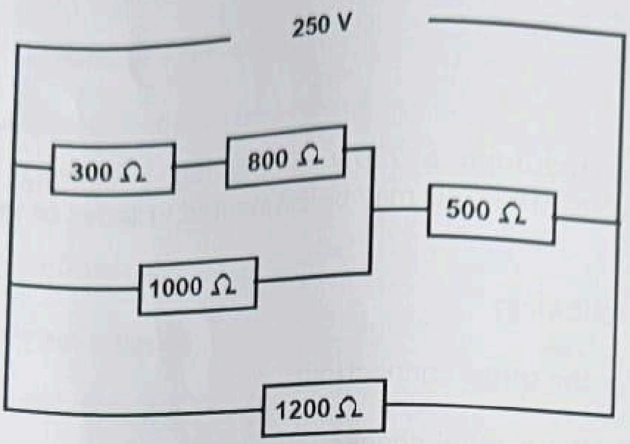


Fig Q10

11. A ship has a displacement of 25500 tonne.

Determine the distance a mass of 82 tonne, already on board, must be moved off the centreline to cause the ship to heel by exactly 1°. (8)

Note: $m \times d = \Delta GM \tan\theta$ *and that* $KM = 6.2$ m, *and* $KG = 5.3$ m.

12. A water tank is 4 m high and 4 m wide. The amount of water in the tank is measured using a pressure transducer in the base of the tank.

Determine EACH of the following:

(a) the thrust on the front face of the tank when it is filled to within 0.5 metre of the top; (5)

(b) the pressure indicated on the transducer, in kilopascals, when the tank is half full. (5)

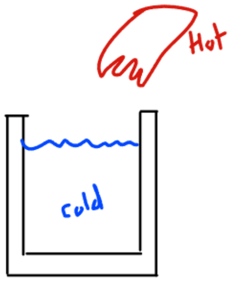
Note: The density of water is 1000 kg/m^3

3. 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 capacity of aluminium = 0.95 kJ/kgK*
the specific heat capacity of water = 4.18 kJ/kgK

$Q = mc\Delta t$



heat loss = heat gain

$Q_{water\,(hot)} = Q_{water\,(cold)} + Q_{Alu}$

		initial	final	Δt	$Q = mc\Delta t$
gain	Alu (cold)	m = 3, c = 950, t = 12	t = x	x − 12	$Q_{Alu} = 3 \times 950\,(x-12)$
gain	water (cold)	m = 2, c = 4180, t = 12	t = x	x − 12	$Q_{cw} = 2 \times 4180\,(x-12)$
loss	water (hot)	m = 5, c = 4180, t = 40	t = x	40 − x	$Q_{HW} = 5 \times 4180\,(40-x)$

heat loss = heat gain

$$Q_{HW} = Q_{Alu} + Q_{cw}$$

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

$$836000 - 20900x = 2850x - 34200 + 8360x - 100320$$

$$970520 = 32110x$$

$$30.22485 = x$$

30.22485 °C Final temp

(2) (a) State Charles's Law for a perfect gas. (2)

(b) A perfect gas at a pressure of 2.4 bar and temperature 44°C is heated until the volume is 60 litres with temperature of 194°C at constant pressure. 2.4

Calculate EACH of the following:

(i) the original volume of the gas in m³; (4)

(ii) the mass of gas. (2)

Note: for the gas R = 0.29 kJ/kgK

b i)

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

$V_1 = x$

$P_1 = 2.4 \text{ bar} = 240{,}000 \text{ Pa}$

$T_1 = 44\,^\circ C = 317 \text{ K}$

$V_2 = 60L = 0.06 \text{ m}^3$

$P_2 = 2.4 \text{ bar} = 240{,}000 \text{ Pa}$

$T_2 = 194 = 467 \text{ K}$

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

$$V_1 = \frac{T_1 V_2}{T_2} = \frac{317 \times 0.06}{467}$$

original vol 0.040728 m^3

b ii)

$$PV = mRT$$

$$\frac{PV}{RT} = m$$

$$\frac{240{,}000 \times 0.06}{290 \times 467} = 0.10633 \text{ kg}$$

3. With regard to the performance of a diesel engine, define EACH of the following terms, stating the formula for calculating the values of such:

(a) indicated power; (2)

(b) brake power; (2)

(c) brake specific fuel consumption; (2)

(d) power loss to exhaust. (2)

a) $IP = x \; p \; l \; a \; n$ $\qquad Eff = \frac{BP}{IP} \times 100$

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

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

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

4. (a) State TWO important thermodynamic properties of refrigerants, explaining their importance. (4)

