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, 08 DECEMBER 2023

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. (a) Explain where the units for specific heat capacity, J/kgK, are derived from. (4)

   (b) A 15 kg cast iron cylinder block is cooled from a temperature of 400°C to 24°C. During cooling it dissipates 2.7 MJ of energy.

   Determine the specific heat capacity of cast iron. (4)

2. (a) State the meaning of the abbreviations 'STP' and 'NTP'. (2)

   (b) 760 grams of a perfect gas occupies a volume of 0.9 m^3 and has a temperature of 28°C. The gas is compressed to a tenth of its original volume where its pressure is 15.4 bar.

   Determine the final temperature. (6)

   Note: R = 290 J/kgK

3. 0.75 kg of Methane (CH_4) is completely burned in 20% excess air.

   Determine EACH of the following:

   (a) the mass of carbon dioxide in the exhaust gases per kg of fuel; (4)

   (b) the mass of nitrogen in the exhaust. (4)

4. A cast steel crank web is joined to a bearing journal by thermal interference fitting. The crank web is bored with an internal diameter of 149.55 mm at a temperature of 20°C. The journal has an external diameter of 150 mm at 20°C.

Determine the highest temperature to which the journal must be cooled in order to slide into the crank web without force. (7)

Note: co-efficient of linear expansion of steel = 0.000016 /°C

5. State and describe the THREE modes of heat transfer, giving an example of each. (9)

6. (a) Describe the basic operation of a vapour compression refrigeration system. (8)

(b) If the refrigeration system described in Q6(a) has a water cooled condenser, explain what will be the effect of a higher cooling water inlet temperature. (2)

Section B

7. (a) Explain the main differences in molecular structures which determine whether the material is a conductor or an insulator. (4)

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

(i) its magnetic effect; (2)

(ii) its chemical effect. (2)

8. Fig Q8 shows two lamps, each of 4 Ω resistance connected in parallel across a 20 V supply.

To avoid exceeding the current rating for the lamps a resistor of 2 Ω is connected in series with the supply.

Calculate EACH of the following:

(a) the power dissipated by each lamp; (4)

(b) the power dissipated by the 2 Ω resistor; (3)

(c) the total energy used by the circuit in 60 minutes. (3)

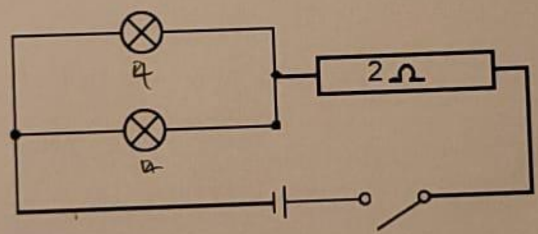

Fig Q8

9. (a) State the meaning of the term *magnetic flux*, stating the units. (2)

(b) A conductor of 7.5 mm diameter has an effective length of 400 mm when carrying a current of 12 A at right angles to a magnetic field. The magnetic flux is measured to be 18 microwebers.

Determine the force on the conductor. (6)

[OVER

10. A battery has an e.m.f. of 38 volts and an internal resistance of 4 ohms. It feeds a circuit consisting of three resistors connected in parallel.

The resistors have values of 10 ohm, 20 ohm and 30 ohm.

Determine EACH of the following:

(a) the battery terminal voltage; (4)

(b) the current in EACH resistor. (4)

11. (a) Determine the thrust load in MN on a bulkhead 8 m wide by 9 m deep when flooded with seawater of density 1025 kg/m^3 on one side only. (6)

(b) Determine the gauge pressure, in bar, at the lowest point on the bulkhead. (2)

12. A ship has a displacement of 33250 tonnes. KM= 5.9 m and KG= 4.7 m.

(a) Explain what is meant by the terms KM and KG. (2)

(b) Determine the distance a mass of 220 tonne, already on board ship, must be moved across the deck to correct a heel of 1.8°. (6)

Note: $m \times d = \Delta\, GM \tan\theta$

1. (a) Explain where the units for specific heat capacity, J/kgK, are derived from. (4)

(b) A 15 kg cast iron cylinder block is cooled from a temperature of 400°C to 24°C. During cooling it dissipates 2.7 MJ of energy.

