CERTIFICATES OF COMPETENCY IN THE MERCHANT NAVY - MARINE ENGINEER OFFICER

STCW 78 as amended CHIEF ENGINEER REG. III/2 - "YACHT 2"
STCW 78 as amended SMALL VESSEL CHIEF ENGINEER <3000 GT, <9000 kW UNLIMITED

058-12 - GENERAL ENGINEERING SCIENCE II

FRIDAY, 09 OCTOBER 2020

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.

All formulae used must be stated and the method of working and ALL intermediate steps must be made clear in the answer.

Section A

1. A steel forging has a mass 6 kg and is cooled from a temperature of 400°C by being completely immersed in a tank containing 8 kg of oil at a temperature of 20°C.

   Calculate the final equilibrium temperature of the oil and the steel forging, assuming there are no heat losses from the tank. The effect of the tank can be ignored. (8)

   Note: s.h.c. of steel = 0.48 kJ/kgK
   s.h.c. of oil = 1.8 kJ/kgK

2. Nitrogen gas has a volume of 0.3 m^3 at 3.5 bar and a temperature of 35°C. The nitrogen is now heated in its vessel until the pressure reaches 1.05 MN/m^2, at constant volume.

   Determine EACH of the following:

   (a) the mass of nitrogen; (3)

   (b) the final temperature of the nitrogen. (5)

   Note: The characteristic gas constant
   R, for nitrogen has a value of 297 J/kgK.

3. (a) Describe, with the aid of a P-h diagram, the condition of the refrigerant fluid as it flows around the basic vapour compression plant. (6)

   (b) List the energy changes that occur in the refrigerant across EACH item of plant in the basic refrigeration system of Q3(a). (4)

4. A 4 cylinder 2 stroke diesel engine under test has a bore of 120 mm and a stroke of 150 mm and runs at 800 revs per minute. 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 579 Nm.

Calculate EACH of the following:

(a) the brake power; (3)

(b) the indicated power; (3)

(c) the mechanical efficiency. (2)

5. Methane (CH_4) 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; (4)

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

6. (a) A straight steel steam pipe is 20 m long at 20°C. In use the temperature rises to 450°C.

Determine the length of the steam pipe when in use. (4)

(b) State the practical considerations that need to be considered before fastening the pipe to the bulkhead. (4)

Note: coefficient of linear thermal expansion for steel = 12 x 10^{-6} m/mK

Section B

7. A solid block of wood is 2 m long x 90 cm wide x 50 cm deep and floats in sea water of density 1025 kg/m^3.

   Calculate the height of block above the water surface (freeboard) given that the wood has a density of 750 kg/m^3 and that it floats horizontally. (8)

8. A box barge has a displacement volume of 18500 m^3 in sea water of density 1025 kg/m^3.

   A ballast tank measuring 6 m long x 12 m wide x 1.6 m deep is positioned equally either side of the centre line above the keel.

   The tank is now completely filled with sea water.

   Calculate the change in position of G, in both magnitude and direction, given that the initial KG=3.8 m. (8)

9. A battery with an e.m.f. of 40 volts is found to have an internal resistance of 3 ohms. It feeds a circuit consisting of three resistors connected in parallel.

   The resistors have values of 120 ohm, 180 ohm and 250 ohm.

   Calculate EACH of the following:

   (a) the battery terminal voltage; (4)

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

10. (a) Define the resistivity of a material. (3)

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

    Calculate the resistance of 1 km of iron wire of 1 mm diameter. (7)

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

11 (a) In a moving coil instrument what is the purpose of a *multiplier* resistor. (2)

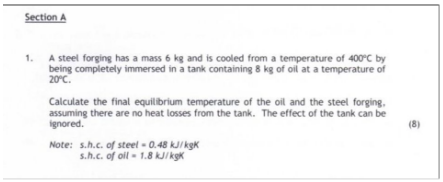
(b) Describe, with the aid of a diagram, the operation of a moving iron instrument. (6)

12. (a) Copper is a familiar conductor of electricity. In relation to its structure explain why it is a good conductor of electricity. (2)

(b) Explain why PVC is not a good conductor of electricity, in relation to its structure. (2)

(c) Explain why conductors have power losses. (2)

(d) State how power losses can be calculated in conductors. (2)



Section A

1. A steel forging has a mass 6 kg and is cooled from a temperature of 400°C by being completely immersed in a tank containing 8 kg of oil at a temperature of 20°C.