(b) State the condition of the refrigerant, at the FOUR key points in a simple refrigeration circuit. (4)

5. Butane (C_4H_{10}) is completely burned in 25% excess air by mass.

Calculate EACH of the following:

(a) the mass of carbon dioxide in the exhaust gases per kg of fuel; (5)

(b) the mass of nitrogen in the exhaust gases per kg of fuel. (5)

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

Carbon

$C_4 = 4 \times 12 = 48$

$\frac{48}{58} = 0.8275862$ kg

Hydrogen

$H_{10} = 10 \times 1 = 10$

$\frac{10}{58} = 0.17241379$ kg

total

$48 + 10 = 58$

Burn Carbon

$C + O_2 = CO_2$

$mols = \frac{mass}{RAM}$ $\frac{0.8275862}{12} = \frac{x}{32}$

2.2068965 kg of oxygen to burn Carbon

Burn Hydrogen

$H_2 + O = H_2O$

$mols = \frac{mass}{RAM}$ $\frac{0.17241379}{2} = \frac{x}{16}$

1.37931 kg of oxygen to burn Hydrogen

a) Mass of Carbon + Mass of oxygen = Mass of CO_2 (in exhaust)

0.8275862 + 2.2068965 = **3.03448 kg**

b) Stoich oxygen 2.2068965 + 1.37931 = 3.5862065 kg

Stoich Air $\dfrac{3.5862065}{0.23}$ = 15.5922 kg

including excess 15.5922 × 1.25 = 19.49025 kg

Nitrogen @ 77% 0.77 × 19.49025 kg = **15.00749 kg**

6. (a) Explain what is meant by EACH of the following terms:

   (i) specific heat capacity; (2)

   (ii) specific enthalpy of evaporation. (2)

(b) 10 kg of liquid at 20°C has 1950 kJ of heat transferred to it raising its temperature to 85°C.

Determine the specific heat capacity. (4)

a)i) the amount of energy in Joules required to increase the temperature of 1kg of a material by 1 degree (C)
Units: Joules/kilogram Kelvin

ii) the amount of energy required to bring about a phase change from a liquid to a gas or vice versa, for 1kg of material
Units Joules/Kilogram

b)

$Q = mc\Delta t$

$Q = 1{,}950{,}000\ J$

$m = 10$

$c = x$

$\Delta t = 65$

$$\frac{Q}{m\Delta t} = c$$

$$\frac{1{,}950{,}000}{10 \times 65} = c$$

3000 J/kg K

7) A conductor of 12.5 mm diameter carries a current of 30 A when it is at right angles to a magnetic field. The conductor has an effective length of 600 mm in the magnetic field and experiences a force of 28 N.

Determine EACH of the following:

(a) the flux density; (4)

(b) the magnetic flux. (4)

a) $F = BIL \sin\theta$

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

$\frac{28}{30 \times 0.6}$

$1.5555\,(T) = B$

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

$BA = \phi$

$1.55556 \times \pi \left(\frac{12.5}{2000}\right)^2$

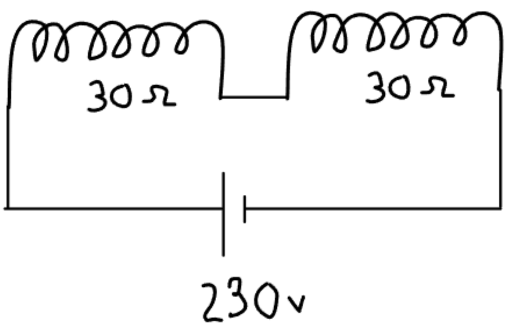
$1.90895 \times 10^{-4}\ \text{wb} = \phi$

8) An electric heater operated from a 230 V supply has a heating element comprising of two 30 Ω coils. The coils may be connected in series or in parallel to give different outputs.