Determine the specific heat capacity of cast iron. (4)

1a) Heat capacity is given in the units Joules per kilogram kelvin. The value for a material may be derived if the energy injected into a system, the mass and the change in temperature are known. The material being measured must stay in the same state, ie liquid, solid or gas.

$$Q = mc\Delta t$$

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

$$\frac{\text{Joules}}{\text{kilogram} \times K} = \text{heat capacity}$$

the units themselves are derived from the energy injected or realsed from a system (in joules) divided by the mass (in kilograms) and the change in temperature observed (in kelvin)

b) $Q = mc\Delta t$

$Q = 2.7\,MJ$

2.7×10^6

$m = 15\,kg$

$c = x$

$\Delta t = 400 - 24 = 376$

$$\frac{2.7 \times 10^6}{15 \times 376} = 478.72\ J/kgK$$

2 (a) State the meaning of the abbreviations 'STP' and 'NTP'. (2)

(b) 760 grams of a perfect gas occupies a volume of 0.9 m^3 and has a temperature of 28°C. The gas is compressed to a tenth of its original volume where its pressure is 15.4 bar.

Determine the final temperature. (6)

Note: R = 290 J/kgK

a) STP - Standard Temperature and Pressure
NTP - Normal Temperature and Pressure

b) $PV = mRT$

$P_1 = x$

$V = 0.9\ m^3$

$m = 0.76\ kg$

$R = 290$

$T = 28°C = 301\ K$

$$P_1 = \frac{mRT}{V}$$

$$P_1 = \frac{0.76 \times 290 \times 301}{0.9}$$

$$P_1 = 73711.555\ (Pa)$$

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

$P_1 = 73711.55 \, (Pa)$

$V_1 = 0.9 \, (m^3)$

$T_1 = 301 \, (k)$

$P_2 = 15.4 \text{ bar} = 1{,}540{,}000 \, (Pa)$ ($\times 100{,}000$)

$V_2 = 0.09 \, m^3$

$T_2 = x$

$$\frac{73711.55 \times 0.9}{301} = \frac{1{,}540{,}000 \times 0.09}{x}$$

$$220.3999834 = \frac{138600}{x}$$

$$x = \frac{138600}{220.3999834}$$

$$x = 628.8566 \text{ k}$$

3. 0.75 kg of Methane (CH_4) is completely burned in 20% excess air.

Determine EACH of the following:

(a) the mass of carbon dioxide in the exhaust gases per kg of fuel; (4)

(b) the mass of nitrogen in the exhaust. (4)

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

Carbon

C = 12

$\frac{12}{16} \times 0.75 = 0.5625$ kg

Burn Carbon

$C + O_2 = CO_2$

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

$\frac{0.5625}{12} = \frac{x}{32}$

x = 1.5 kg of oxygen to burn carbon

Hydrogen

$H_4 = 4$ total = 16

$\frac{4}{16} \times 0.75 = 0.1875$ kg

Burn Hydrogen

$H_2 + O = H_2O$

$\frac{mass}{RAM} = mols$ $\frac{0.1875}{2} = \frac{x}{16}$

x = 1.5 kg of oxygen to burn Hydrogen

a) Mass of CO_2 = Mass of Carbon + Mass of Oxygen

0.5625 + 1.5 = **2.0625 kg**

b) **Nitrogen**

Stoich oxygen = 1.5 + 1.5 = 3 kg

stoich Air $\frac{3}{0.23}$ = 13.04347 kg

total Air = 13.04347 × 1.2 = 15.65217 kg

Nitrogen in exhaust = 15.65217 × 0.77 = **12.05217 kg**

(4) A cast steel crank web is joined to a bearing journal by thermal interference fitting. The crank web is bored with an internal diameter of 149.55 mm at a temperature of 20°C. The journal has an external diameter of 150 mm at 20°C.

Determine the highest temperature to which the journal must be cooled in order to slide into the crank web without force. (7)

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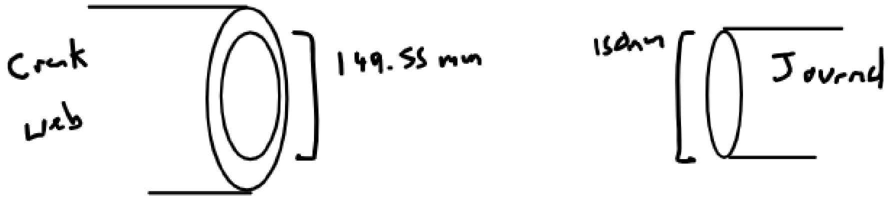

D + expansion = New Diameter

(expansion = $D \alpha \Delta t$)

