GENERAL ENGINEERING SCIENCE II March 2018

Attempt ALL questions

Marks for each question are shown in brackets.

1. Define EACH of the following:

   (a) the freezing point; (3)

   (b) the boiling point. (3)

2. A mass of 0.049 kg of a perfect gas is contained in a cylinder at a constant temperature of 47°C. At a pressure of 1 bar the density of the gas is 1.225 kg/m^3.

   Calculate EACH of the following:

   (a) the density of the gas when the pressure is reduced to 80 kN/m^2; (4)

   (b) the characteristic gas constant. (5)

3. A copper sphere has a diameter of 49 mm at a temperature of 12°C. The sphere is heated until its temperature rises to 506°C and there are no heat losses.
   Calculate EACH of the following:

   (a) the increase in the surface area; (5)
   (b) the specific heat added. (3)

   Note: area of a sphere = 4 πr^2 *specific heat capacity of copper = 0.395 kJ/kgK coefficient of linear expansion of copper = 0.000017/°C*

4. A mass of 1.75 kg of methane gas (CH_4) is completely burned in 24% excess air.

Calculate EACH of the following:

(a) The stoichiometric oxygen required; (6)

(b) The actual mass of air supplied. (3)

Note: *relative atomic masses: carbon = 12, oxygen = 16, hydrogen = 1*
air contains 23% oxygen by mass

5. The area of an indicator diagram taken off one cylinder of a four-cylinder, four-stroke internal combustion engine is 374 mm^2 and the length is 68 mm. The bore of the engine is 225 mm, the stroke is 325 mm and the speed is 300 rev/min. All of the cylinders develop equal power.
Calculate EACH of the following:

(a) The mean indicated pressure; (3)

(b) The indicated power of the engine. (6)

Note: *spring constant is 1 mm = 1 bar*

6. (a) State and describe the THREE modes of heat transfer. (6)

(b) With reference to a marine boiler give ONE example of EACH of the THREE modes in Q6(a). (3)

7. (a) State the units of EACH of the following:

   (i) flux;

   (ii) flux density;

   (iii) magnetomotive force;

   (iv) inductance. (4)

   (b) The active length of a conductor carrying a current of 42 Amps at right angles to a magnetic field is 800 mm. The force on the conductor is 21 N.

   Calculate the strength of the magnetic field. (4)

8. A 4 Ohm resistor is connected in parallel with a 6 Ohm resistor, and this combination is connected in series with an 8 Ohm resistor. The current flowing through the 8 Ohm resistor is 7.5 Amps.

   Calculate EACH of the following:

   (a) The applied voltage; (4)

   (b) The current in EACH of the parallel resistors. (4)

9. (a) Define the temperature coefficient of resistance. (2)

   (b) The resistance of a coil of copper wire is 175 Ohm at a temperature of 15°C.

Calculate the temperature of the coil when the resistance increases to 245 Ohm. (6)

Note: temperature coefficient of resistance of copper at 15°C = 0.00425/°C

10. In a moving coil meter, explain EACH of the following terms and describe how the torque is produced:

    (a) Deflecting or driving torque; (3)

    (b) Restraining torque; (3)

    (c) Damping torque. (3)

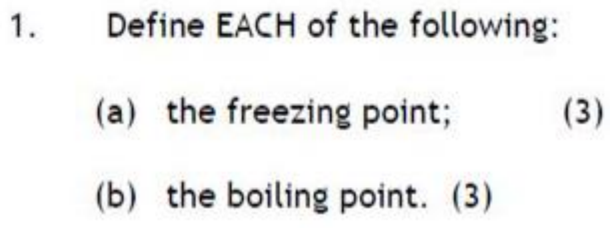
11. (a) Derive the power formula in terms of voltage and resistance. (4)

(b) A ship's oil heater has a power rating of 2.75 kW.

