FEDERAL UNIVERSITY OF TECHNOLOGY, OWERRI
SCHOOL OF PHYSICAL SCIENCES
DEPARTMENT OF PHYSICS
2015/2016 HARMATTAN SEMESTER Time: 3hrs
PHY 201: APPLIED ELECTRICITY I Date: 27/04/16

Instruction: Answer Question **ONE** and any other three questions.

QUESTION 1

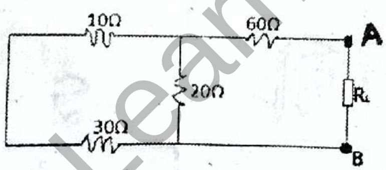
a) A 45Ω resistor is connected to the terminate of a battery whose emf is 12.0v and whose internal resistance is 0.5Ω. Calculate the current in the circuit.

b) i. Define the resistivity of a copper wire.
ii. A copper wire in a typical house has a diameter of about 1.5mm. How long would a wire be in order to have a resistance of 10.0Ω, if the resistivity is 1.68×10^{-8}Ωm?

c) A voltage source having emf of 12v and internal resistance of 1Ω is connected to two resistors of 4Ω and 8Ω connected in parallel,
i. Draw and label the circuit
ii. What is the current flowing through the 8Ω resistor?

d) An electric current of 10A is divided into three branches of resistors R_1,R_2 and R_3 with resistances of 1Ω, 2Ω and 3Ω respectively.
i. Draw the circuit diagram
ii. Find the current in each branch of the circuit.

e) What is the load resistance R_L that will ensure maximum power transfer in the circuit shown below?



f) i. What is Peak-to-peak value of an alternating waveform?
ii. A supply voltage has a mean value of 250V.
Calculate (a) the maximum value
(b) The rms value
(c) The peak factor of the supply voltage

g) In a single phase series a.c. circuit containing only purely capacitance, draw and label the following
(a) the circuit diagram
(b) the current and voltage waveform
(c) the phasor diagram. Comment how the current and voltage relate in the circuit diagram.

h) A coil having a resistance of 6Ω and an inductance of 0.03H is connected across a 100V, 50Hz sine wave supply. Calculate (i) the impedance (ii) the power factor

i) What is a j-operator in an a.c. circuit?

QUESTION 2

a) Explain the potential difference between two points in a circuit.

b) What is the kilo-watt hour (kw-h)? What is the equivalent in Joules?

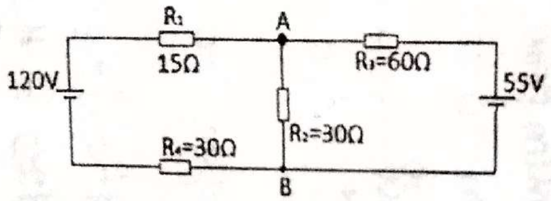
c) Two coils which are close together have a mutual inductance of 330mH. If the emf in the coil is 120V, what is the rate of change of the current in coil 2?

QUESTION 3

a) State the two Kirchoff's laws

b) i. State the superposition theorem.

ii. Using superposition theorem only, calculate the voltage drop over R_2 in the circuit shown below.



QUESTION 4

a) Draw the circuit diagram, the current and voltage waveforms and the phasor diagrams for the following single phase series a.c. circuit.

(i) Purely resistive a.c. circuit

(ii) Purely inductive a.c. circuit

(iii) Comment on the current and voltage relationships in each

b) A current of 5A flows through an a.c. circuit containing a resistor of resistance 8Ω and two reactances $X_L = 6\Omega$ and $X_c = 12\Omega$.

(i) Obtain the p.d across each element

(ii) Calculate (1) the impedance and the effective voltage of the circuit (2) the phase angle between voltage and current.

QUESTION 5

a) Draw phasor diagram for the following:

(i) Series R-L-C and

(ii) Parallel R-L-C circuits of resonance

b) A circuit of (6 + j8)A passes through a resistor of resistance 2Ω in an a.c. circuit. What is the power dissipated on the resistor?

c) An a.c. circuit having a resistance of 50Ω and a capacitance of 40μF are connected across a 230V, 50Hz supply.

Calculate (i) the current in the circuit (ii) the phase of the current relative to the applied voltage (iii) express the impedance in rectangular and polar notations.

