

# ELECTRICAL ENGINEERING

## PAPER - I

**Time Allowed: 3 Hours**

**Maximum Marks: 200**

*Candidates should attempt SIX questions, selecting TWO questions from Section - A, ONE from Section - B, ONE from Section - C and TWO from Section - D.*

### SECTION A

1. (a) For the circuit shown in Fig. 1, find the Thevenin and Norton equivalent circuits looking in at terminals 'a' and 'b'

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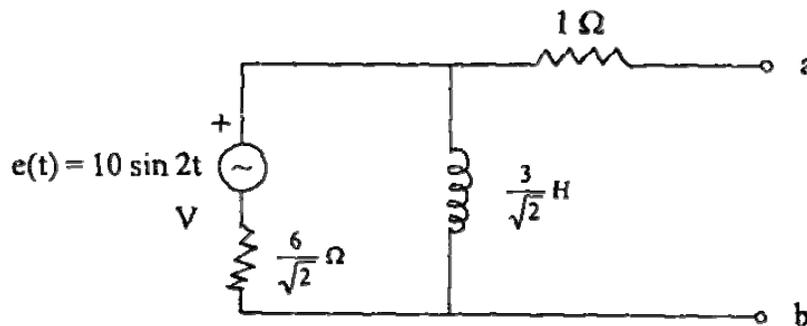


Fig. 1

- (b) In the R-L-C circuit shown in Fig. 2,  $I_s = 10$  A,  $R = 1$   $\Omega$ ,  $L = 1$  H,  $C = 1$   $\mu$ F and  $i_L(0^-) = 0$ . Determine  $v(0^+)$ ,  $\frac{dv}{dt}(0^+)$  and  $\frac{d^2v}{dt^2}(0^+)$  after the switch is closed at  $t = 0$ .

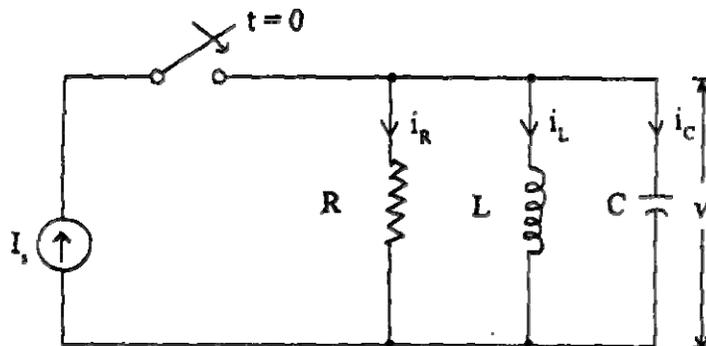


Fig. 2

- (c) An industrial consumer is operating a 3-phase 10 kW induction motor at a lagging power factor of 0.8 and at a source voltage of 400 V r.m.s. He wishes to raise the power factor to 0.95 lagging by connecting a circuit element in parallel to the load (motor). Indicate the type of circuit element (inductive or capacitive) and find its value if the operating frequency is 50 Hz. Give your comments on the new line and motor currents.

12

2. (a) A 415 V, three-phase generator supplies power to both a delta- and a star-connected load in the manner shown in Fig. 3. All the phase impedances are identical and specifically equal to  $(5 + j 8.66)\Omega$ . Compute the total generator current in each line.