Calculate the electrical energy used in MJ when it is switched on for TWO hours. (3)

12. (a) Describe how an e.m.f. is induced in the armature conductors of a DC generator. (6)

(b) List the factors that affect the value of the induced voltage in Q12(a). (4)

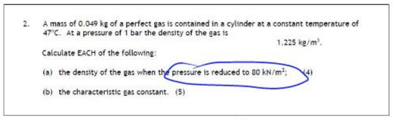


1. Define EACH of the following:

(a) the freezing point; (3)

(b) the boiling point. (3)

a) The point at which the enthalpy of fusion occurs, zero degrees Celsius (in water) 273K in water the temperature at a liquid turns into a solid. in water the occurs at zero degrees Celsius, for a pure substance this is usually at a specific temperature, for a mixture (salt and water) the freezing point is over a range of temperatures. This is also affected by pressure high pressure lowers the freezing point.
b) the temperature at which liquid turns into a gas (change of state), also affected by pressure. High pressure = high boiling point, low pressure = low pressure
Boiling point of water is 100ºC, again pure substances have a boiling point, impure having a boiling range.



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1.225 kg/m³.

Calculate EACH of the following:

(a) the density of the gas when the pressure is reduced to 80 kN/m²; (4)

(b) the characteristic gas constant. (5)

$Pv = mRt$

$m = 0.049$
$T = 47°C = 320°K$
$P = 1\,bar = 100{,}000$
$V = 0.04$
$P_2 = 80{,}000$

a) $\boxed{d = \frac{m}{v}}$

Density
$1.225 = \frac{0.049}{V}$

$V = \frac{0.049}{1225} = 0.04\,m^3$

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

$P_1 V_1 = P_2 V_2$

$\frac{100{,}000 \times 0.04}{80{,}000} = \boxed{V_2 = 0.05\,m^3}$

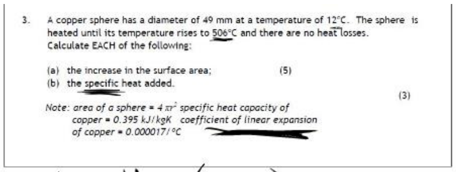
Density
$d = \frac{0.049}{0.05}$

$0.98\,Kg/m^3$

b) $Pv = mRt$

$\frac{100000 \times 0.04}{(0.049 \times 320)} = R = 255\,J/KgK$

$0.255\,\frac{KJ}{KgK}$



3. A copper sphere has a diameter of 49 mm at a temperature of 12°C. The sphere is heated until its temperature rises to 506°C and there are no heat losses. Calculate EACH of the following:

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Note: area of a sphere = $4\pi r^2$ specific heat capacity of copper = 0.395 kJ/kgK coefficient of linear expansion of copper = 0.000017/°C

a) old + (increase) = new

old × 2α × Δt

Surface Area = $4\pi r^2$

$d = 49$ mm

$r = 0.0245$ mm

Area $4\pi r^2 = 7.542963961 \times 10^{-3}$ m^2

$2\alpha = 0.000017 \times 2 = 3.4 \times 10^{-5}$

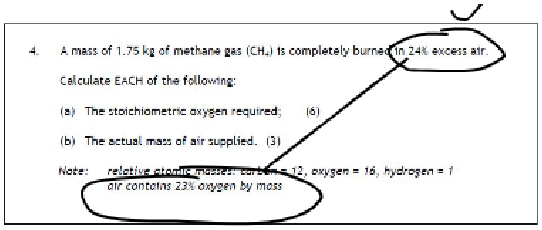
$\Delta t = 494$

increase $= 7.542963961 \times 10^{-3} \times 3.4 \times 10^{-5} \times 494$

$= \boxed{1.266 \times 10^{-4}\ m^2}$

$Q = mc\Delta t$

$Q = 1 \times 395 \times 494 = 195{,}130$ Joules



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Calculate EACH of the following:

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Note: relative atomic masses: carbon = 12, oxygen = 16, hydrogen = 1
air contains 23% oxygen by mass

$C = 12$ $H = 1$ $O = 16$

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

Amount of Carbon

$$\frac{12}{16} \times 1.75 = 1.3125$$

Amount of Hydrogen

$$\frac{4}{16} \times 1.75 = 0.4375\ \text{kg}$$

Amount of oxygen
Carbon

$$C + O_2 = CO_2$$

$$H_2 + O = H_2O$$

$$\frac{\text{Mass}}{\text{RAM}} \quad \frac{1.3125}{12} = \frac{x}{32}$$

$$\frac{0.4375}{2} = \frac{x}{16}$$

$$\boxed{3.5\ \text{kg}}$$

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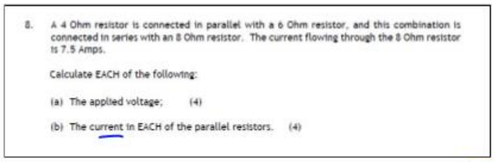
a) Oxygen = 7 Kg

b) Amount of Air $\frac{7}{0.23} = 30.43478$ Kg

$\boxed{37.739 \text{ Kg}}$



8. A 4 Ohm resistor is connected in parallel with a 6 Ohm resistor, and this combination is connected in series with an 8 Ohm resistor. The current flowing through the 8 Ohm resistor is 7.5 Amps.

