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, 03 JULY 2026

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 Qualifications Scotland 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.

Qualifications Scotland

Maritime & Coastguard Agency

GENERAL ENGINEERING SCIENCE II

Attempt ALL questions

Marks for each question are shown in brackets.

Section A

1. (a) Explain why the units for specific heat capacity are in J/kgK. (2)

(b) A cast iron anchor has a mass of 45 kg and a temperature of 450°C. After losing 4200 kJ of heat energy it has a temperature of 255°C.

Determine EACH of the following:

(i) the specific heat capacity of Cast Iron; (3)

(ii) how much more heat transfer is required to reduce the temperature to 25°C. (3)

2. (a) Define Boyles Law. (2)

(b) A perfect gas at an initial pressure, temperature and volume of 2.75 bar, 185°C and 90 litres respectively is cooled at constant pressure until its temperature is 15°C.

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

3. Benzene (C_6H_6) is completely burned in 20% excess air.

Determine EACH of the following:

(a) the calorific value of Benzene per kg of fuel; (4)

(b) the mass of nitrogen in the exhaust gases per kg of fuel. (4)

Note: take air as 78% Nitrogen, Calorific value of carbon = 32.8MJ/kg, Lower Calorific value of Hydrogen = 120.1 MJ/kg

[OVER

4. (a) In a vapour compression refrigeration system explain how the refrigerant flow rate is controlled through the thermostatic expansion valve. State what this control is trying to achieve. (4)

(b) In a vapour compression refrigeration system, describe the primary function of EACH of the following:

(i) the expansion valve; (2)

(ii) the evaporator. (2)

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

6. A 2 stroke diesel engine is tested over a 24 hour period and uses 1.8 tonnes of fuel. The power of the engine is tested using a dynamometer which gives a steady state torque reading of 4.5 kNm at 800 rpm. The mechanical efficiency was later found to be 89%.

Determine EACH of the following:

(a) the brake power; (3)

(b) the indicated specific fuel consumption; (3)

(c) the brake thermal efficiency. (3)

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

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.

Determine EACH of the following:

(a) the value of the unknown resistor R; (3)

(b) the power dissipated by this resistor; (3)

(c) the total energy consumed by the circuit in 2 hours. (3)

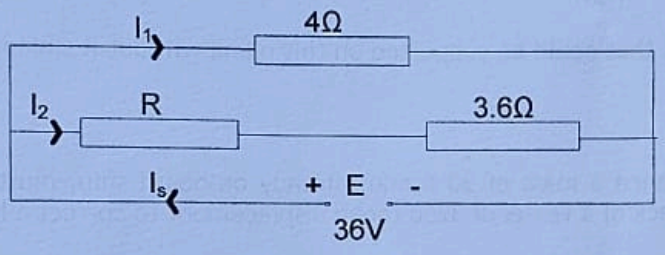

FIG Q7

8. (a) List THREE means by which electricity may be produced. (3)

(b) State the THREE main effects of an electric current. (3)

(c) State TWO practical examples of EACH effect in Q8(b). (3)

9. The navigation lights on a vessel are fed from a d.c supply. Four lights, each with a resistance of 4 Ω are connected in parallel and each draws a current of 5A.

Determine EACH of the following:

(a) the power dissipated by each lamp; (3)

(b) the total power consumed by the circuit if the total resistance of the cables was 0.6 Ω; (3)

(c) the supply voltage. (2)

[OVER

10. A conductor with an effective length of 300 mm and a diameter of 9.5 mm is carrying a current of 25 A at right angles to a magnetic field. The force on the conductor is 18 N.

Determine EACH of the following:

(a) the flux density; (4)

(b) the magnetic flux. (4)

11. A plank of wood is 4.88 m long x 25.8 cm wide x 175 mm deep and floats horizontally in calm water. Take the water density as 1010 kg/m^3 and the density of wood as 710 kg/m^3

Determine the mass that could be supported on this plank without it sinking. (8)

12. Determine the distance a mass of 30 tonne, already on-board ship, must be moved across the deck of a vessel of 3250 tonne displacement to correct a heel of 1.8°. (8)

Note: KM = 6.1 m, KG = 5 m, and m x d = Δ GM tan θ

1. (a) Explain why the units for specific heat capacity are in J/kgK. (2)

(b) A cast iron anchor has a mass of 45 kg and a temperature of 450°C. After losing 4200 kJ of heat energy it has a temperature of 255°C.

