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, 19 MARCH 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. Explain what is meant by EACH of the following terms:

   (a) heat energy; (2)

   (b) higher calorific value; (2)

   (c) convection; (2)

   (d) enthalpy of fusion. (2)

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

   (b) 420 grams of a perfect gas has a volume of 0.8 m^3 at a temperature of 88°C The gas is compressed to a quarter of the original volume where its pressure is 200 kN/m^2

   Determine the final temperature of the gas. (6)

   Note: R = 290J/kgK

3. LPG (C_3H_8) is completely burned using 30% excess air.

   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)

4. A brass bearing is to be shrink fitted to a steel shaft. The bearing has an internal bore of 69.82 mm at a temperature of 20°C. The steel shaft has an external diameter of 70 mm at 20°C.

   Calculate the lowest temperature to which the bearing must be heated in order to slide onto the shaft without force (8)

   Note: coefficient of linear expansion of brass = 0.000018 / °C

5. A 2 stroke diesel engine was tested over a 24 hour period and used 1.8 tonnes of fuel. The power of the engine was tested using a dynamometer which gave 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; (2)

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

   (c) the brake thermal efficiency. (3)

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

6. (a) Describe the basic functions of the key components of a vapour compression refrigeration system. (6)

   (b) If the refrigeration system described in 6(a) has a water cooled condenser what will be the effect of a higher cooling water inlet temperature if the flow rate remains the same. (2)

Section B

7. A wooden beam is 3 m long x 20 cm wide x 75 mm deep and floats horizontally in sea water of density 1025 kg/m^3.

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

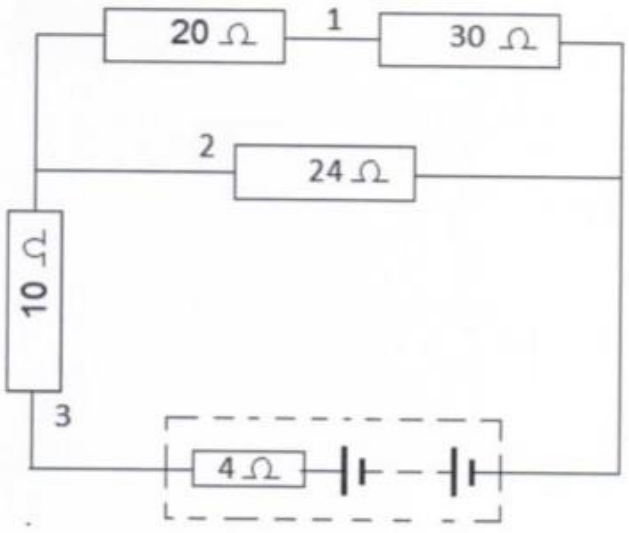
8. A ship has a displacement volume of 6430 m^3 in sea water of density 1025 kg/m^3.

   Two double bottom tanks each measuring 12.5 m long x 5.5 m wide x 2.1 m deep are positioned equally, one either side of the centre line.

   These tanks are now completely filled with heavy fuel oil of density 968 kg/m^3.

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

9. Determine the current at EACH of the points 1, 2 & 3 in the circuit shown in Fig Q9 if the cell e.m.f. is 32 V. (9)



10. (a) In relation to their structure explain why metals are good conductors of electricity. (2)

(b) In relation to their structure explain why insulators are not a good conductors of electricity. (2)

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

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

11. (a) State Lenz's Law. (2)

(b) A conductor with an effective length of 500 mm creates a magnetic flux 280 μWb when carrying a current of 45 A. The force on the conductor is 40 N.

Calculate the diameter of the conductor. (6)

12. The circuit in Fig Q12 has a voltmeter as shown. When the switch is open the reading on the voltmeter is 30 V, when the switch is closed the voltage drops to 26.67 V.

(a) Explain the reason for the change in the voltmeter readings. (4)

(b) Determine the resistance of the cell. (5)

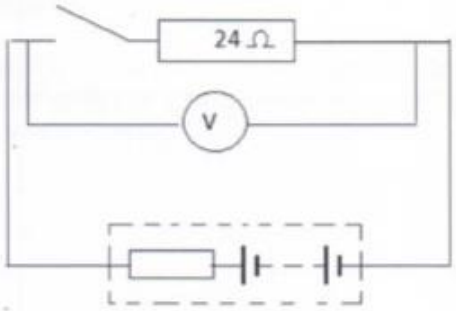


Fig Q12

Section A

1. Explain what is meant by EACH of the following terms:

   (a) heat energy; (2)