2015/2016 EXAM SOLUTIONS

No 1

a $E = I(r+R)$; $I = \frac{E}{r+R}$

Given $E = 12V$, $R = 45\Omega$ and $r = 0.5\Omega$

$I = \frac{12}{0.5+45} = \frac{12}{45.5} = 0.26A$

b i) The resistivity of a copper wire is the resistance of a unit length of a copper wire with uniform cross-sectional area.

ii) Given $d = 1.5mm = 1.5\times10^{-3}m$, $R = 10\Omega$

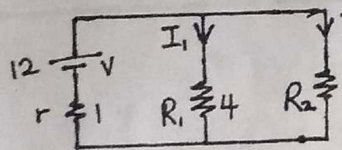
$\rho = 1.6\times10^{-8}\Omega m$

$\rho = \frac{RA}{L} \Rightarrow L = \frac{RA}{\rho}$

but $A = \frac{\pi d^2}{4} = \frac{\pi(1.5\times10^{-3})^2}{4} = 1.76\times10^{-6}m$

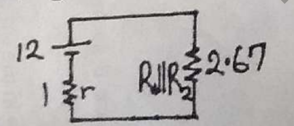
$\therefore L = \frac{10\times1.76\times10^{-6}}{1.6\times10^{-8}} = 1104.5m$

c i



ii) $R_1 \| R_2 = \frac{R_1R_2}{R_1+R_2} = \frac{4\times8}{4+8} = \frac{32}{12} = 2.67\Omega$

The diagram becomes



$V = IR_{eq}$

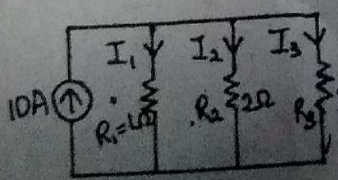
$I = \frac{V}{R_{eq}}$

$I = \frac{12}{2.67+1} = 3.27A$

$I_1 = \frac{IR_2}{R_1+R_2} = \frac{3.27\times8}{8+4} = 2.18A$

$I_2 = \frac{IR_1}{R_1+R_2} = \frac{3.27\times4}{8+4} = 1.09A$

d i)



ii) $\frac{1}{R_{eq}} = \frac{1}{R_1} + \frac{1}{R_2} + \frac{1}{R_3} = 1 + \frac{1}{2} + \frac{1}{3} = \frac{11}{6}$

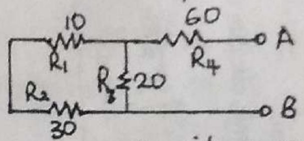
$R_{eq} = \frac{6}{11} = 0.54\Omega$

$I_1 = \frac{R_{eq}}{R_1}.I = \frac{0.54\times10}{1} = 5.4A$

$I_2 = \frac{R_{eq}}{R_2}.I = \frac{0.54\times10}{2} = 2.7A$

$I_3 = \frac{R_{eq}}{R_3}.I = \frac{0.54\times10}{3} = 1.8A$

e) Maximum power transfer occurs when $R_L = R_{TH}$ so to find R_{TH}, we remove R_L



Due to open circuit, no current flows through R_4 ie

$R_{TH} = (R_1+R_2)\| R_3 + R_4 = (30+10)\|20 + 0$

$= 40\|20 = \frac{40\times20}{40+20}$

$R_{TH} = 13.33\Omega$

$\therefore$ For MPT to occur, $R_L = 13.33\Omega$

f) i. This is the value between the negative and positive vertical direction of a waveform.

ii) a. The mean value is also called the average value

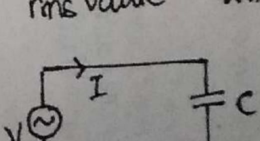
$V_{av} = 0.637V_m$

$\therefore V_m = \frac{V_{av}}{0.63} = \frac{250}{0.637} = 392.46V$

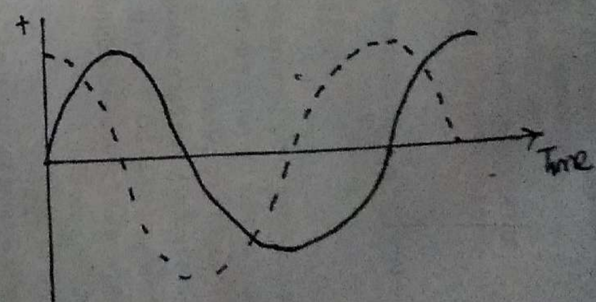
b. $V_{rms} = \frac{V_m}{\sqrt{2}} = \frac{392.46}{\sqrt{2}} = 277.5V$

c. $K_a = \frac{\text{max value}}{\text{rms value}} = \frac{V_m}{V_{rms}} = \frac{392.46}{277.5} = 1.41$

g) a.

