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, 25 JUNE 2021

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) Explain the units for specific heat capacity J/kgK. (2)

   (b) An iron casting has a mass of 15 kg and a temperature of 200°C.

   Determine the temperature after losing 1100 kJ of heat energy. (6)

   Note: Specific Heat Capacity of Cast Iron = 477J/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.

   Calculate 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.

   Calculate 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 gases per kg of fuel. (4)

[OVER

4. (a) State TWO desirable properties of refrigerants. (2)

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

(i) the condenser; (2)

(ii) the expansion valve; (2)

(iii) 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%.

Calculate 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. (a) Briefly describe the structure of an atom. (2)

(b) State the feature of the atomic structure of some materials which makes them good conductors. (2)

(c) Describe what is meant by electrical current (flow). (2)

(d) Outline what else is required to make current flow happen. (2)

8. (a) List FOUR means by which electricity may be produced. (2)

(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. THREE lights are connected in parallel and EACH draws a current of 5 A. The lamps have a resistance of 3 Ω each.

Calculate EACH of the following:

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

(b) the total power consumed by the circuit if the total resistance of the cables was 0.6 Ω; (4)

(c) the supply voltage. (2)

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

Calculate 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

Calculate the maximum 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 $m * d = \Delta GM \tan\theta$

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

(b) An iron casting has a mass of 15 kg and a temperature of 200°C.

Determine the temperature after losing 1100 kJ of heat energy. (6)

Note: Specific Heat Capacity of Cast Iron = 477J/kgK

Joules per kilogram kelvin

a) the amount of energy in Joules required to heat one kilogram of a material by one degree kelvin

b) $Q = mc\Delta t$

$Q = 1{,}100{,}000\ J$

$m = 15$

$c = 477$

$\Delta t = x$

$Q = m\ c\ \Delta t$

$1{,}100{,}000 = 15 \times 477x$

$$\frac{1{,}100{,}000}{15(477)} = x = 153.738$$

$00 - 153.738 = 46.2613\,^{\circ}C$

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.

Calculate 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

$Q = mc\Delta t$

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

$$PV = mRt$$

a) increasing pressure decreases volume, and vice versa at a constant temperature.

b) i) $P = 2.75$ bar $= 275{,}000$

$V = 90\ L = 0.09\ m^3$

$m = x$

$R = 290$

$t = 185 + 273 = 458\ K$

$275{,}000 \times 0.09 = x\ 290 \cdot 458$

$$\frac{275{,}000 \times 0.09}{290 \cdot 458} = x = 0.18634\ \text{kg}$$

b)

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

$V_1 = 0.09$ $V_2 = x$

$T_1 = 458\,k$ $T_2 = 288$

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

$$x = 0.05659388 \ m^3$$

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

Calculate 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 gases per kg of fuel. (4)

RAM Carbon = 12 Oxygen 16 H = 1

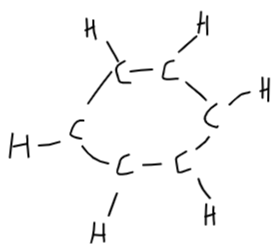
23% Oxygen in Air by vol

77% Nitrogen in Air by vol

How much Carbon and Hydrogen are we burning? (1 kg Fuel)

C_6H_6 $C = 12$ $C_6 = 12 \times 6 = 72$

$\frac{72}{78} \times 1 = 0.923077$ kg of Carbon



$H = 1$ $H_6 = 1 \times 6 = 6$

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

total = 78

Burn Carbon

$$C + O_2 = CO_2$$

$$\frac{\text{Mass}}{\text{RAM}} \quad \frac{0.92377}{12} = \frac{x}{32}$$

$\frac{\text{Mass of Carbon}}{\text{Mass of Oxy}} = \frac{\text{Mass } CO_2}{3.38508}$

$x = 2.461538$ kg of Oxygen to burn carbon

Burn Hydrogen

$$H_2 + O = H_2O$$

$$\frac{\text{Mass}}{\text{RAM}} \quad \frac{0.076923}{2} = \frac{x}{16}$$

$x = 0.615384$ kg of oxygen to burn Hydrogen

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a) Mass of CO_2 produced by kg fuel = 3.38508 kg

b) Mass oxygen Required to burn 1kg Fuel

2.461538 + 0.615384 = 3.076922 kg Oxygen Required

Amount of Air Required

$x \times 0.23 = 3.076922$

Air = 13.3774174

Add 20% = 16.0535 kg of Air

Nitrogen = (Air) × 0.77 = 12.3612 of Nitrogen

4. (a) State TWO desirable properties of refrigerants. (2)

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

(i) the condenser; (2)

(ii) the expansion valve; (2)

(iii) the evaporator. (2)

a) non explosive, non toxic etc

b)

condenser removes the heat energy from the super heated refridgerant lowering the saturation point

expansion values reduces the rpessure of the high pressure low temeprature liquid

the evaporator removes the heat from the compenent space. resulting in superheated gas.