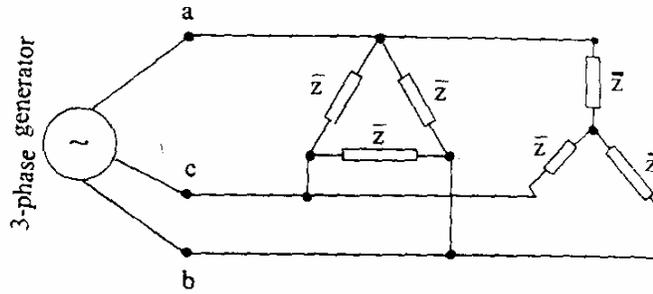


Fig. 3

- (b) Show that the resonant frequency  $\omega_0$  of an R-L-C series circuit is geometric mean of  $\omega_1$  and  $\omega_2$ , the lower and upper half-power frequencies respectively. 10
- (c) Prove that for BIBO stability, the roots of the characteristic equation or the poles of the system transfer function cannot be located in the right half of s-plane or on the  $j\omega$ -axis, 12
3. (a) A system is described by the following state variable equations:
- $$\begin{bmatrix} \dot{x}_1(t) \\ \dot{x}_2(t) \end{bmatrix} = \begin{bmatrix} -1 & 1 \\ 0 & -2 \end{bmatrix} \begin{bmatrix} x_1(t) \\ x_2(t) \end{bmatrix} + \begin{bmatrix} 1 \\ -1 \end{bmatrix} U(t),$$
- where  $U(t)$  is Unit step input and the output
- $$y(t) = [1 \quad 1] \begin{bmatrix} x_1(t) \\ x_2(t) \end{bmatrix}$$
- Determine  $y(t)$ ,  $t \geq 0$  when the initial values of the states at time  $t = 0$  are  $x_1(0) = x_2(0) = 1$ . 10
- (b) A unity feedback system has an open-loop transfer function
- $$G(s) = \frac{10000}{s(s+10)^2}$$
- Determine the phase margin of the system in degrees. 10
- (c) The transfer function of a phase-lead controller is given as  $G_c(s) = \frac{1+aTs}{1+Ts}$ ,  $a > 1$  and  $T$  is a constant depending on the circuit parameters. Determine the maximum value of the phase lead which can be obtained from this controller. 12

## SECTION B

4. (a) Explain the concept of wave impedance for plane waves travelling in a lossless medium and show how this may be extended to cover the case of a conductive medium. Show that the reflection coefficient for plane waves travelling in a vacuum and falling with normal incidence upon a medium having wave impedance  $\eta$  is given by
- $$\frac{(\eta - \eta_0)}{(\eta + \eta_0)}$$
- Show that when a plane wave is incident normally upon a medium with permeability  $\mu_0$  permittivity  $\epsilon_0$  and conductivity  $\sigma$  the fraction of power absorbed is approximately  $2(2\omega\epsilon_0/\sigma)^{1/2}$ .

- (b) Derive an expression for characteristic impedance of a coaxial transmission line with inner and outer radius are a and b respectively.

12

- (c) Show that in a source free homogeneous isotropic linear medium, the time harmonic electric and magnetic fields are

Given by 
$$E = -\nabla \times F + \frac{\nabla(\nabla \cdot A)}{j\omega\epsilon} - j\omega\mu A$$
 and

$$H = \nabla \times A + \frac{\nabla(\nabla \cdot F)}{j\omega\epsilon} - j\omega\epsilon F$$

where A and F are magnetic and electric vector potential.

12

5. (a) Write the Maxwell's equation in a good conductor for time harmonic fields. Show that the conduction current density J in a good conductor must satisfy

$$\nabla(\nabla \cdot J) - \nabla^2 J = -j\omega\mu\sigma J$$

12

- (b) Explain relaxation time constant for a metal. Derive an expression for the continuity of current equation for dynamic current. Show that the volume charge density is a solution of

$$\frac{\partial \rho_v}{\partial t} + (\sigma / \epsilon) \rho_v = 0$$

12

- (c) Show that for metals  $\eta = \sqrt{\frac{\omega\mu}{2\sigma}}(1+j)$

$$k = \sqrt{\frac{\omega\mu\sigma}{2}}(1-j)$$

where  $\eta$  is intrinsic wave impedance of the medium and k is the wave number.

12

## SECTION C

6. (a) Explain the current conduction mechanism in a semiconductor. Explain how doping changes the conductivity of a semiconductor? Show that the Fermi level lies halfway between the valence and conduction band of an intrinsic semiconductor.

12

- (b) Explains electron and hole mobilities and drift velocities.

12

- (c) What is piezoelectricity? What are the different applications in which piezoelectricity is used? Describe materials that show piezoelectricity.

12

7. (a) What do you understand by magnetic hysteresis ? Differentiate between hard and soft magnetic material.

12

- (b) What is the domain theory of magnetization? What is Curie temperature? Can Curie temperature of a material be changed?

12

- (c) Explain the basic properties of dielectrics. What do you understand by the loss tangent and susceptibility?