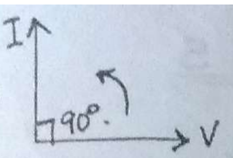


b.



current = - - - - -

voltage = ______

c) 

Voltage lags by 90° or Current leads by 90° in a purely capacitive circuit

h i. $Z = \sqrt{R^2 + X_L^2}$

Given $R = 6\Omega$, $X_L = \omega L = 2\pi f L = 2\pi \times 50 \times 0.03$

$X_L = 9.42\Omega$

$Z = \sqrt{6^2 + 9.42^2} = \underline{11.16\Omega}$

ii. Power factor $= \frac{R}{Z} = \frac{6}{11.16} = \underline{0.54}$

i A j-operater is used to represent a complex part of a parameter in an AC circuit.

QUESTION 2

a The potential difference between two points in a circuit is the energy required to move a positive test charge from one of the points to the other in the circuit. (Also see variant in 2013/14 exam No1)

b Kilowatt hour (kw-h) is a measure of electrical energy equivalent to a power consumption of 1000 watts for 1 hour

$1kW = 1000 Watt = 1000 J/s$

$1kw\text{-}h = 1000\frac{J}{s} \times 3600 s = 3600000 J$

$\therefore 1kwh = \underline{3.6MJ}$

c $V_1 = M_{12}\frac{di_2}{dt}$

given $M_{12} = 330mH = 330 \times 10^{-3}H$, $V_1 = 120V$

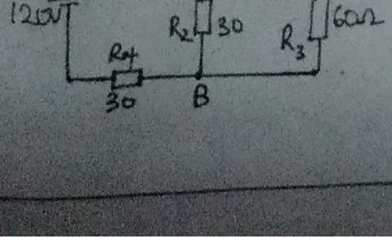
$\therefore \frac{di_2}{dt} = \frac{V_1}{M_{12}} = \frac{120}{330 \times 10^{-3}} = \underline{363.64 A/s}$

QUESTION 3

a Same as 2014/2015 test – 3a

b i) Same as 2014/2015 exam – 1g

ii) When 120V is acting alone,



$R_{eq} = R_1 + R_4 + R_2 || R_3 = 15 + 30 + \frac{30 \times 60}{30 + 60}$

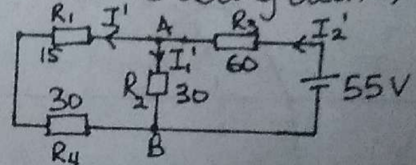
$R_{eq} = 65\Omega$

$I = \frac{V}{R_{eq}} = \frac{120}{65} = 1.85\Omega$

$\therefore I_1 = \frac{IR_3}{R_2 + R_3} = \frac{1.85 \times 60}{60 + 30} = 1.23A$

$I_2 = \frac{IR_2}{R_2 + R_3} = \frac{1.85 \times 30}{60 + 30} = 0.62A$

When 55V is acting alone,



$R_{eq} = (R_1 + R_4) || R_2 + R_3$

$= \frac{(15+30)(30)}{(15+30)+30} + 60 = \frac{45 \times 30}{45 + 30} + 60$

$R_{eq} = 18 + 60 = 78\Omega$

$\therefore I_2' = \frac{V}{R_{eq}} = \frac{55}{78} = 0.71A$

$I_1' = \frac{I_2' \times (R_1 + R_4)}{R_2 + (R_1 + R_4)} = \frac{0.71 \times 45}{45 + 30} = 0.43A$

$I' = \frac{I_2' R_2}{R_2 + (R_1 + R_4)} = \frac{0.71 \times 30}{45 + 30} = 0.28A$

Superimposing to get current in branch AB,

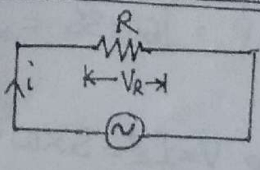
$I_1 + I_1' = 1.23 + 0.43 = 1.66A$

Since the current across $R_2 = 1.66A$, then Voltage drop over R_2 is

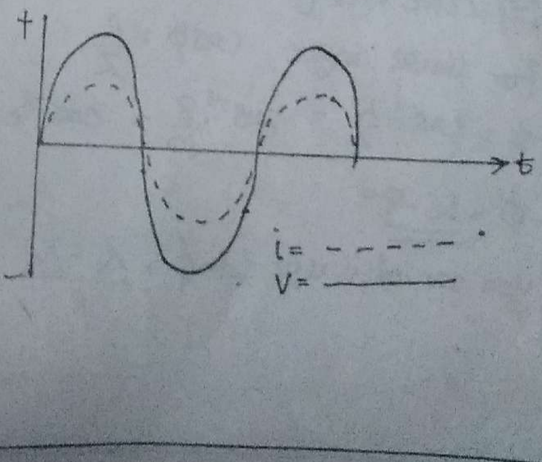
$V = IR = 1.66 \times 30 = \underline{49.8V}$