Determine EACH of the following:

(i) the specific heat capacity of Cast Iron; (3)

(ii) how much more heat transfer is required to reduce the temperature to 25°C. (3)

a)

b)

$Q = 4{,}200{,}000\ J$

$m = 45\ kg$

$c = x$

$\Delta t = 450 - 255 = 195$

$Q = mc\Delta t$

$4{,}200{,}000 = 45(x)\,195$

$\frac{4200000}{45 \times 195} = x$

$478.63\ J/kgK$

2. (a) Define Boyles Law. (2)

(b) A perfect gas at an initial pressure, temperature and volume of 2.75 bar, 185°C and 90 litres respectively is cooled at constant pressure until its temperature is 15°C.

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

a)

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

$P_1 = 2.75 bar = 275,000 (P_a)$ $\quad P_2 = 2.75 bar = 275,000 Pa$

$V_1 = 90 L = 0.09 m^3$ $\quad V_2 = x$

$T_1 = 185°C = 458 k$ $\quad T_2 = 15°C = 288 k$

i) $pv = mRt$

$275,000 \times 0.09 = x\,(290)(458)$

$24750 = x\,132820$

$\frac{24750}{132820} = x$

0.186342 kg

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

$\frac{0.09}{458} = \frac{x}{288}$

$0.056594 m^3$

Final vol

3. Benzene (C_6H_6) is completely burned in 20% excess air.

Determine EACH of the following:

(a) the calorific value of Benzene per kg of fuel; (4)

(b) the mass of nitrogen in the exhaust gases per kg of fuel. (4)

Note: take air as 78% Nitrogen, Calorific value of carbon = 32.8MJ/kg, Lower Calorific value of Hydrogen = 120.1 MJ/kg

H = 1 C = 12 O = 16 Air 22% oxygen

Carbon

$6 \times 12 = 72$

$\frac{72}{78} \times 1 = 0.923076$ kg

Hydrogen

$6 \times 1 = 6$

$\frac{6}{78} \times 1 = 0.076923$ kg

total

78

a) Cal content

0.923076×32.8 MJ + 0.076923×120.1 MJ

30.2769 + 9.23846 = **39.515 MJ/kg**

Burn Carbon

$C + O_2 = CO_2$

mols = mass / RAM $\frac{0.923076}{12} = \frac{x}{32}$

2.461538 Kg of oxy Req to burn Carbon

Burn Hydrogen

$H_2 + O = H_2O$

$\frac{0.076923}{2} = \frac{x}{16}$

0.615384 kg of oxy Req to burn Hydrogen

Stoich oxy = 2.461538 Kg + 0.615384 kg

3.076738

Stoich air @ 22% oxygen

$x \; 0.22 = 3.076738$

$x = \frac{3.076738}{0.22}$

$x = 13.98517 \text{ kg}$

include excess @ 20%.

$1.20 \times 13.98517 = 16.7822 \text{ kg}$

Nitrogen @ 78%.

$0.78 \times 16.7822 \text{ kg} = \boxed{13.0901 \text{ kg}}$

4. (a) In a vapour compression refrigeration system explain how the refrigerant flow rate is controlled through the thermostatic expansion valve. State what this control is trying to achieve. (4)

(b) In a vapour compression refrigeration system, describe the primary function of EACH of the following:

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

6. A 2 stroke diesel engine is tested over a 24 hour period and uses 1.8 tonnes of fuel. The power of the engine is tested using a dynamometer which gives a steady state torque reading of 4.5 kNm at 800 rpm. The mechanical efficiency was later found to be 89%.

Determine EACH of the following:

(a) the brake power; (3)

(b) the indicated specific fuel consumption; (3)

(c) the brake thermal efficiency. (3)

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

$$Imep = \frac{A\,\phi}{L} \qquad IP = z\,p\,Lan \qquad BP = T\,2\pi N$$

$$Eff = \frac{BP}{IP} \times 100 \qquad Isfc = \frac{\text{fuel consumption kg/h}}{IP\ (kW)} \qquad bte = \frac{BP\ (\text{watts} = \frac{J}{s})}{\text{Cal content} \times \text{fuel consumption}}$$

$$\frac{J}{\cancel{kg}} \times \frac{\cancel{kg}}{sec}$$

a) $BP = 4500 \times 2\pi \times 13.333$

$800\ Rpm \div 60 = 13.333\ Rev/sec$

$BP = 376{,}991\ (Watts)$

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

$0.89 = \frac{376,991}{IP}$

$IP = \frac{376\,991}{0.89}$

$IP = 423,585.4$ Watts

423.585 kW

fuel consumption $= \frac{1800\ kg}{24hr}$

$75\ kg/hour$

$Isfc = \frac{75}{423.585}$

$0.17706\ kg/kw$

c) $bte = \frac{BP \ (watts = \frac{J}{s})}{\text{Cal content} \times \text{fuel consumption}}$

