**CERTIFICATES OF COMPETENCY IN THE MERCHANT NAVY - MARINE ENGINEER OFFICER**

EXAMINATIONS ADMINISTERED BY THE
**SCOTTISH QUALIFICATIONS AUTHORITY**
ON BEHALF OF THE
**MARITIME AND COASTGUARD AGENCY**

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

**043-12 - GENERAL ENGINEERING SCIENCE II**

**FRIDAY, 19 OCTOBER 2018**

**1400 - 1600 hrs**

Examination paper inserts:

Notes for the guidance of candidates:

1. Candidates are required to obtain 50% of the total marks allocated to this paper to gain a pass.
2. Non-programmable calculators may be used.
3. All formulae used must be stated and the method of working and ALL intermediate steps must be made clear in the answer.

Materials to be supplied by examination centres:

Candidate's examination workbook

**GENERAL ENGINEERING SCIENCE II**

**Attempt ALL questions**

**Marks for each question are shown in brackets.**

1. (a) Define specific heat capacity, stating the SI unit. (3)

   (b) Calculate the heat energy rejected when a mass of 5 kg of brass is cooled from a temperature of 215ºC to 25ºC. (4)

   *Note: for brass c = 0.393 kJ/kgK*

2. With reference to combustion in boilers and internal combustion engines, explain EACH of the following:

   (a) the meaning of the term stoichiometric air supply; (2)

   (b) the reasons for supplying excess air; (3)

   (c) the effects of an inadequate air supply. (4)

3. A hydraulic system pipeline consists of a total length of 15 m of steel pipe with an internal diameter of 25 mm and is completely filled with oil.

   During working the temperature of the system rises by 38ºC.

   Calculate the overflow volume of the oil in litres. (7)

   *Note:* $\alpha_{steel} = 1.2 \times 10^{5}/ºC$

   $\gamma_{oil} = 9 \times 10^{-4}/ºC$

4. A six cylinder, single acting, two-stroke diesel engine develops a brake power of 1260 kW at a speed of 120 rev/min. The indicated mean effective pressure is 5.5 bar, the mechanical efficiency is 90% and the length of the stroke is 25% greater than the bore.

Calculate EACH of the following:

(a) the cylinder diameter; (7)

(b) the stroke length. (2)

5. (a) Explain the purpose of insulating engineering plant. (6)

(b) List THREE properties of a good insulator. (3)

6. (a) State Charles' Law for a perfect gas. (3)

(b) During a constant pressure process at 15 bar, the temperature of a perfect gas increases from 27ºC to 147ºC. The initial specific volume is 0.235m$^3$/kg.

Calculate EACH of the following:

(i) the final specific volume; (3)

(ii) the specific work done. (3)

7. A coil of copper wire at an initial temperature of 18ºC takes a current of 2.75 Amps from a 110 Volt supply. After a period of time the current falls to 2.2 Amps for the same supply voltage.

Calculate the temperature rise of the coil. (10)

*Note: temperature coefficient of resistance of copper = 0.00425/ºC at 0ºC*

8. (a) State Faraday's TWO Laws of electromagnetic induction. (4)

(b) A magnetic flux of 4.4 mWb is produced by a current carrying coil having 2250 turns. The current direction is completely reversed in one-tenth of a second.

Calculate the average e.m.f. induced in the coil. (5)

9. (a) Explain the term *the internal resistance of an electric cell*, stating the effect it has on the terminal voltage of the cell. (4)

(b) SIX cells, each having an e.m.f. of 2 volts, are connected in series. The internal resistance of each cell is 0.12 Ω and the current flow is 0.5 Amps.

Calculate the terminal voltage. (4)

10. THREE lamps are connected in parallel. EACH lamp has a resistance of 4.4 Ω and draws a current of 5.2 Amps.

Calculate EACH of the following:

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

(b) the supply voltage. (4)

11. (a) State the main differences between electromagnets and permanent magnets, giving TWO examples of EACH. (4)

(b) Explain why electromagnets are preferred for industrial applications. (4)

12. (a) Describe *electrical current flow*. (4)

(b) State the essential properties, with reference to atomic structure of EACH of the following:

(i) an electrical conductor; (2)

(ii) an electrical insulator. (2)

1. (a) Define specific heat capacity, stating the SI unit. (3)

(b) Calculate the heat energy rejected when a mass of 5 kg of brass is cooled from a temperature of 215ºC to 25ºC. (4)