   (b) higher calorific value; (2)

   (c) convection; (2)

   (d) enthalpy of fusion. (2)

a) heat energy is the total amount of energry in a system, caused by molecular motion, and it is dependent upon the mass of the object, measured in Joules.

b) the amount of energy produced by a complete combustion of a fuel, including trapping the prodcuts and allowing the whole system to return to room temperature (measured in joules per kilogram)

c) Convection is the transfer of energy through a liquid or a gas through convection currents be they natural or forced.

d) Enthalpy of fusion is the energy removed from a system as a gas changes state into a liquid, measured in Joules per kg

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

   (b) 420 grams of a perfect gas has a volume of 0.8 m^3 at a temperature of 88°C The gas is compressed to a quarter of the original volume where its pressure is 200 kN/m^2

   Determine the final temperature of the gas. (6)

   Note: R = 290J/kgK

STP - Standard temeperature and Pressure
NTP normal temperature and pressure

$P_v = mRt$

$m = 0.42$

$V = 0.8$

$t = 88 + 273 = 361$

$R = 290$

$$x = \frac{0.42 \times 290 \times 361}{0.8}$$

$P_1 = 54962.25$ (Pa)

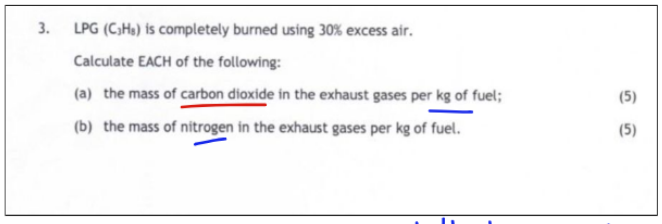
$$\frac{P_1 V_1}{T_1} = \frac{P_2 V_2}{T_2}$$

$$\frac{54962 \times 0.8}{361} = \frac{200{,}000 \times 0.2}{T_2}$$

$$T_2 = \frac{40000}{121.79944}$$

$T_2 = 328.4$ K

55 °C



3. LPG (C_3H_8) is completely burned using 30% excess air.

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)

C = 12 H = 1 O = 16

23% oxy 77% Nitrogen

Mass of Carbon and Hydrogen in 1kg of fuel

$C_3 = 3 \times 12 = 36$

$H_8 = 1 \times 8 = 8$

$C_3H_8 = 44$

Carbon $\frac{36}{44} \times 1 = 0.818182 kg$

Hydrogen $\frac{8}{44} \times 1 = 0.18181818 kg$

Burn Carbon

$C + O_2 = CO_2$

Mass / RAM $\frac{0.818182}{12} = \frac{x}{32}$

$x = 2.181818 kg$ oxygen required to burn Carbon

Burn Hydrogen

$H_2 + O = H_2O$

Mass / RAM $\frac{0.18181818}{2} = \frac{x}{16}$

$x = 1.45454545 kg$ oxygen to burn Hydrogen

Mass of CO_2

Mass Carbon + Mass oxygen = Mass CO_2

$0.818182 + 2.181818 = 3\ kg$

Mass of Nitrogen (stoichio)

Oxygen Required to burn 1kg fuel

$2.181818\ kg + 1.45454545 = 3.636363\ kg$

Amount of Air (stoichio)

$x\ 0.23 = 3.636363$

$x = 15.81027668\ kg$

Add 30% extra air

$15.81027668 \times 1.3 = 20.55335968\ kg$

Nitrogen in exhaust.

$20.55335968 \times 0.77 =$ **15.826 kg**

4. A brass bearing is to be shrink fitted to a steel shaft. The bearing has an internal bore of 69.82 mm at a temperature of 20°C. The steel shaft has an external diameter of 70 mm at 20°C.

Calculate the lowest temperature to which the bearing must be heated in order to slide onto the shaft without force (8)

Note: coefficient of linear expansion of brass = 0.000018 / °C

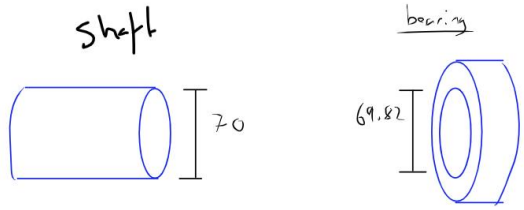
Expansion

$(d \times \alpha \times \Delta t) = 0.18$

$69.82 \times 0.000018 \times x = 0.18$

$\Delta t = 143.2254$

Final temp min 163.22°C



5. A 2 stroke diesel engine was tested over a 24 hour period and used 1.8 tonnes of fuel. The power of the engine was tested using a dynamometer which gave 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; (2)