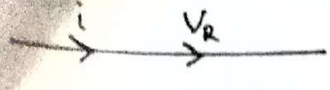
QUESTION 4

a)(i)



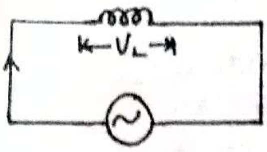
circuit diagram

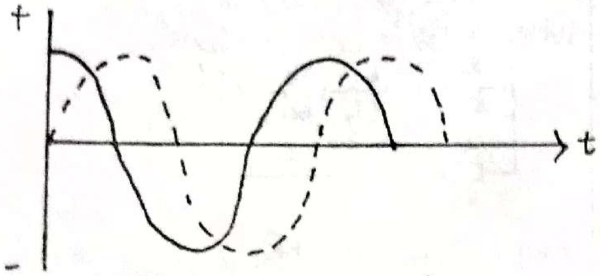




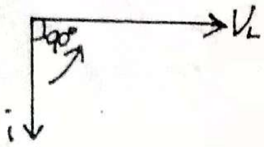
Phasor diagram

ii)





current = - - - -
Voltage = ———



iii) For purely resistive, current and voltage has no phase difference
For purely inductive voltage leads or current lags by 90°

b i) $V_R = IR = 5\times 8 = \underline{40V}$

$V_L = IX_L = 5\times 6 = \underline{30V}$

$V_c = IX_c = 5\times 12 = \underline{60V}$

ii) Impedance $Z = \sqrt{R^2 + (X_L - X_c)^2}$

$Z = \sqrt{8^2 + (6-12)^2} = \sqrt{64+36} = \sqrt{100}$

$Z = \underline{10\Omega}$

Effective voltage $V = IZ = 5\times 10 = \underline{50V}$

For phase angle, $\cos\phi = \frac{R}{Z}$

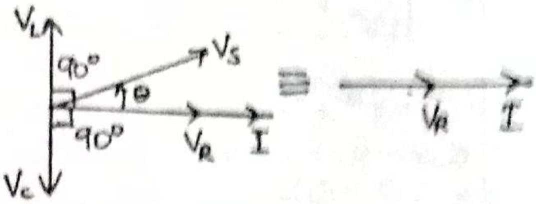
$\phi = \cos^{-1}\frac{R}{Z} = \cos^{-1}\frac{8}{10} = \cos^{-1}0.8$

$\phi = \underline{36.9°}$

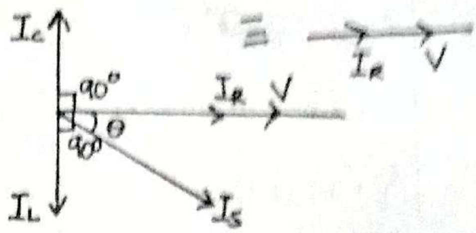
you can also use $\tan\phi = \frac{X_L - X_c}{R}$

QUESTION 5

a) i.



ii.



b) $P = I^2R$

Given $I = 6+j8$, $R = 2\Omega$

$P = (6+j8)^2\times 2 = (36+j48+j48-64)2$

$P = \underline{(-56+j192)W}$

c) i $V = IZ$

but $Z = \sqrt{R^2+X_c^2} = \sqrt{R^2+\left(\frac{1}{\omega C}\right)^2} = \sqrt{R^2+\left(\frac{1}{2\pi fC}\right)^2}$

given $R = 50\Omega$, $f = 50Hz$, $C = 40\mu F = 40\times 10^{-6}F$

$Z = \sqrt{50^2 + \left(\frac{1}{2\pi\times 50\times 40\times 10^{-6}}\right)^2} = 93.98\Omega$

$\therefore I = \frac{V}{Z} = \frac{230}{93.98} = \underline{2.45A}$

ii) $\tan\phi = \frac{-X_c}{R}$

$X_c = \frac{1}{2\pi\times 50\times 40\times 10^{-6}} = 79.58$

$\phi = \tan^{-1}\frac{-X_c}{R} = \tan^{-1}\frac{-79.58}{50}$

$= \tan^{-1}-1.59 = -57.85$

$\phi = -57.85°$

iii) Here impedance $Z = 93.98\Omega$

$\therefore Z = (93.98 + j0)\Omega \rightarrow$ Rectangular

$Z = (93.98\angle 0°)\Omega \rightarrow$ Polar