12

## SECTION D

8. (a) A balanced bridge has the following arm parameters:-  
 Arm AB -  $K_1 = 1500 \Omega$  in parallel with  
 $C_1 = 0.03 \mu\text{F}$ .  
 Arm BC -  $K_2 = 1876 \Omega$  in series with  
 $C_2 = 0.03 \mu\text{F}$ .  
 Arm CD - Unknown.  
 Arm DA -  $C_3 = 0.5 \mu\text{F}$ .  
 If an a.c. voltage of frequency 1 kHz is applied across the junction 80, find the parameters of arm CD.
- 12
- (b) What is meant by absolute measurement of electrical quantities? Describe the method of absolute measurement of ohm.
- 10
- (c) An electrodynamic wattmeter is employed to measure power in a single phase circuit. The load voltage is 230 V and the load current is 5 Amps. at a lagging power factor of 0.1. The wattmeter potential coil has a resistance of  $10,000 \Omega$  and an inductive reactance negligible compared to resistance. Determine percentage error in the wattmeter reading. Inductance of coil is 100 mH and pressure coil is connected on load side, to
9. (a) During the measurement of a capacitor, following ten readings were obtained:  
 1.002, 0.998, 1.005, 1.009, 0.995, 0.997, 1.004, 1.008, 1.003 and  $0.994 \mu\text{F}$ .  
 Calculate
- (i) the arithmetic mean,
  - (ii) the deviation from the mean,
  - (iii) average deviation and
  - (iv) standard deviation.
- 12
- (b) Discuss the merits and demerits of potentiometers used as transducers.  
 A linear resistance potentiometer is 100 mm long and is uniformly wound with a wire of total resistance  $10,000 \Omega$ . Under normal conditions, the slider is at the centre of the potentiometer. Determine the linear displacement when the resistance of the potentiometer as measured by Wheatstone bridge is  $3700 \Omega$ . If it is possible to measure a minimum value of  $5 \Omega$  resistances with the above arrangement, determine the resolution of potentiometer in mm.
- 10
- (c) Discuss how the d.c. calibration of a dynamometer wattmeter is done by comparison with standard wattmeter.
- 10
10. (a) What is meant by phantom or fictitious loading of energy meters?  
 An a.c. energy meter is tested for half hour run at a supply voltage of 230 V with a current of 12 Amps. at 0.8 p.f. lag. The dial reading at the beginning of test was 58.5 and at the end was 59.5. The meter constant is 1200 revolutions per kWh. The meter revolutions registered during the test were 1150. Find out

- (i) error in registration and
- (ii) error in r.p.m. of energy meter.  
How error in r.p.m. can be rectified?

12

- (b) Explain the working of binary ladder digital to analog converter using R-2R ladder network with four input voltages.

If in the above DAC a reference voltage of 12 V is used, what will be its resolution and full scale output?

10

- (c) The inductance of a moving iron instrument is given by  $L = (0.01 + k_1\theta)^2 \mu\text{H}$  where  $\theta$  is angular deflection in radians from zero position. The angular deflection in radians corresponding to currents of 1.5 and 4.S Amps. are  $\pi/6$  and  $\pi/3$  respectively. Find the value of k.

10

# ELECTRICAL ENGINEERING

## PAPER - II

**Time Allowed: 3 Hours**

**Maximum Marks: 200**

*Candidates should attempt FIVE questions in all, including Question No.1 which is compulsory. The remaining FOUR questions are to be attempted by selecting at least ONE question from each of the Sections A, B, C and D.*

*Assume suitable data, if necessary and indicate the same clearly.*

## SECTION A

*Question 1 is compulsory*

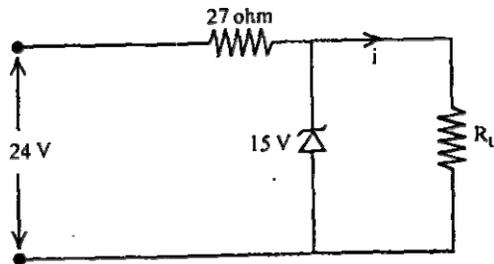
1. A. Choose and write the correct answer

$2 \times 10 = 20$

- (a) The surge impedance of a 400 kV, 100 km transmission line is 300 ohms. For a 200 km length the line surge impedance will be  
 (i) 300 ohms                      (ii) 150 ohms  
 (ii) 600 ohms                      (iv) 400 ohms
- (b) For protection of parallel feeders fed from one end, the relays required are  
 (i) Non-directional relays at the source end and directional relays at the load end  
 (ii) Non-directional relays at both ends  
 (iii) Directional relays at source end and non-directional relays at load end  
 (iv) Directional relays at both ends
- (c) The stability of arc in vacuum depends on  
 (i) The contact material only  
 (ii) The contact material and its vapour pressure  
 (iii) The circuit parameters only  
 (iv) The combination of (ii) and (iii).
- (d) The power systems are operated with power angle around  
 (i)  $10^\circ$               (ii)  $30^\circ$               (iii)  $70^\circ$               (iv)  $80^\circ$
- (e) For a slip ring induction motor, if the rotor resistance is increased, then  
 (i) starting torque and efficiency increase  
 (ii) starting torque decreases but efficiency increases  
 (iii) starting torque increases but efficiency decreases  
 (iv) starting torque and efficiency decrease
- (f) A 3-phase synchronous generator with constant steam input supplies power to an infinite bus at a lagging power factor. If the excitation is increases  
 (i) both power angle and power factor decrease  
 (ii) both power angle and power factor increase  
 (iii) the power angle decreases while power factor increases  
 (iv) the power angle increases while power factor decreases