*Note: for brass c = 0.393 kJ/kgK*

a) The amount of energy required to raise 1kg of a material by 1 degree celcius.

$$\text{units} = \frac{J}{kg\,K}$$

$$Q = mc\,\Delta t$$

b) $Q = mc\Delta t$

$m = 5$

$c = 393$

$\Delta = (215 - 25) = 190$

$Q = 5 \times 393 \times 190$

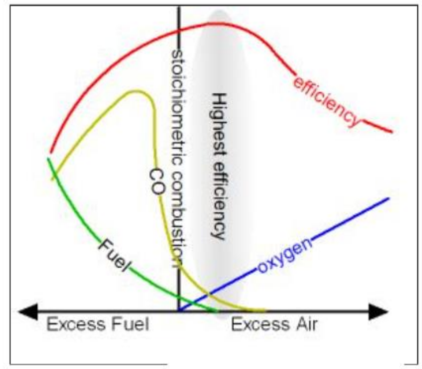
$= 373350\ J$

2. With reference to combustion in boilers and internal combustion engines, explain EACH of the following:

(a) the meaning of the term stoichiometric air supply; (2)

(b) the reasons for supplying excess air; (3)

(c) the effects of an inadequate air supply. (4)




a) The minimum amount of air required to bring about complete combustiuon of a certain quantity of fuel.

b) reasons for supplying excess air: increases the effciency of the engine

its very unlikely that the fuel has access to the correct amount of oxygen it requires to burn in the engine, to ensure that the fuel molecules are close enough to oxygen molecules to burn completely, we supply excess oxygen, and hence excess air.

reduces CO emmsions, reduces cost as it reduces unburnt fuel in the exhaust,

c) inadequate air supply

reduce efficeny of engine, increase CO levels due incomplete combustion of the fuel, increases in soot, unburnt carbon in exhaust. this leads to more maitnenecne required.
Burn more fuel for power output, so more costly

3. A hydraulic system pipeline consists of a total length of 15 m of steel pipe with an internal diameter of 25 mm and is completely filled with oil.

During working the temperature of the system rises by 38ºC.

Calculate the overflow volume of the oil in litres. (7)

*Note:* $\alpha_{steel} = 1.2 \times 10^{-5}/^{\circ}C$

$\gamma_{oil} = 9 \times 10^{-4}/^{\circ}C$

$\gamma$

Volume of the pipe (cold) = Volume of oil (cold)

Volume of oil (HOT) - Volume of pipe (HOT) = Overflow

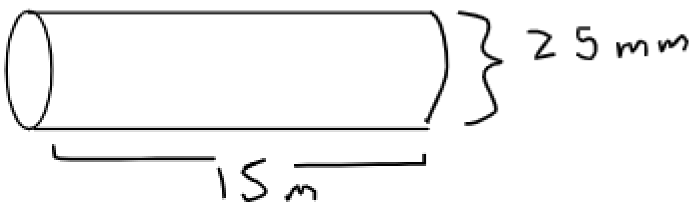
Length + expansion = New length

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

**Pipe** $Vol + (Vol\ 3\alpha\ \Delta t) = New\ vol$

**Oil** $Vol + (Vol\ \gamma\ \Delta t) = New\ vol$

Vol pipe (cold)




$= 0.025$ m

$R = 0.0125$ m

$$\text{Vol} = \pi r^2 h$$

$$(0.0125)^2 \pi \times 15$$

$$= 7.363107782 \times 10^{-3}$$

$$\boxed{7.3631 \times 10^{-3}}$$

Vol pipe hot

$Vol + (Vol\ 3\alpha\ \Delta t) = New\ vol$

$7.3631 \times 10^{-3} + (7.3631 \times 10^{-3} \times 3 \times 1.2 \times 10^{-5} \times 38)$

$1.00727314 5 \times 10^{-5}$

$10.07 \times 10^{-6}$

$Vol = 7.3731 7 2721 \times 10^{-3}$

$7.373 \times 10^{-3}$

Vol oil hot

$$Vol + (Vol \gamma \Delta t) = \text{New vol}$$

$$7.3631 \times 10^{-3} + (7.3631 \times 10^{-3} \times 9 \times 10^{-4} \times 38)$$

$$2.5181802 \times 10^{-4}$$

$$Vol = 7.61491802 \times 10^{-3}$$

7.622

Volume of oil (HOT) - Volume of pipe (HOT) = Overflow

$$7.61491802 \times 10^{-3} - 7.37317 2721 \times 10^{-3} = 2.417453 \times 10^{-4} \ m^3$$

$$241.745 \times 10^{-6}$$

↓ ×1000

0.241745 Litres

4. A six cylinder, single acting, two-stroke diesel engine develops a brake power of 1260 kW at a speed of 120 rev/min. The indicated mean effective pressure is 5.5 bar, the mechanical efficiency is 90% and the length of the stroke is 25% greater than the bore.