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

(c) the brake thermal efficiency. (3)

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

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

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

$T = 4500$ Nm

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

$BP = 4500 \times 2\pi \times 13.33333 = 376991.1184$ watts

376.991 kW

b) $Isfc = \frac{fc}{I.P.}$

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

$0.89 = \frac{376991.1184}{IP}$

$IP = \frac{376991.1184}{0.89}$

$= 423585.5213$ Watts

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

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

$= 0.1770599\ kg/kwh$

c) $\text{Break thermal Eff} = \frac{BP}{fc \times cal}$

$fc = 0.020833333\ kg/s$

$cal = 44 \times 10^6\ J/kg$

BP 376 991 W

$\text{Break thermal eff} = \frac{376991}{0.020833333 \times 44 \times 10^6} = 0.41126$

41.126 %

6. (a) Describe the basic functions of the key components of a vapour compression refrigeration system. (6)

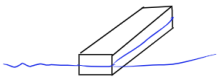
(b) If the refrigeration system described in 6(a) has a water cooled condenser what will be the effect of a higher cooling water inlet temperature if the flow rate remains the same. (2)

a) basic :

Section B

7. A wooden beam is 3 m long x 20 cm wide x 75 mm deep and floats horizontally in sea water of density 1025 kg/m³.

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



Mass of board = Mass of displaced water

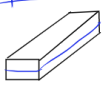
$l = 3m = 3m$
$w = 20cm = 0.2m$
$d = 75mm = 0.075m$
$Vol = 0.045m^3$
$Mass = d \times v = 750 \times 0.045$
$33.75\ kg$

Water

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

$\frac{33.75}{1025} = 0.0329268\ m^3$

depth of beam



$V = w \times l \times d$

$0.0329268 = 3 \times 0.2 \times d$

$\frac{0.0329268}{3 \times 0.2} = d = 0.054780\ m$

Freeboard

$0.075 - 0.054780 = 0.020122\ m$

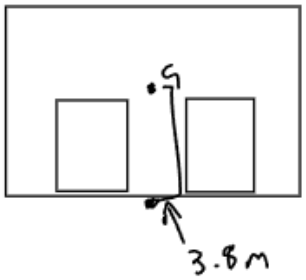
8. A ship has a displacement volume of 6430 m^3 in sea water of density 1025 kg/m^3.

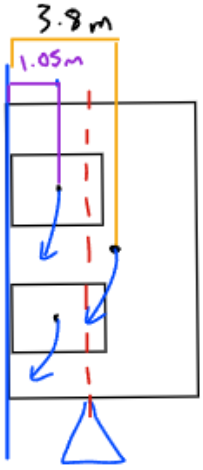
Two double bottom tanks each measuring 12.5 m long x 5.5 m wide x 2.1 m deep are positioned equally, one either side of the centre line.

These tanks are now completely filled with heavy fuel oil of density 968 kg/m^3.

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

M G B K





tank 2.1 m deep

$\frac{2.1}{2} = 1.05$

Mass of ship

$d = \frac{m}{v}$ $d \times v = mass$

$1025 \times 6430 = 6590750$ kg

6590.75 t

Mass of 2 tank

$(12.5 \times 5.5 \times 2.1) \times 2 \times 968 = 279510$ kg

279.51 t

Name	Mass (t)	Force	Distance	Moment	Dir C/A
Ship	6590.75		3.8	25044.85	C
tanks	279.51		1.05	293.4855	C
Pivot (New centre of gravity)	6870.26		x	$6870.26x$	A

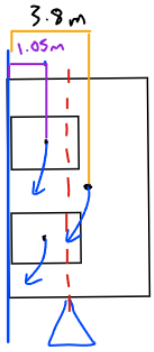
totoal downwards forces = total upwards forces

Ship + tanks = Pivot (New centre of gravity)

Sum of the clockwise moments = sum of the anitclockwise moments

$$25044.85 + 293.4855 = 6870.26x$$

$$x = 3.68811 \text{ m}$$



we can see a drop in the centre of gravity, the ship is sitting deeper in the water.