- (g) A 90 MVA, 11 kV water wheel generator has an inertia constant  $H = 3$ . The stored energy in the rotor at synchronous speed is
- (i) 40 kJ                      (ii) 270 kJ  
 (iii) 270 MJ                  (iv) 40 MJ

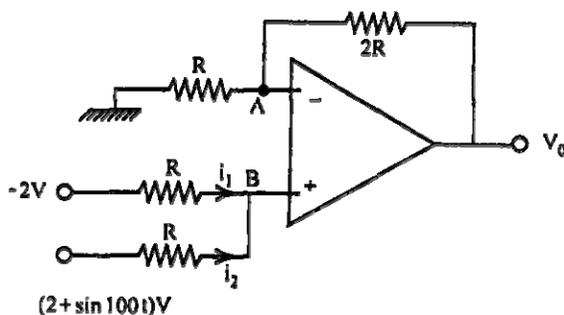
(h)



In the circuit shown above, the zener diode is ideal. The minimum value of  $R_L$  up to which the output voltage remains constant is

- (i) 27 ohms  
 (ii) 45 ohms  
 (iii) 15 ohms  
 (iv) 24 ohms
- (i) The Boolean expression  $X = B + A.B + A.B$  is equivalent to
- (i)  $A + B$   
 (ii)  $\bar{A} . B$   
 (iii)  $\frac{A + B}{A + B}$   
 (iv)  $A . B$

(j)



A non inverting operational amplifier summer is shown in the above figure. The output voltage  $V_0$  is

- (i)  $3/2 \sin 100t$                       (ii)  $3 \sin 100 t$   
 (iii)  $\sin 100 t$                           (iv)  $2 \sin 100 t$

B. Explain the following:

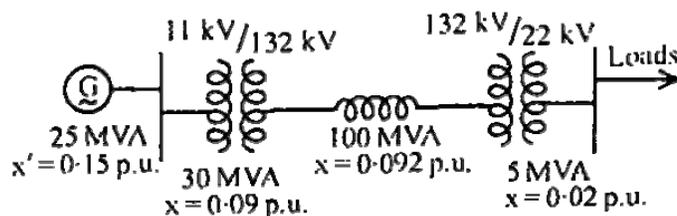
$5 \times 4 = 20$

- (a) Surge impedance loading of a transmission line.  
 (b) The basic difference between the magnetizing current of a large capacity transformer and the magnetizing inrush current.  
 (c) A loss of excitation relay used for alternator protection.  
 (d) The purpose of different flags and their working in an Intel 8085 microprocessor.

2. (a) A 220 V d.c. compound generator has resistances of the armature, shunt and series windings as 0.1 ohm, 50 ohms and 0.06 ohm, respectively. The load current is 100 A at 220 V. Find the induced e.m.f. and armature current when the machine is connected as a (i) long shunt, (ii) short shunt. (iii) how will the ampere-turn of the series winding will change if in (i) a diverter resistance of 0.1 ohm be connected in parallel with series winding? Ignore armature reaction. 12
- (b) Calculate efficiency, voltage at the secondary terminals and primary input current when supplying full load secondary current at power factor (i) unity (ii) 0.8 lag, for a 4 kVA, 230/460 V single phase transformer.  
The following are test results  
Open circuit with 230 V applied to LV side – 0.6 A, 75 W  
Short circuit with 20 V applied to HV side - 10 A, 60 W. 20
- (c) Summarize the conditions for proper parallel operation of (i) single-phase transformers, and (ii) 3-phase transformers. 8
3. (a) A synchronous generator supplies rated power at 0.8 p.f. lagging. Its resistance and synchronous reactance are 0.01 and 1.0 pu. Calculate the terminal voltage if the open circuit voltage is 2.1 p.u. What is the minimum allowable excitation voltage? 14
- (b) From the short circuit test on a 50 H.P., 440 V, 50 Hz, 6 pole star connected, 3-phase induction motor, the following data were obtained  
 $V = 230$  V,  $I = 140$  A,  $\cos \phi = 0.35$  (line values). The motor drives a load having a constant torque of 300 N.m. Estimate the maximum percentage reduction in the supply voltage possible before the motor stalls. Assume that the copper losses are equally divided between the stator and the rotor. Neglect magnetizing current. 14
- (c) Name the chief methods of speed control of a 3-phase induction motor. Explain briefly one of the most modern methods of speed control of an induction motor namely (v/f) control. 12

## SECTION B

4. (a) Explain with necessary diagram the phenomena of current chopping in an air blast circuit breaker. How this problem can be rectified by using resistance switching? Why mostly air blast circuit breakers are susceptible to current chopping? 12
- (b)



A symmetrical 3-phase short circuit occurs on the 22 kV bus bars of the circuit shown as a one-line diagram in the above figure. Calculate the fault current and the fault apparent power.