Calculate EACH of the following:

(a) the cylinder diameter; (7)

(b) the stroke length. (2)

$$Imep = \frac{A\alpha}{L} \qquad IP = x \ p \ l a n \qquad BP = T 2\pi n \qquad I_{spec} = \frac{IP}{\text{consumption} \times \text{cal value}}$$

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

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

a)

$$0.9 = \frac{1260\ kW}{IP}$$

$$IP = \frac{1,260,000}{0.9} = 1,400,000\ W$$

$IP = x\ p\ l\ a\ n$

$IP = 1,400,000$

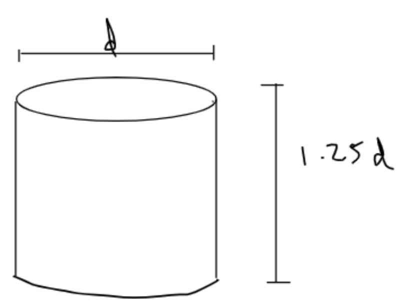
$x = 6$

$p = 5.5$ bar $= 550,000$ (Pa)

$L = 1.25d$

$a = \frac{d^2}{4}\pi$

$n = \frac{120}{60} = 2$




$$\frac{d^2}{4}\pi$$

Area $\pi r^2 = \pi \left(\frac{d}{2}\right)^2 = \pi \frac{d^2}{4}$

$$IP = x \quad p \quad l \quad a \quad n$$

$$1{,}400{,}000 = 6 \times 550{,}000 \times 1.25d \times \frac{d^2}{4}\pi \times 2$$

$$1400{,}000 = 6479534.848\, d^3$$

$$\frac{1400{,}000}{6479534.848} = d^3$$

$$\sqrt[3]{\frac{1400{,}000}{6479534.848}} = 0.6000600\ m$$

a) $d = 0.6\ m$

b) $0.6 \times 1.25 = 0.75\ m$

| 5. | (a) Explain the purpose of insulating engineering plant. | (6) |
|---|---|---|
| | (b) List THREE properties of a good insulator. | (3) |

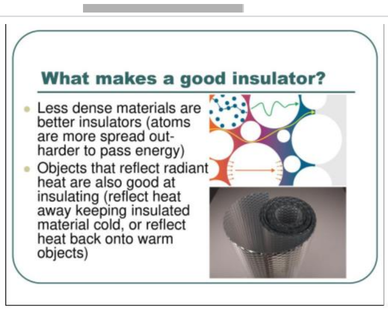
Heat insulation - cost to owner, environmental

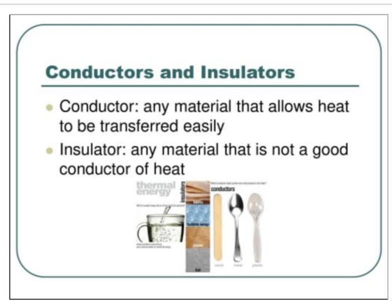
Electrical - safty

Sound - comfort, Health and safety

A good electrical insulator, doesnt have valence electrons, or a giant lattice structurs. This doesnt allow electrons to flow freely.

Good heat insulators, non flammable, non toxic, high air content.



6. (a) State Charles' Law for a perfect gas. (3)

(b) During a constant pressure process at 15 bar, the temperature of a perfect gas increases from 27°C to 147°C. The initial specific volume is 0.235m³/kg.