$D = 150$

$\alpha = 0.000016$

$\Delta t = x$

New D = 149.55

$$150 + 150(0.000016)(x) = 149.55$$

$$x = \frac{149.55 - 150}{150(0.000016)}$$

$\Delta t = x = -187.5$

Find temp = start temp + change

$20 - 187.5 = -167.5°C$

or 105.5 K

5. State and describe the THREE modes of heat transfer, giving an example of each. (9)

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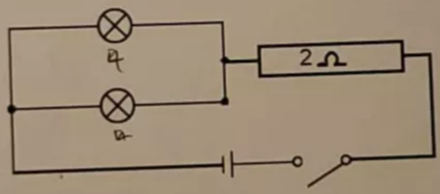
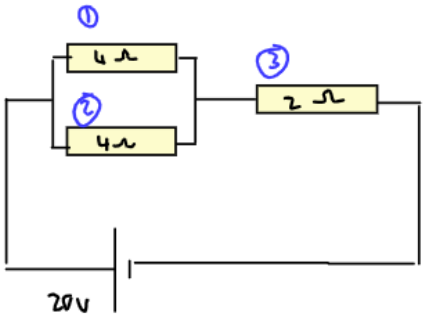


Fig Q8

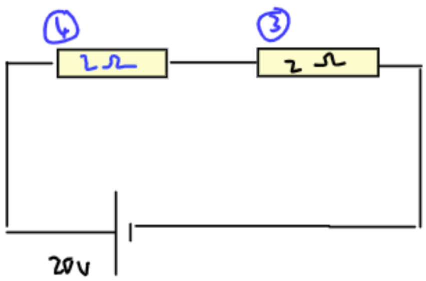


Res over Parallel section R_1 R_2

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

$$\frac{1}{R_T} = \frac{1}{4} + \frac{1}{4}$$

$$R_T = 2\,\Omega$$



Res over Series Section R_4 R_3

$$R_T = R_4 + R_3$$

$$2 + 2 = 4\,\Omega$$

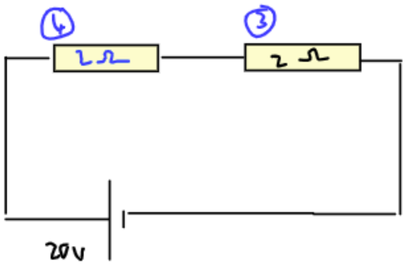
Circuit

V = 20

I = 5 Amps

R = 4

$I = \frac{V}{R} = \frac{20}{4} = 5$ Amp



Voltage drop over R_4 R_3

④

V = 10 V

I = 5

R = 2

③

V = 10V

I = 5

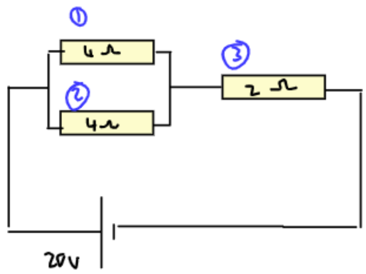
R = 2

$V = I \times R$

b) Power on R_3

P = IV

$P = 5 \times 10 = 50$ watts



a) Power on each lamp (R_1, R_2)

①
$V = 10$
$I = 2.5$ Amps
$R = 4$

②
$V = 10$
$I = 2.5$ Amps
$R = 4$

$I = \frac{V}{R} = \frac{10}{4} = 2.5$

$P = IV$
2.5×10
25 Watts

$P = IV$
2.5×10
25 watts

c) total Power = $25 + 25 + 50 = 100$ watts $\left(\frac{J}{sec}\right)$

in 60 mins = 1 hour

$100 \frac{J}{sec} \times 3600 = \boxed{360{,}000 \text{ J}}$

9. (a) State the meaning of the term *magnetic flux*, stating the units. (2)

(b) A conductor of 7.5 mm diameter has an effective length of 400 mm when carrying a current of 12 A at right angles to a magnetic field. The magnetic flux is measured to be 18 microwebers.

Determine the force on the conductor. (6)

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

Magnetic flux is the technical name for a magnetic field. It is measured in Weber and can be found in a few ways. One way would be to multiply the flux density (in Tesla) by the cross sectional area inside of the conductor (inside the loop)

$B \times A = \phi$

↑ magnetic flux

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

$B = \frac{18 \times 10^{-6}}{\left(\frac{7.5}{2000}\right)^2 \pi}$

$B = 0.40743665$ (Tesla)

$F = BIL\sin\theta$

$F = x$

$B = 0.40743665$

$I = 12$ Amps

$L = 0.4$m

$\theta = 90$

$F = 0.40743665 \times 12 \times 0.4$

$= 1.9556959$ N

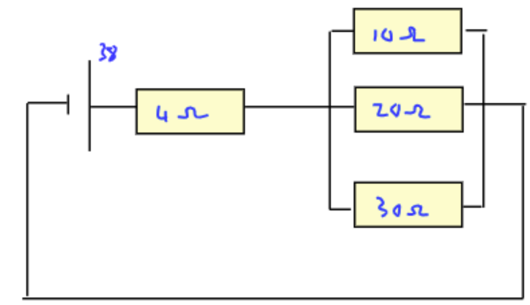
10. A battery has an e.m.f. of 38 volts and an internal resistance of 4 ohms. It feeds a circuit consisting of three resistors connected in parallel.