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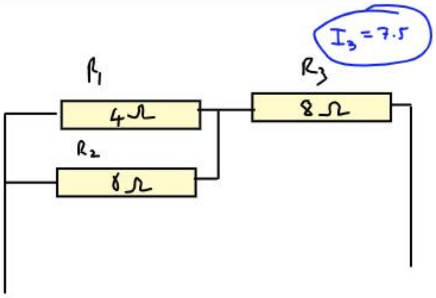


Circuit Current = 7.5

Circuit Resistance

Parallel Resistance

$\left(\frac{1}{4} + \frac{1}{6}\right) = \frac{1}{2.4}$ $\boxed{2.4 = R}$

Series Resistance

$2.4 + 8 = 10.4\ \Omega$

Voltage. $= 7.5 \times 10.4 =$

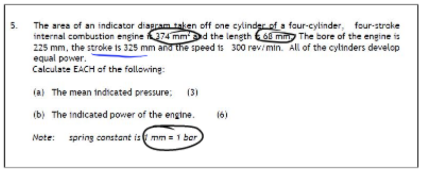
$= 78$ volts

Voltage drop

$V = IR$ $7.5 \times 2.4 = 18$ volts

$I_1 = \frac{18}{4} = 4.5$ Amps

I_2 $\frac{18}{6} = 3$ Amps



5. The area of an indicator diagram taken off one cylinder of a four-cylinder, four-stroke internal combustion engine is 374 mm² and the length is 68 mm. The bore of the engine is 225 mm, the stroke is 325 mm and the speed is 300 rev/min. All of the cylinders develop equal power.

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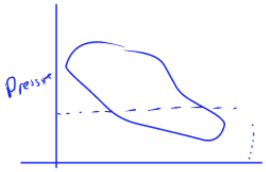
Note: spring constant is 1 mm = 1 bar



$$I_{mep} = \frac{\text{Area} \times \text{spring}}{\text{length}}$$

a) $I_{mep} = \frac{374\text{ mm}}{68} = 5.5\text{ bar} = 550{,}000\ (\text{Pa})$

b) $IP = x\,p\,l\,a\,n$

$x = 4$

$p = 550{,}000$

$L = 325\text{ mm} = 0.325\text{ m}$

$a = \pi r^2$

$d = 225\text{mm} = 0.225\text{m}$

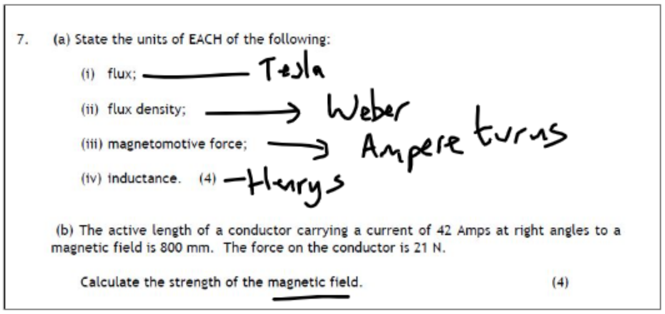
$r = 0.1125\text{ m}$

$a = \pi(0.1125)^2$

$N = \frac{300\text{ Rev}}{1\text{ min}} = \frac{300}{60} = \frac{5}{2} = 2.5$

$IP = 4 \times 550{,}000 \times 0.325 \times \pi(0.1125)^2 \times 2.5$

$IP\ 71.072\text{ KW}$



7. (a) State the units of EACH of the following:

(i) flux; — Tesla

(ii) flux density; → Weber

(iii) magnetomotive force; → Ampere turns

(iv) inductance. (4) — Henrys

(b) The active length of a conductor carrying a current of 42 Amps at right angles to a magnetic field is 800 mm. The force on the conductor is 21 N.