Calculate EACH of the following:

(i) the final specific volume; (3)

(ii) the specific work done. (3)

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

a) increase in temperature leads to an increase in volume at a constant pressure for a perfect gas. a directly proportional relationship

b) $P_1 = 15\text{ bar} = 1{,}500{,}000\ (Pa)$ $P_2 = 15\text{ bar} = 1{,}500{,}000\ (Pa)$

$t_1 = 27°C = 300\text{ K}$ $T_2 = 147°C = 420\text{ K}$

$V_1 = 0.235$ $V_2 = x$

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

$$\frac{0.235}{300} = \frac{x}{420}$$

$$\frac{420 \times 0.235}{300} = x = 0.329\ m^3/kg$$

ii) work = change in vol x Pressure

$(0.329 - 0.235) \times 1{,}500{,}000$

$0.094 \times 1{,}500{,}000 =$

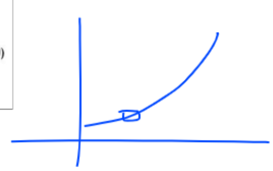
$= 141000 \text{ J/kg}$

7. A coil of copper wire at an initial temperature of 18ºC takes a current of 2.75 Amps from a 110 Volt supply. After a period of time the current falls to 2.2 Amps for the same supply voltage.

Calculate the temperature rise of the coil. (10)

*Note: temperature coefficient of resistance of copper = 0.00425/ºC at 0ºC*

$R_T = R_t(1 + \alpha \Delta t)$



$T =$ new temp $= T$

$t =$ old temp $= 18$

$\alpha = 0.00425$

$\Delta t = \Delta t$

Initial

$V = 110v$

$I = 2.75$ Amps

$R = \frac{110}{2.75} = 40\Omega$

Final

$V = 110v$

$I = 2.2$ Amps

$R = \frac{110}{2.2} = 50\Omega$


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

$$R_T = R_t(1 + \alpha \Delta t)$$

$$50 = 40(1 + 0.0425(\Delta t))$$

$$50 = 40 + 0.17(\Delta t)$$

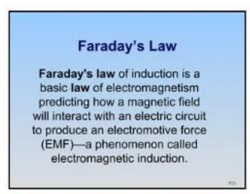
$$50 - 40 = 0.17 \Delta t$$

$$\frac{10}{0.17} = \Delta t = 58.82\,^{\circ}C$$

8. (a) State Faraday's TWO Laws of electromagnetic induction. (4)

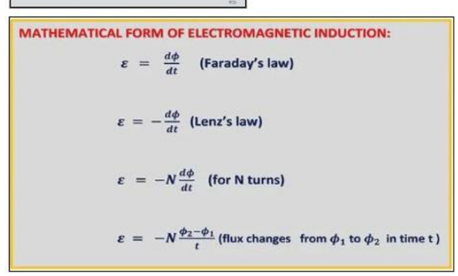
(b) A magnetic flux of 4.4 mWb is produced by a current carrying coil having 2250 turns. The current direction is completely reversed in one-tenth of a second.

Calculate the average e.m.f. induced in the coil. (5)

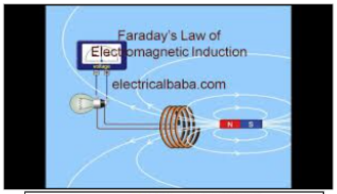


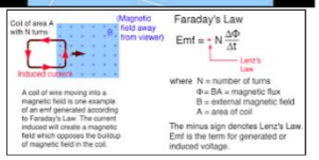

a) If you drag a magnet over a wire, it will induce an electric current in the wire.

If the magnet is bigger, moved faster, or over a larger number of windings this will increase the current induced in the wire.



$$Emf = N \times \frac{\Delta \phi}{\Delta t}$$




$$2250 \times \frac{4.4 \times 10^{-3}}{0.1} = 99 \text{ volts}$$

9. (a) Explain the term *the internal resistance of an electric cell*, stating the effect it has on the terminal voltage of the cell. (4)

(b) SIX cells, each having an e.m.f. of 2 volts, are connected in series. The internal resistance of each cell is 0.12 Ω and the current flow is 0.5 Amps.

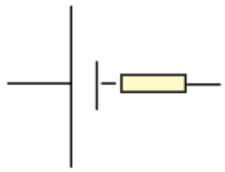
Calculate the terminal voltage. (4)

Internal rsistance of a cell is due to the internal make up of the battery, or due to an internal resistor. This is to avoid an accidedntal instant discharge.