Calculate the final equilibrium temperature of the oil and the steel forging, assuming there are no heat losses from the tank. The effect of the tank can be ignored. (8)

Note: s.h.c. of steel = 0.48 kJ/kgK
s.h.c. of oil = 1.8 kJ/kgK

$Q = mc\Delta t$

Energy lost (steel) = Energy gained (oil)

		Start	Find	Δt	$Q = mc\Delta t$ Calc
lose	Steel	mass = 6 kg temp = 400 c = 480	$t = x$	$(400 - x)$	$Q = 6 \times 480 (400 - x)$
gain	oil	mass = 8 kg temp = 20 c = 1800	$t = x$	$(x - 20)$	$Q = 8 \times 1800 (x - 20)$

$6 \times 480 (400 - x) = 8 \times 1800 (x - 20)$

$2880 (400 - x) = 14400 (x - 20)$

$1152000 - 2880x = 14400x - 288000$

$140000 = 17280x$

$x = 83.333\ ^\circ C$

Find temp

2. Nitrogen gas has a volume of 0.3 m^3 at 3.5 bar and a temperature of 35°C. The nitrogen is now heated in its vessel until the pressure reaches 1.05 MN/m^2, at constant volume.

Determine EACH of the following:

(a) the mass of nitrogen; (3)

(b) the final temperature of the nitrogen. (5)

Note: The characteristic gas constant R, for nitrogen has a value of 297 J/kgK.

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

a) $V = 0.3 m^3$

$p = 3.5 bar \quad 350,000 Pa \ (N/m^2)$

$m = x$

$t = 35 + 273 = 308°K$

$r = 297$

$$\frac{350,000 \times 0.3}{297 \times 308} = m$$

$1.1478 kg$

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

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

$P_1 = 350{,}000$

$T_1 = 35 + 273$

$= 308$

$P_2 = 1.05\ MN/m^2$

$= 1.05 \times 10^6$

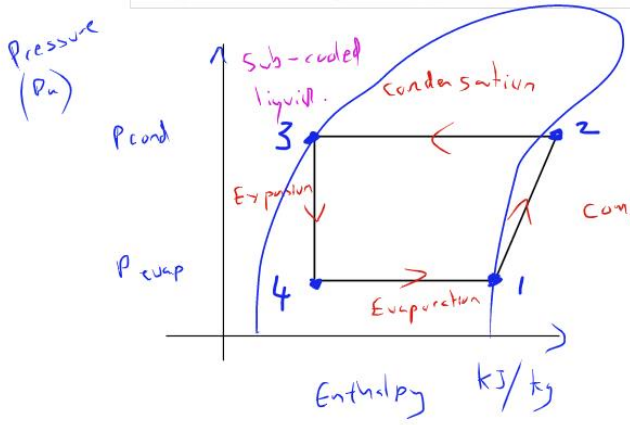
$T_2 = x$

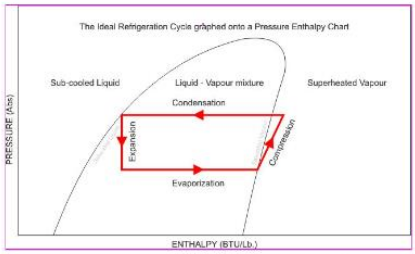
$$\frac{350{,}000}{308} = \frac{1.05 \times 10^6}{x}$$

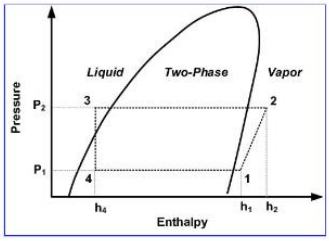
$x = 924\ K$

3. (a) Describe, with the aid of a P-h diagram, the condition of the refrigerant fluid as it flows around the basic vapour compression plant. (6)

(b) List the energy changes that occur in the refrigerant across EACH item of plant in the basic refrigeration system of Q3(a). (4)







1)

2)

3)

4. A 4 cylinder 2 stroke diesel engine under test has a bore of 120 mm and a stroke of 150 mm and runs at 800 revs per minute. The mean effective pressure was found to be 600 kN/m². During the test a torsion meter on the shaft gave a reading of 579 Nm.