$\frac{J}{kg} \times \frac{kg}{sec}$

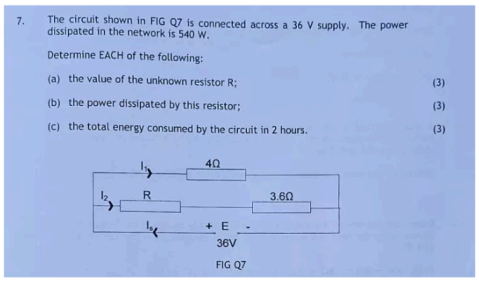
$BP = 376,991$

fuel consumption $= \frac{1800\ kg}{24hr} = 75\ kg/hour \xrightarrow{\div 3600} 0.0208333\ kg/sec$

$Cal = 44 \times 10^6\ J$

$bte = \frac{376,991}{44 \times 10^6 \times 0.0208333} \times 100$

41.126%



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

Determine EACH of the following:

(a) the value of the unknown resistor R; (3)

(b) the power dissipated by this resistor; (3)

(c) the total energy consumed by the circuit in 2 hours. (3)

FIG Q7

Circuit

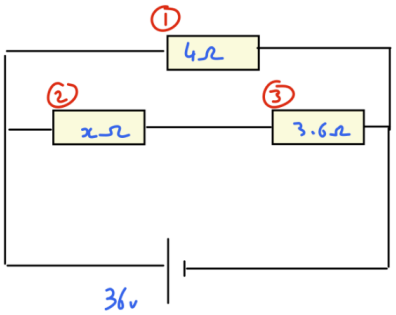
a) $P = 540$ watts

$P = IV$

$540 = I(36)$

$\frac{540}{36} =$

15 Amps



find current for R1

(1)

$V = 36$

$I = 9$ Amps

$R = 4$

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

find voltage drop across R3

$15 - 9 = 6$ Amps

(3)

$V =$

$I = 6$

$R = 3.6$

$V = I \times R$

$6 \times 3.6 = 21.6$

find RES for R2

(2)

$V = 36 - 21.6 = 14.4$v

$I = 6$

$R = x$

$R = \frac{V}{I} = \frac{14.4}{6} =$ **2.4 Ω**

b) $P = IV$

$P_2 = I_2 V_2$

$= 6 \times 14.4 =$ **86.4 watts**

c) 540 watts

0.54 kW

× 2h

1.08 kwhr

8. (a) List THREE means by which electricity may be produced. (3)

(b) State the THREE main effects of an electric current. (3)

(c) State TWO practical examples of EACH effect in Q8(b). (3)

9. The navigation lights on a vessel are fed from a d.c supply. Four lights, each with a resistance of 4 Ω are connected in parallel and each draws a current of 5A.

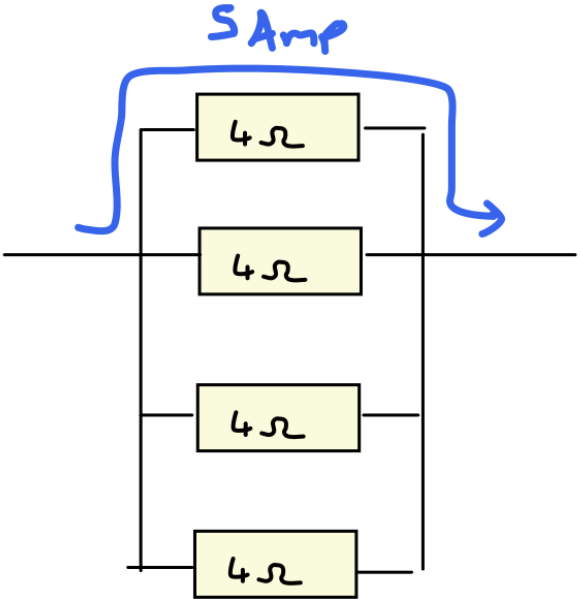
Determine EACH of the following:

(a) the power dissipated by each lamp; (3)

(b) the total power consumed by the circuit if the total resistance of the cables was 0.6 Ω; (3)

(c) the supply voltage. (2)

a)