Calculate the strength of the magnetic field. (4)

$F = BIl\cancel{\sin\theta}$

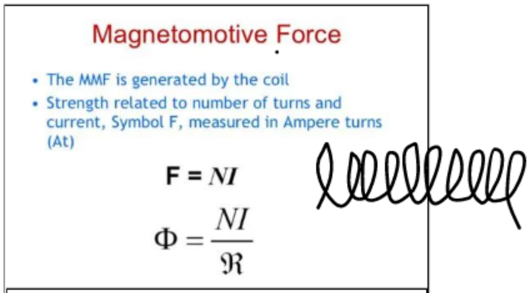
$I = 42$

$l = 0.8\text{m}$

$F = 21$

$21 = B \times 42 \times 0.8$

$\frac{21}{42 \times 0.8} = \boxed{0.625\text{ Tesla.}}$

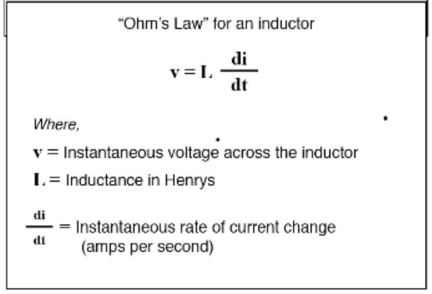


Magnetomotive Force

- The MMF is generated by the coil
- Strength related to number of turns and current, Symbol F, measured in Ampere turns (At)

$$F = NI$$

$$\Phi = \frac{NI}{\Re}$$



"Ohm's Law" for an inductor

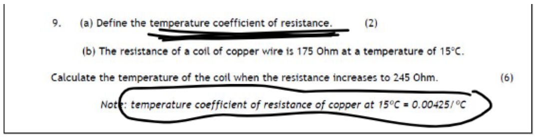
$$v = L\frac{di}{dt}$$

Where,

v = Instantaneous voltage across the inductor

L = Inductance in Henrys

$\frac{di}{dt}$ = Instantaneous rate of current change (amps per second)



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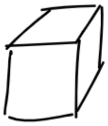
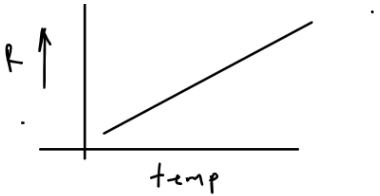




The amount of increase in resistence in a material for every one degree (centigrade or kelvin) increase in temperature, usually given at a certain temperature, eg, 15°C

Original + increase = New

$$R_t\left(1+\alpha(T-t)\right)=R_T$$

$$175\left(1+\alpha(T-t)\right)=245$$

$$175\left(1+0.00425(x-15)\right)=245$$

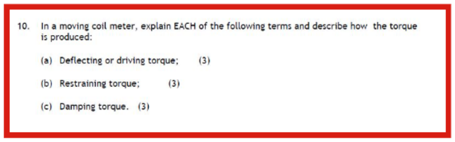
$$1+0.00425(x-15)=1.4$$

$$x-15=\frac{0.4}{0.00425}$$

$$x=109$$

$$\cancel{1+}\,0.00425(x-15)=\left(\frac{245}{175}\right)-1$$

$$0.00425(x-15)=\left(\frac{245}{175}\right)-1$$



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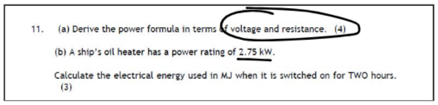


11. (a) Derive the power formula in terms of voltage and resistance. (4)

(b) A ship's oil heater has a power rating of 2.75 kW.

Calculate the electrical energy used in MJ when it is switched on for TWO hours. (3)

$$\text{Watt}=\frac{J}{s}$$

$$P=IV$$

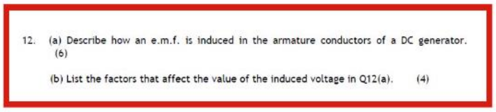
$$I=\frac{V}{R}$$

$$P=\left(\frac{V}{R}\right)\times V$$

$$P=\frac{V^2}{R}$$

$$P=\frac{\text{Work}}{\text{time}}$$

$$2750\,W=\frac{2750\,J\ \times 60\ \times 60\ \times 2}{1\ \ s\ \times 60\ \times 60\ \times 2}=\boxed{19.8\ MJ}$$



12. (a) Describe how an e.m.f. is induced in the armature conductors of a DC generator. (6)

(b) List the factors that affect the value of the induced voltage in Q12(a). (4)