Calculate EACH of the following:

(a) the brake power; (3)

(b) the indicated power; (3)

(c) the mechanical efficiency. (2)

$Eff = \frac{BP}{IP}$ $\quad BP = T\,2\pi\,N$

$IP = x\,p\,a\,N$ (Imep)

bore = diameter = 120mm = 0.12 m

$r = 0.06$

area $= \pi r^2 = \pi(0.06)^2$

length = 150 mm = 0.15 m

$N = \frac{800\ Rev}{60\ sec} = 13.333\ Rev/s$

Imep = p = 600,000

$x = 4$

$T = 579\ Nm$

$BP = 579 \times 2\pi \times 13.33333$

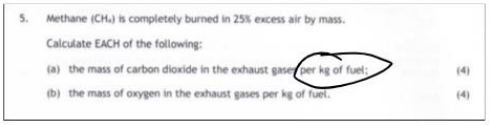
a) $BP = 48506.19057$ Watts

b) $IP = 4 \times 600{,}000 \times 0.15 \times \pi(0.06)^2 \times 13.333333$

54286.7 Watts

c) $Eff = \frac{BP}{IP} = \frac{48506.19057}{54286.7} = 0.89351$

89.351 %



5. Methane (CH_4) 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; (4)

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

C = 12 H = 1 O = 16

Air = 23% oxy

$C = 12$ $H_4 = 4$ $CH_4 = 16$

Mass of Carbon

$\frac{12}{16} \times 1 = 0.75\,kg$

Mass of Hydrogen

$\frac{4}{16} \times 1 = 0.25\,kg$

Burn Carbon

$C + O_2 = CO_2$

Burn hydrogen

$H_2 + O = H_2O$

Mass / RAM $\quad \frac{0.75}{12} = \frac{x}{32}$

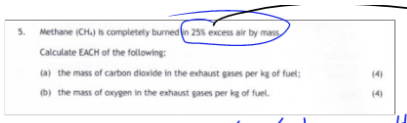
Mass / RAM $\quad \frac{0.25}{2} = \frac{x}{16}$

$\frac{0.75 \times 32}{12} = x = 2\,kg$ oxygen

$x =$ 2 kg oxygen to burn hydrogen.

a) Carbon + Oxygen = CO_2

$0.75 + 2 = 2.75\,kg$



b)

oxygen required for Carbon + Hydrogen

2kg + 2kg = 4kg

25% 1kg Oxygen

Mass	75% Nitrogen	23% oxygen	Mass
Vol	78%	21%	

Amount of Air Required

4kg oxygen = 0.23 Air

$\frac{4}{0.23}$ = Air = 17.39130

Air + 25% = 17.3913 × 1.25 = 21.73 kg

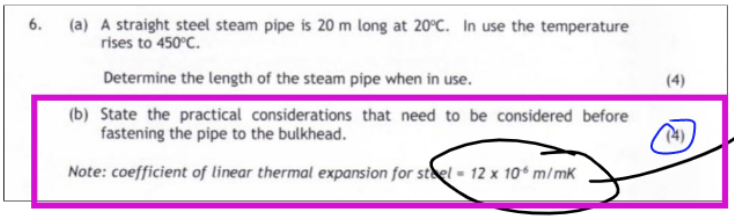
Input oxygen

21.73 × 0.23 = 5kg

Input − Burnt Oxygen = Output

5 − 4 = 1

Ans: 1KG



6. (a) A straight steel steam pipe is 20 m long at 20°C. In use the temperature rises to 450°C.

Determine the length of the steam pipe when in use. (4)

(b) State the practical considerations that need to be considered before fastening the pipe to the bulkhead. (4)

Note: coefficient of linear thermal expansion for steel = 12 x 10^{-6} m/mK

12×10^{-6} m/mK

a) Length + extension = New length

$L + (L \times \alpha \times \Delta t) =$

$20 + (20 \times 12 \times 10^{-6} \times 430) = 20.1032$ m

b)

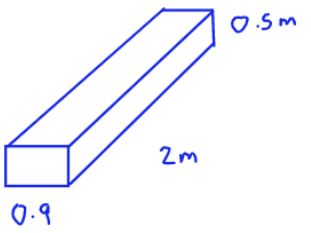
linear expansion due to heating and cooling the pipe, this would cause an extenesion or contractions of the pipe. In very long pipes this would be noticable, and could cause damage. Expansion vlaues or Bellows can compensate for this.