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

Conduction – heat transfer across solids (not it liquids or gasses) an example would be metal tubes in a boiler, or the heat exchanger in cold water

convection - heat transfer by a liquid or a gas, convectional current through forced or natural convectional currents. An example is the hot water in a boiler

Radiation - heat transfer by the electromagetic spectrum, radiation can pass through a vacuum and it is the heat we feel from the sun. An example onboard would be the heat from the radition of a flame inside the boiler.

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%.

Calculate 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

Diagram

$$Imep = \frac{\text{Area } \alpha}{\text{length}}$$

$$Eff(mech) = \frac{BP}{IP}$$

IP = x plan

a) $BP = T 2\pi N$

$$N = \frac{800 \text{ Rev}}{\text{min}} = \frac{800}{60} = 13.33333 \text{ Rev/s}$$

$T = 4500$ N

$BP = 4500 \times 2\pi \times 13.3333 = 376{,}991.1183$

376.991 kW

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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%.

Calculate 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

$$Eff = \frac{BP}{IP} \qquad 0.89 = \frac{376,991.1183}{IP}$$

$$IP = \frac{376,991.1183}{0.89} = 423585 \text{ Watt}$$

$$423.585 \text{ kW}$$

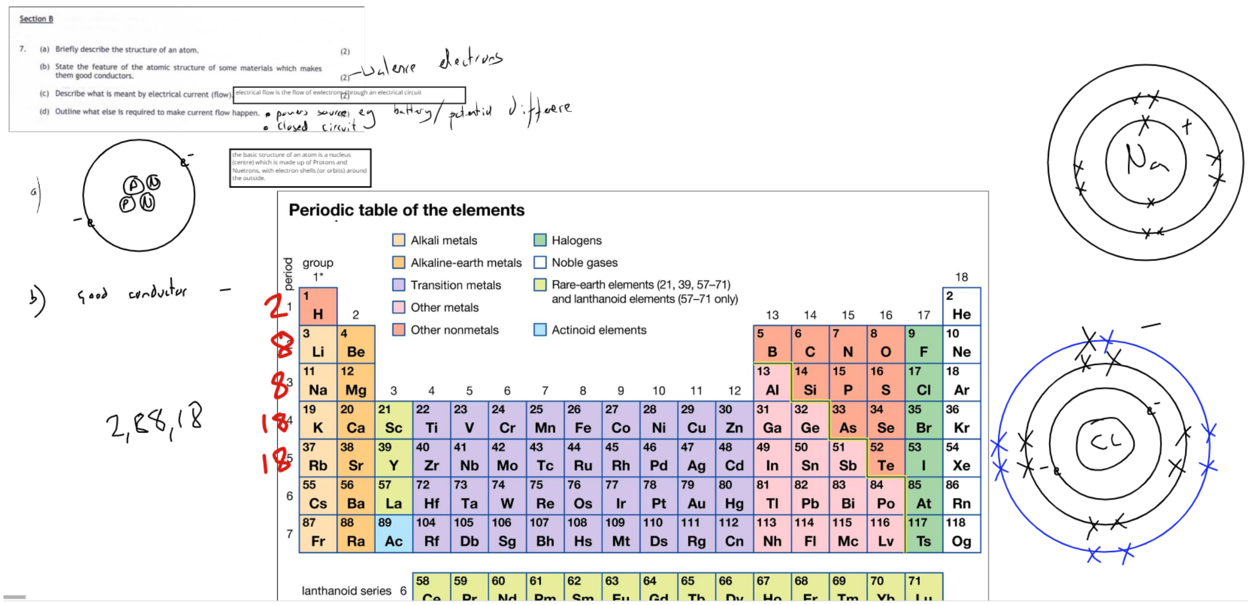
b) $$Isfc = \frac{\dot{m} \ \ Kg/hour}{IP \ \ (kw)}$$

$$\frac{1800/24}{423.585}$$

$$= 0.1770599 \text{ Kg/kwh}$$

c) $$\text{Break thermal eff} = \frac{BP}{m \cdot C} = \frac{376,991.1183}{0.020833 \times 44 \times 10^6} = 0.411269$$

efficiency = 41.127 %



8.	(a)	List FOUR means by which electricity may be produced.	(2)
	(b)	State the THREE main effects of an electric current.	(3)
	(c)	State TWO practical examples of EACH effect in Q8(b).	(3)