There is voltage drop over this internal resistance, which drops the EMF down to the terminal voltage.

voltage drop can calculated using ohms law, as the internal resistance is known, and the EMF is also known.

b)



×6

$$\begin{pmatrix} V = 2v \\ I \\ R = 0.12\Omega \end{pmatrix}$$

$V = 12v$ = emf
$I = 0.5$
$R = 0.72\Omega$

the Raw EMF off the 6 cells will be 12 volts. But each resistor will have a small voltage drop over each one. We can model those 6 reisistors as one big reisistor with a R = 0.72 ohms

Voltage drop

V
$I = 0.5$
$R = 0.72$


$V = IR$
$V = 0.5 \times 0.72$
$V = 0.36$ volts

so the voltage drop over the internal reisistors is 0.36volts

$12v - 0.36 = 11.64$ volt (Terminal Voltage)

EMF − Ir = Terminal voltage

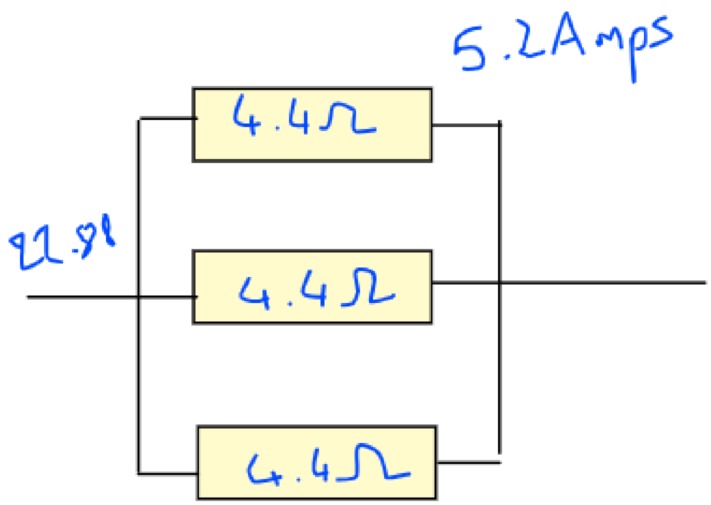
$V = Ir$

10. THREE lamps are connected in parallel. EACH lamp has a resistance of 4.4 Ω and draws a current of 5.2 Amps.

Calculate EACH of the following:

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

(b) the supply voltage. (4)



a) $P = IV$


$P = 5.2 \times 22.88$

$P = 118.976$ watts

$V = I \times R$

$V = 5.2 \times 4.4$

$= 22.88$ v

b) 22.88 volts

| | | |
|---|---|---|
| 11. | (a) State the main differences between electromagnets and permanent magnets, giving TWO examples of EACH. | (4) |
| | (b) Explain why electromagnets are preferred for industrial applications. | (4) |

electro

- soft iron core

soft iron core doesnt hold onto the magnetic field, so the magnet can be switched on and off

- uses electricity

solenoids
inside of cathoray televisions
recycling plants
AC generators, AC motors

permenant

- steel

permenant magnet due to all the atomic dipoles lining up. This means that steel can magnetised.

- no electricity

fridge magnet
Microwaves
housing in DC electric motors/ generators
moving coild instruments

Generally AC power genration is more widely used, this requyired electromagnets rather than permenenat magnets

Weight - electromagets are lighter, so they are better for moving applications such as electric cars, trains, etc.

Control we can vary the intensity of the electric field in a electromagnet, so we have more control over the device

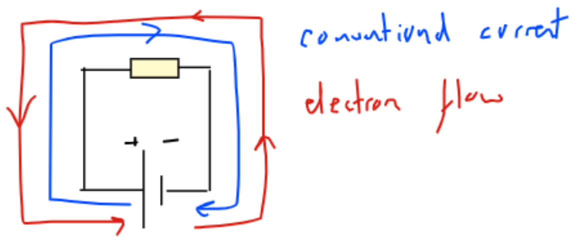
12. (a) Describe *electrical current flow*. (4)

(b) State the essential properties, with reference to atomic structure of EACH of the following:

(i) an electrical conductor; (2)

(ii) an electrical insulator. (2)

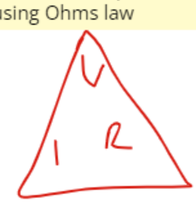
a)




Electrical current flow is caused by electrons moving around a circuit.

The electrons move from negative to positive in the circuit, this is called electron flow, the opposite is called convenetial current, which goes from posisitve to negative.

It is measured in Amps (I) and can be calculated for a given circuit using Ohms law




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

b i)

valence electrons
Giant lattice structure