Safety and practicallity. If the pipework is carrying hot contents, be aure that it is well lagged, and safe to touch. If it contains cold contents, be sure to insulate to reduce condensation and corrosion on the outisde.

Section B

7. A solid block of wood is 2 m long x 90 cm wide x 50 cm deep and floats in sea water of density 1025 kg/m³.

Calculate the height of block above the water surface (freeboard) given that the wood has a density of 750 kg/m³ and that it floats horizontally. (8)



$Vol = w l d$

$Vol = 0.9 \times 2 \times 0.5 = 0.9\ m^3$

$d = \frac{m}{V}$

Wood

$m = dv =$

$750 \times 0.9 = 675\ kg$

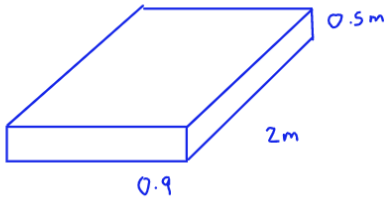
Mass of water displaced = Mass of object

$= 675$

$V \times d$

$\times 1025 = 675$

volume of water $= \frac{675}{1025} = 0.65854\ m^3$



$x \cdot 2 \cdot 0.9 = 0.65854$

submerged

$0.36585\ m$

Free $= 0.134146\ m$

8. A box barge has a displacement volume of 18500 m^3 in sea water of density 1025 kg/m^3.

A ballast tank measuring 6 m long x 12 m wide x 1.6 m deep is positioned equally either side of the centre line above the keel.

The tank is now completely filled with sea water.

Calculate the change in position of G, in both magnitude and direction, given that the initial KG=3.8 m. (8)

Name	Mass	Dis	Mom	Direction
ship =	18962.5	3.8		
load	118.08	0.8		
ship + load =	19080.58	x		

$(18962.5 \times 3.8) + (118.08 \times 0.8) = 19080.58\,x$

$x = 3.78143$ New kg

Change $3.8 - 3.7814 = 0.0185$ m down

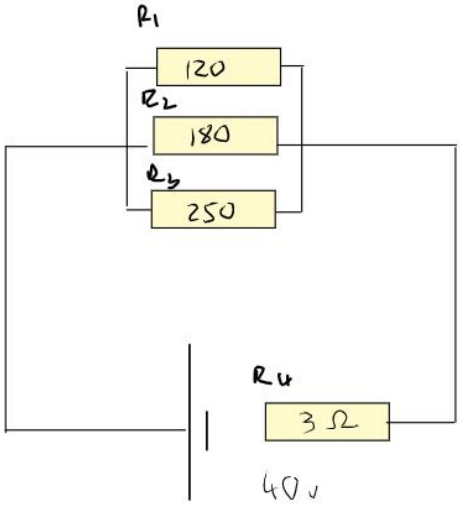
9. A battery with an e.m.f. of 40 volts is found to have an internal resistance of 3 ohms. It feeds a circuit consisting of three resistors connected in parallel.

The resistors have values of 120 ohm, 180 ohm and 250 ohm.

Calculate EACH of the following:

(a) the battery terminal voltage; (4)