$$KG_{new} = 3.68811$$

$$KG_{old} = 3.8$$

$$\Delta KG = 3.8 - 3.68811 = 0.11188 \text{ m}$$

change of centre of gravity is 0.11188 m downwards

9. Determine the current at EACH of the points 1, 2 & 3 in the circuit shown in Fig Q9 if the cell e.m.f. is 32 V. (9)

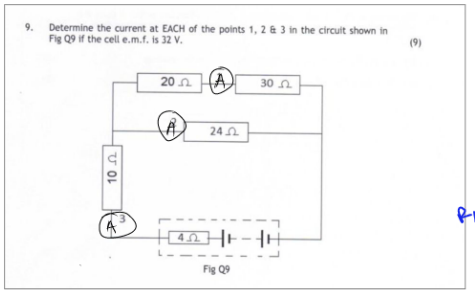
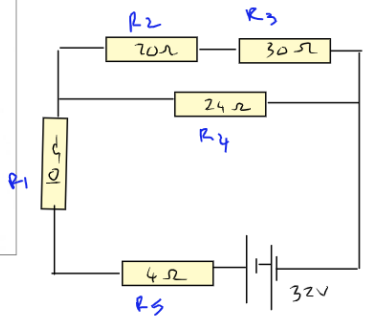


Fig Q9

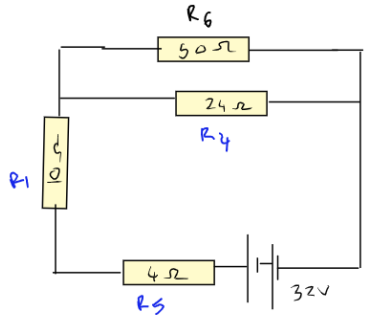
Calculate Circuit Resistance



Over Series

$R_T = R_2 + R_3$

$R_T = 20 + 30 = 50$

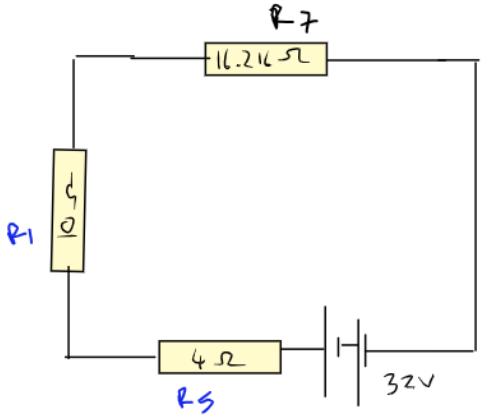


Over Parallel

$\frac{1}{R_T} = \frac{1}{R_4} + \frac{1}{R_6}$

$\frac{1}{R_T} = \frac{1}{50} + \frac{1}{24}$

$R_T = 16.216\ \Omega$



Over Series

$R_T = R_1 + R_5 + R_7$

$R_T = 4 + 10 + 16.216$

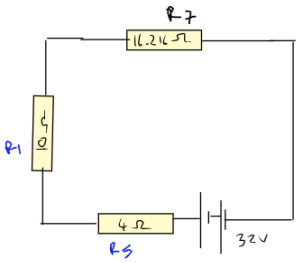
$R_T = 30.216$

Calculate Circuit Current.

Circuit Resistance = $30.216\ \Omega$

$V = 32$

$I = \frac{32}{30.216} = 1.059$ Amps

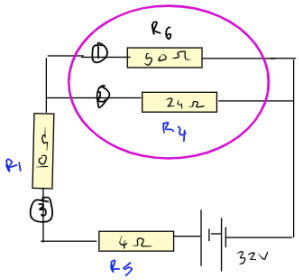


Calculate Voltage drop across each component/section

$V_5 = 4 \times 1.059 = 4.236$ volts

$V_1 = 10 \times 1.059 = 10.59$ volts

$V_7 = 16.216 \times 1.059 = 17.172744$ volts

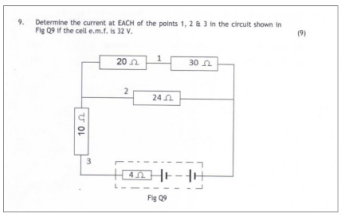


Calculate Current across Parallel section

Supply Voltage = 17.172744 volts

$I = \frac{V}{R}$ $I_6 = \frac{17.172744}{50} = 0.34345488$ Amps

$I_4 = \frac{17.172744}{24} = 0.715531$ Amps



① = 0.34345488 Amps

② = 0.715531 Amps

③ = 1.059 Amps

10. (a) In relation to their structure explain why metals are good conductors of electricity. (2)