Fossil fules, hydroelectric, solar, nuclear power stations

b) heating, magnetic, chemical

c) heating- commerical electric heater (hairdryer)
heating in wired due to resistence

Magnetic - electromagnet. Solenoid, dor buzzer that puuls a bolt.
Electric generator, motor

Chemical - electro plating, electrolysis, nickle cadmium plating. charging a lead acid battery, lithium ion

9. The navigation lights on a vessel are fed from a d.c supply. THREE lights are connected in parallel and EACH draws a current of 5 A. The lamps have a resistance of 3 Ω each.

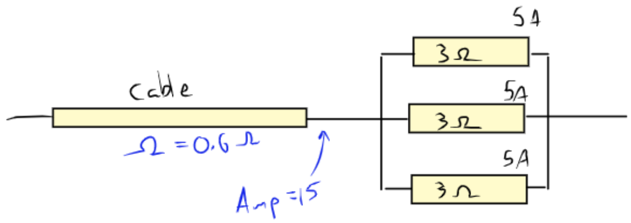
Calculate EACH of the following:

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

(b) the total power consumed by the circuit if the total resistance of the cables was 0.6 Ω; (4)

(c) the supply voltage. (2)

$P = IV$



a) $P = I(I \cdot R)$

$P = 5(5 \times 3) = 75$ Watts

b) Cable

$P = IV$

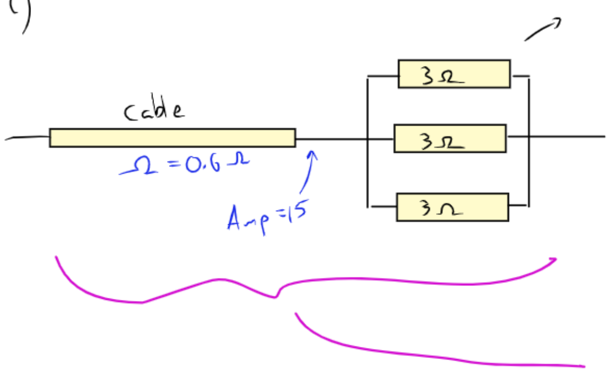
$P = I(IR)$

$P = 15(15 \times 0.6) = 135$ Watts

total power $= 135 + (75) \times 3$

360 watts

c)



Resistance over Parallel

$\frac{1}{R_T} = \frac{1}{3} + \frac{1}{3} + \frac{1}{3}$

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

$R_T = 1\ \Omega$

Resistance over Series

$1 + 0.6 = 1.6\ \Omega$

V
I R

Voltage $= I \times R$

$15 \times 1.6 = 24$ volts

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

Calculate EACH of the following:

(a) the flux density; (4)

(b) the magnetic flux. (4)

Flux density Tesla

$F = BIL\sin\theta$

$L = 300\text{mm} = 0.3\text{m}$

$I = 25\text{A}$

$\theta = 90^\circ$

$F = 18\text{ N}$

$18 = x \times 25 \times 0.3 \times \sin 90$

$\frac{18}{25 \times 0.3} = x = 2.4$ Tesla

Magnetic Flux

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

$d = 9.5\text{mm} = 0.0095\text{m}$

$r = 4.75 \times 10^{-3}$

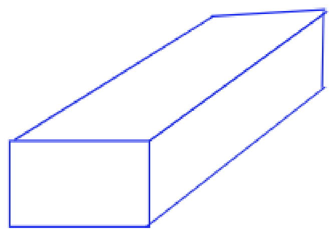
$BA = \phi$

$2.4 \times (4.75 \times 10^{-3})^2 \times \pi = \phi$

1.70117×10^{-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

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



$l = 4.88$ m

$w = 0.258$ m

$d = 0.175$ m

$V = 0.220332\ m^3$

Mass of water displaced

$0.220332 \times 1010 = 222.53532$ kg

Mass of plank

$0.220332 \times 710 = 156.43572$ kg

Total mass supported by plank

$222.53532 - 156.43572 = 66.09961$ 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 $m * d = \Delta\, GM \tan\theta$

$GM = KM - KG$

$6.1 - 5 = 1.1$

$m = 30$

$d = x$

$\Delta = 3250$

$GM = 1.1$

$\theta = 1.8$

$$30x = \frac{3250 \times 1.1 \times \tan 1.8}{30}$$

$$x = 3.74496\ m$$