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



Resistance over Parallel section

$$\frac{1}{R_T} = \frac{1}{120} + \frac{1}{180} + \frac{1}{250}$$

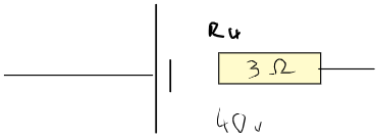
R_T 55.9006 Ω

Resistance over series

55.9006 + 3 = 58.9006

Circuit current

$$I = \frac{V}{R} = \frac{40}{58.9006} = 0.6791099863 \text{ Amps}$$

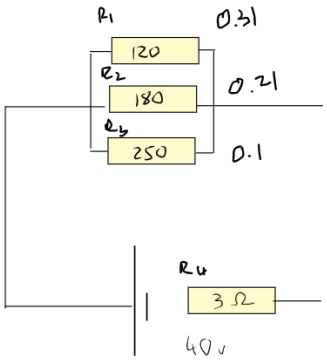


Voltage drop over R_4

$V = I \times R$

$0.6791099863 \times 3 = 2.03$

37.962 Volts



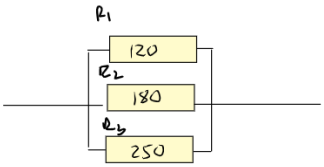
Current over each resistor

$I_4 =$ 0.6791099863

$R_1 R_2 R_3$

R_T 55.9006 Ω

Supply voltage = 37.962



$I_1 = \frac{37.962}{120} = 0.316$ A

$I_2 = \frac{37.962}{180} = 0.2109$ A

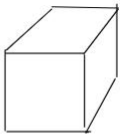
$I_3 = \frac{37.962}{250} = 0.151848$ A

10. (a) Define the resistivity of a material. (3)

(b) The resistance of 1.9 km of copper wire of 0.5 mm diameter is 170 ohms.
Calculate the resistance of 1 km of iron wire of 1 mm diameter. (7)

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

a)



the amount of resistence when passing a known current through a unit cube of material (1 meter cube)

units Ω metres

formula

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

b) Copper

$L = 1900$ m

$d = 0.5$ mm $= 5 \times 10^{-4}$ m

$R = 170\ \Omega$

$\rho =$

$A = \pi (5 \times 10^{-4})^2$

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

$170 = \frac{\rho \times 1900}{\pi (2.5 \times 10^{-4})^2}$

$\rho = 1.7568168 \times 10^{-8}$ ✓

iron

$L = 1000$

$d = 1$ mm

$r = 0.5$ mm

$r = 0.5 \times 10^{-3}$ m

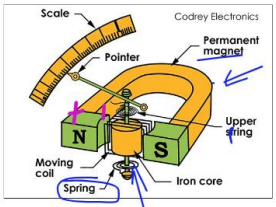
$\rho = 5.9 (1.7568168 \times 10^{-8})$

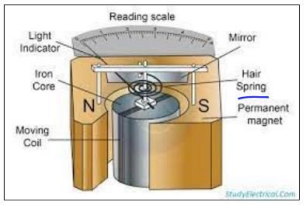
$R = \frac{\rho L}{A} = \frac{5.9 (1.7568168 \times 10^{-8}) \times 1000}{\pi (0.5 \times 10^{-3})^2}$

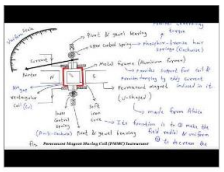
$\frac{1.03685 \times 10^{-4}}{7.85 \times 10^{-7}} = 132.038\ \Omega$

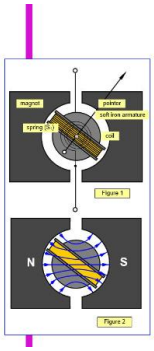
11 (a) In a moving coil instrument what is the purpose of a *multiplier* resistor. (2)

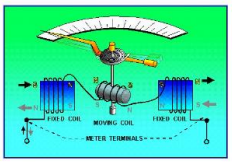
(b) Describe, with the aid of a diagram, the operation of a moving iron instrument. (6)









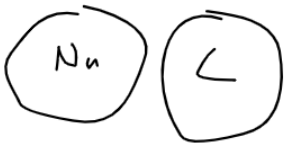


12. (a) Copper is a familiar conductor of electricity. In relation to its structure explain why it is a good conductor of electricity. (2)

(b) Explain why PVC is not a good conductor of electricity, in relation to its structure. (2)

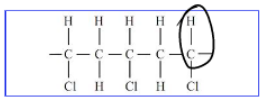
(c) Explain why conductors have power losses. (2)

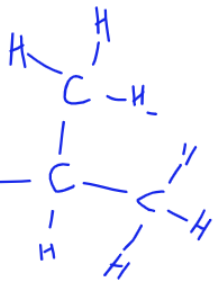
(d) State how power losses can be calculated in conductors. (2)



a) giant lattice structure
valence electrons

b) Poly vinly chloride





doesnt have a giant lattic strucure, doesnt have valence electrons,

c) internal resistance, P= IV (v= IR)