$P = IV$

$V = I \times R$

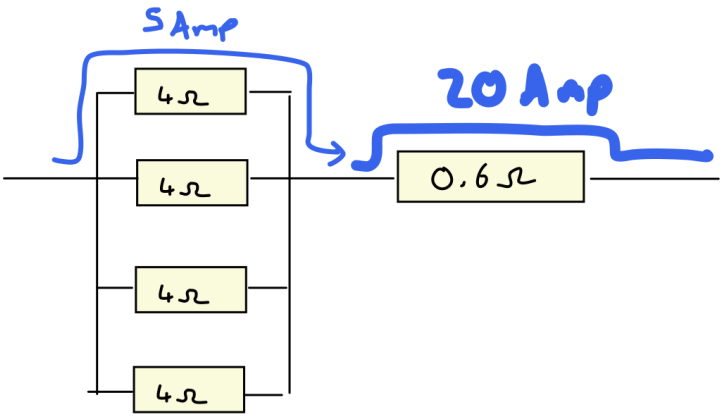
$V = 5 \times 4 = 20\ V$

$P = 5 \times 20$

100 watts

each lamp

b)



voltage drop across cables

$V = 20 \times 0.6 = 12v$

$I = 20$

$R = 0.6$

$V = I \times R$

$P = IV$

$P = 20 \times 12$

240 watts

$4 \times 100 + 240 = \boxed{640 \text{ Watts}}$

c) Supply voltage = Voltage drop (lamps) + Voltage drop (cables)

$20 + 12 = \boxed{32v}$

10. A conductor with an effective length of 300 mm and a diameter of 9.5 mm is carrying a current of 25 A at right angles to a magnetic field. The force on the conductor is 18 N.

Determine EACH of the following:

(a) the flux density; (4)

(b) the magnetic flux. (4)

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

a) $F = 18N$

$B = x$

$I = 25A$

$L = 0.3m$

$\sin\theta = 1$

$18 = x(25)(0.3)$

$\frac{18}{7.5} = x$

2.4 Tesla

b) $BA = \phi$

$B = 2.4\ T$

$A = \left(\frac{9.5}{2000}\right)^2 \pi = 7.08821 \times 10^{-5}\ m^2$

$2.4 \times 7.08821 \times 10^{-5} = \phi$

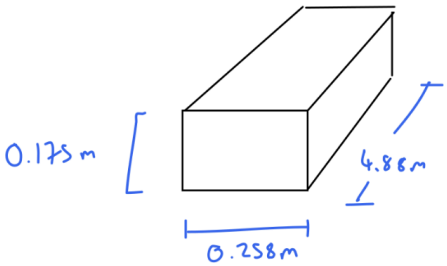
1.701172×10^{-4} Wb

11. A plank of wood is 4.88 m long x 25.8 cm wide x 175 mm deep and floats horizontally in calm water. Take the water density as 1010 kg/m^3 and the density of wood as 710 kg/m^3

Determine the mass that could be supported on this plank without it sinking. (8)

volume of wood = volume of water displaced

mass of wood + EXTRA load = mass of water displaced



$$\text{Vol wood} = L \times w \times h$$
$$= 4.88 \times 0.258 \times 0.175$$
$$= 0.220332 \text{ m}^3$$

$$\text{Vol water} = 0.220332 \text{ m}^3$$

Mass wood

$m = d \times \text{vol}$

$710 \times 0.220332 = 156.435$ kg

Mass of water

$m = d \times \text{vol}$

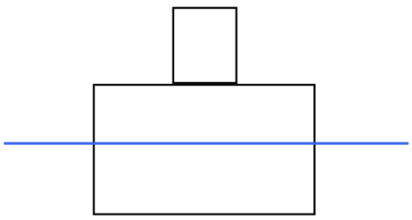
$1010 \times 0.220332 = 222.5353$ kg

Mass Water − Mass Wood = Mass Extra load

$222.5353 - 156.435 =$ **66.10032 kg**

12. Determine the distance a mass of 30 tonne, already on-board ship, must be moved across the deck of a vessel of 3250 tonne displacement to correct a heel of 1.8°. (8)

Note: KM = 6.1 m, KG = 5 m, and m x d = Δ GM tan θ



$m = 30$t

$d = x$

$\Delta = 3250$

$GM = KM - KG = 6.1 - 5 = 1.1$ m

$\tan(1.8)$

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

$30x = 3250(1.1)\tan(1.8)$

$x = \dfrac{112.3489}{30}$

$x = 3.74496$ m