Determine EACH of the following:

(a) the power output for the series connection; (4)

(b) the power output for the parallel connection. (4)



a) $P = IV$

Find total R

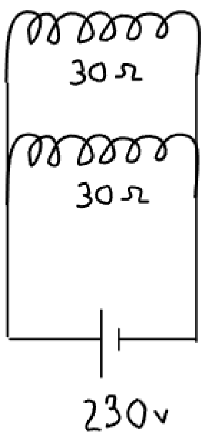
$R_T = R_1 + R_2$

$30 + 30 = 60\Omega$

$I = \frac{V}{R} = \frac{230}{60} = 3.83333$ Amps

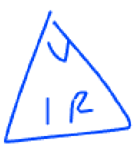
$P = I \times V$

$3.833333 \times 230 =$ **881.67 Watts**



b) $\frac{1}{R_T} = \frac{1}{30} + \frac{1}{30}$

$R_T = 15\ \Omega$



$I = \frac{230}{15} = 15.333$ Amps

$P = IV = 15.3333 \times 230$

3526.67 Watts

9. (a) Name TWO sources of electricity; (2)

(b) Explain what happens to the electrical resistance of most metals as the temperature rises. Briefly explain why this occurs. (3)

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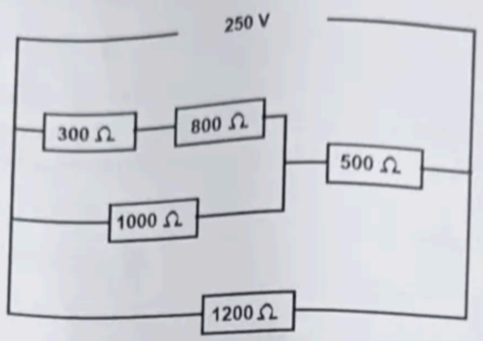
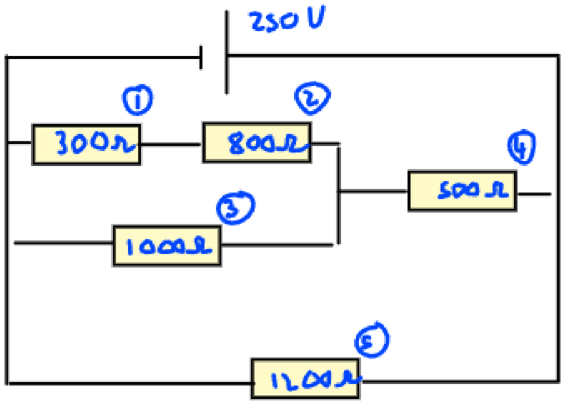


Fig Q10

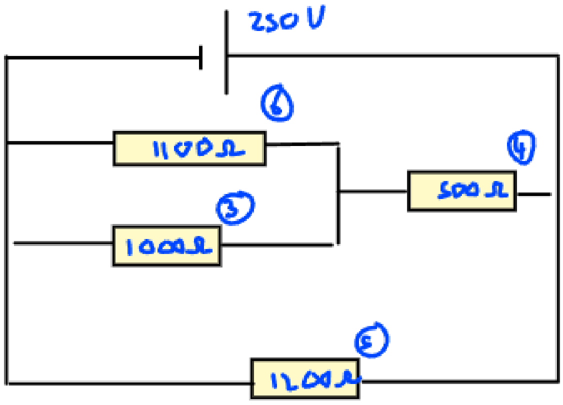


Res over R_1 R_2

$$R_T = R_1 + R_2$$

$$= 300 + 800$$

$$= 1100$$

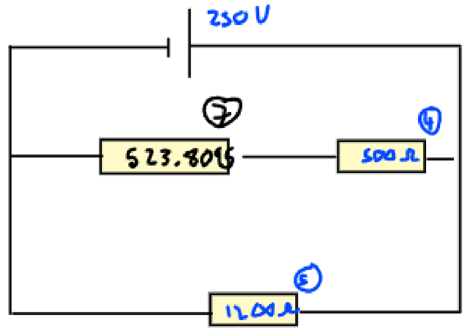


R over R_3 and R_6

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

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

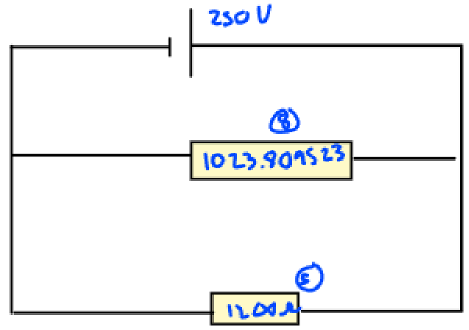
$$R_T = 523.809523\ \Omega$$



R over R_4 and R_7

$R_T = 523.809523 + 500$

$= 1023.909523\ \Omega$



R over R_5 and R_8

$$\frac{1}{R_T} = \frac{1}{1023.8095} + \frac{1}{1200}$$

$R_T = 552.4625\ \Omega$

Circuit

$V = 250$

$I = 0.45251937$ Amps

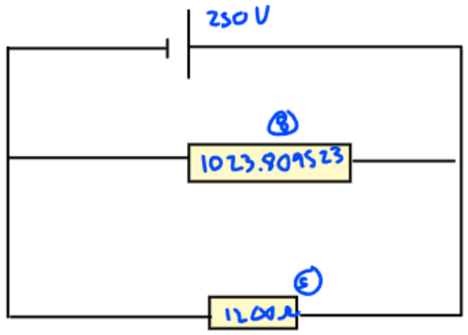
$R = 552.4625\ \Omega$

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

a) total Resistance **552.46 Ω**

b) 0.452519 Amps

how is the current split over R8 and R5?