(b) In relation to their structure explain why insulators are not a good conductors of electricity. (2)

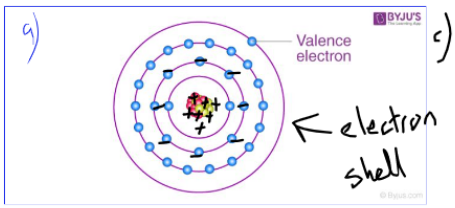
(c) State why conductors have power losses. (2)

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

valence electrons — no valence electrons

giant lattic — no giant lattice

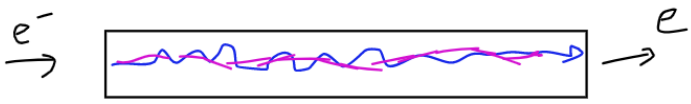
a)

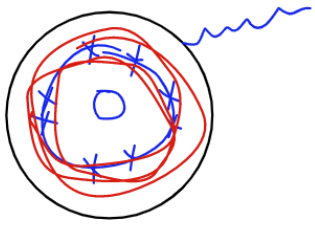


c) becuase of internal resistance caused by the electrons passing through the molecular strucutre of the conductor. higher resistence causes power losses, this power is lost as heat

d) $P = IV$

power losses can be calcualted using the P=IV formula and ohms law, using the inormation avliable be it the overall resistance, current, or voltage.

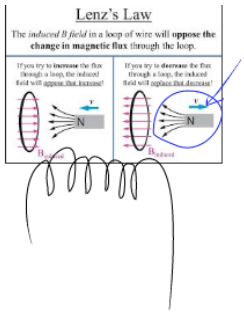


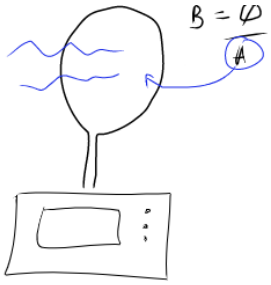


11. (a) State Lenz's Law. (2)

(b) A conductor with an effective length of 500 mm creates a magnetic flux 280 μWb when carrying a current of 45 A. The force on the conductor is 40 N.

Calculate the diameter of the conductor. (6)





b) $F = BIL \sin\theta$

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

$L = 500\,mm = 0.5\,m$

$I = 45$

$F = 40$

$B = x$

$40 = x \cdot 45 \cdot 0.5$

$\frac{40}{45 \cdot 0.5} = x$

$= 1.7778$ Tesla

$\phi = 280 \times 10^{-6}$ wb

$B = 1.7778$

$A = \frac{280 \times 10^{-6}}{1.77778} = 2.8 \times 10^{4}$

$A = 1.575 \times 10^{-4}$

$\pi r^2 = 1.575 \times 10^{-4}$

$d = 0.014161$ m

12. The circuit in Fig Q12 has a voltmeter as shown. When the switch is open the reading on the voltmeter is 30 V, when the switch is closed the voltage drops to 26.67 V.

(a) Explain the reason for the change in the voltmeter readings. (4)

(b) Determine the resistance of the cell. (5)

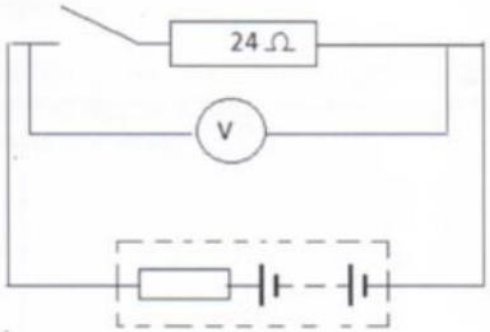


Fig Q12

a) when the switch is open, the circuit is broken, and no current is flowing.

the volt meter reading shows the EMF of the battery at 30 volts.

Once the switch is closed, the circuit is now complete, and there will be a voltage drop over each component. This includes the internal resistor

We can see there is a 26.67 volt drop over the 24 ohm resistor, so therefore there must be a 30-26.67=3.33Volt drop over the internal resistance of the cell.

b) EMF − Ir = termind Voltage

30 26.67

I = ? r = ?

we need to find the current in order to clacualte the internal resisitace.

using 24Ω Resistor

V = 26.67

I = 1.11125 Amps

R = 24Ω

$I = \frac{V}{R} = \frac{26.67}{24}$

Voltage drop (internd)

Ir = 3.33

1.11125 x r = 3.33

$r = \frac{3.33}{1.11125}$

r = 2.9966 Ω