The resistors have values of 10 ohm, 20 ohm and 30 ohm.

Determine EACH of the following:

(a) the battery terminal voltage; (4)

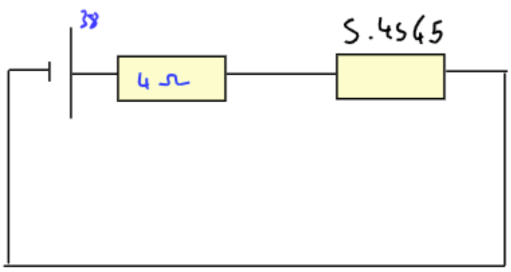
(b) the current in EACH resistor. (4)



Res in Parrallel section

$$\frac{1}{R_T} = \frac{1}{10} + \frac{1}{20} + \frac{1}{30}$$

$$R_T = 5.4545\,\Omega$$



Res in Series

$$R_T = 4 + 5.4545 = 9.4545\,\Omega$$

Circuit

$V = 38$

$I = 4.01923$ Amps

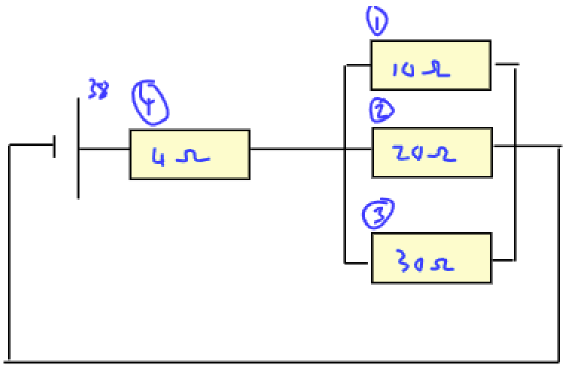
$R = 9.4545$

$$I = \frac{V}{R} \quad \frac{38}{9.4545}$$

$$I = 4.01923 \text{ Amps}$$

Emf - IR = supply Voltage.

a) $38 - 4.01923 \times 4 = 21.923$ volts



Current over R_1 R_2 R_3

b)

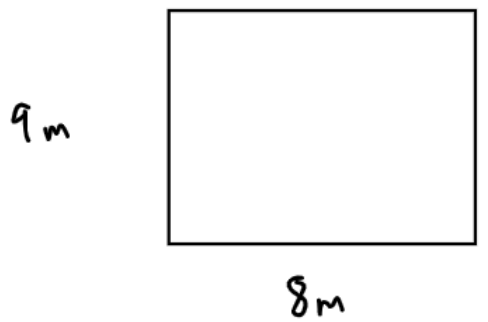
①	②	③
$V = 21.923$	$V = 21.923$	$V = 21.923$
$I = 2.1923$ Amp	$I = 1.09615$ Amps	$I = 0.7307666$ Amps
$R = 10$	$R = 20$	$R = 30$

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

11. (a) Determine the thrust load in MN on a bulkhead 8 m wide by 9 m deep when flooded with seawater of density 1025 kg/m^3 on one side only. (6)

(b) Determine the gauge pressure, in bar, at the lowest point on the bulkhead. (2)

a)



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

$= 1025 \times 9.81 \times 9 \times 8 \times 4.5$

$F = 3{,}257{,}901$ N

3.257901 MN

b) $P = \rho g h$

$= 1025 \times 9.81 \times 9$

$= 90497.25$ (Pa)

0.9049725 bar

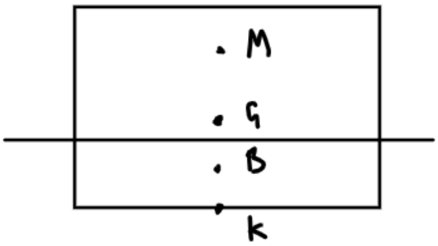
12. A ship has a displacement of 33250 tonnes. KM= 5.9 m and KG= 4.7 m.

(a) Explain what is meant by the terms KM and KG. (2)

(b) Determine the distance a mass of 220 tonne, already on board ship, must be moved across the deck to correct a heel of 1.8°. (6)

Note: $m \times d = \Delta GM \tan\theta$

a)



KM is the distance from the Keel to the Metacentre of the ship.

KG is the distance from centre of Gravity of the ship.

b)

$md = \Delta GM \tan\theta$

$m = 220$

$d = x$

$\Delta = 33250$

$GM = 5.9 - 4.7 = 1.2\,m$

$\theta = 1.8$

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

$$d = \frac{33250 \times 1.2 \times \tan 1.8}{220}$$

$$d = 5.69958\ m$$