8

$V = 250$

$I = 0.2441860$

$R = 1023.8$

5

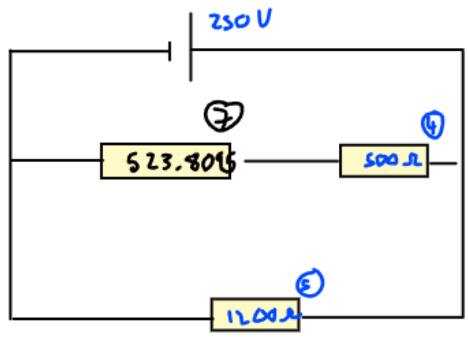
$V = 250$

$I = 0.208333$ Amps

$R = 1200$

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

voltage drop over R4 and R7



7

$V = 127.9069$ V

$I = 0.2441860$

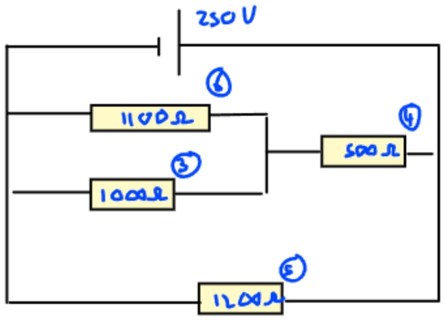
$R = 523.8095$

4

$V = 122.093$ V

$I = 0.2441860$

$R = 500$



how is current split over R3 and R6?

6

V = 127.9069

I = 0.116279 Amps

R = 1100

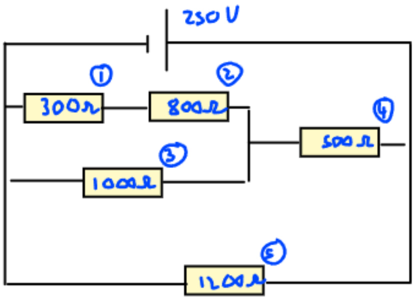
3

V = 127.9069

I = 0.1279069 Amps

R = 1000

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



Voltage drop over R1 and R2

1

V = 34.8837

I = 0.116279

R = 300

2

V = 93.0232 Volts

I = 0.116279

R = 800

$V = I \times R$

c) Voltage drop over 800 Ω = **93.0232 Volts**

(11). A ship has a displacement of 25500 tonne.

Determine the distance a mass of 82 tonne, already on board, must be moved off the centreline to cause the ship to heel by exactly 1°. (8)

Note: $m \times d = \Delta\, GM \tan\theta$ and that $KM = 6.2$ m, and $KG = 5.3$ m.

$$d = \frac{\Delta\ GM\ \tan\theta}{m}$$

$$d = \frac{25500 \times (6.2 - 5.3) \tan 1}{82}$$

$$d = 4.885289\ m$$

(12) A water tank is 4 m high and 4 m wide. The amount of water in the tank is measured using a pressure transducer in the base of the tank.

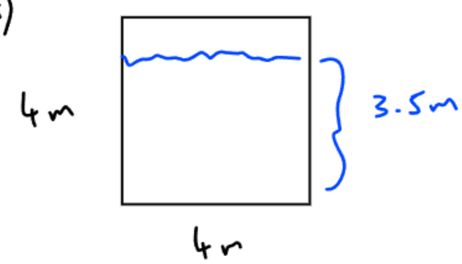
Determine EACH of the following:

(a) the thrust on the front face of the tank when it is filled to within 0.5 metre of the top; (5)

(b) the pressure indicated on the transducer, in kilopascals, when the tank is half full. (5)

Note: The density of water is 1000 kg/m³

a)



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

$1000 \times 9.81 \times (3.5 \times 4)\left(\frac{3.5}{2}\right)$

240345 N

b) $P = \rho g h$

$1000 \times 9.81 \times 2 = 19620$ (Pa)

19.62 (kPa)