10

- (c) Explain with necessary diagram the principle of operation of a distance protection scheme. How 3-zone stepped units help to achieve fast discrimination? How many units are required for a complete protection scheme? How the CTs and VTs associated with these relays are connected to a 3-phase transmission line? Indicate the reasons of mode of connections of CTs and VTs in such a way

18

5. (a) A 50 Hz two pole turbo alternator rated 50 MVA, 13.2 kV has an inertia constant  $H = 5.0$  MJ/MVA. Determine the kinetic energy stored in the rotor at synchronous speed. Determine the acceleration if the input less the rotational losses is 65000 HP and the electrical power developed is 40 MW. If the acceleration computed for the generator is constant for a period of 10 cycles, determine the change in torque angle in that period and the r.p.m. at the end of 10 cycles. Assume that the generator is synchronized with a large system and has no accelerating torque before the 10 cycles period begins.

18

- (b) Explain with necessary diagrams the different kinds of HVDC links used in HVDC system. Also explain the relative advantages and disadvantages of using these links. What are the precautions needed for series and parallel connection of thyristors to construct a HVDC system?

12

- (c) Assume that the equations between the sending end voltage and current with the corresponding receiving end voltage and current in terms of A, B, C, D constants of a long transmission line are known, derive equations for sending end and receiving end power.

10

## SECTION C

6. (a) Two 8 bits Hex numbers are stored in Memory locations 2000 H and 2001 H respectively. Develop a suitable program with proper comments in assembly level language to multiply these two Hex numbers by shift and add technique. Store the 16 bit results in two memory locations 2002 H and 2003 H respectively with 'hi-byte' in 2002 H and 'b-byte' in 2003 H, In which way "Shift and Add" technique used for multiplication is better suited for multiplication than "repeated addition" method?

18

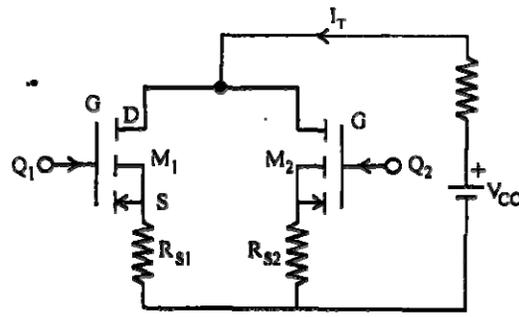
- (b) A single pole 8 way rotary switch is connected to port A, of a 8255 chip, starting from bit 0 to bit 7 positions. When the switch is manually rotated to bit position 3, a fan connected to bit 3 of port B is to be switched on. Further when the manually rotated switch is changed to bit position 5, a television set is to be made on whose switch is connected to bit position 5 of port B, associated with 8255 chip. It is to be assumed that necessary "control word" for making port A in input mode and port B in output mode have been done via the control port. Further latching circuits have been provided in port B, so that once the fan and the television set is on, they will remain 'on' unless the switch position comes to bit 7 of port A. When both of them will be made automatically off by sending bit '0's to bit position 3 and 5 respectively to port B. Develop the necessary program in Assembly level language with comments, and the hardware connection of the rotary switch. Latching circuit diagrams need not be provided.

22

7. (a) (i) Draw with proper labelling the steady state switching models (circuit diagram and equivalent circuit) of a MOSFET. How many different types of MOSFETS are available? Name them. How do they respond to different gate (or input) voltage? Explain with necessary diagram how the mm-on time of a MOSFET can be reduced?

10

- (ii)



Parallel Connection of MOSFETS

Two MOSFETS which are connected in parallel similar to the above figure, carry a total current,  $I_T = 25$  A. The drain to source voltage of  $M_1$  is  $V_{DS1} = 2.0$  V and that of  $M_2$  is  $V_{DS2} = 35$  V. Determine the drain current of each transistor and difference in current sharing if the current sharing series resistances are (i)  $R_{S1} = 0.35$  ohm,  $R_{S2} = 0.2$  ohm, and (ii)  $R_{S1} = R_{S2} = 0.5$  ohm.

10

(b) Describe with necessary diagrams

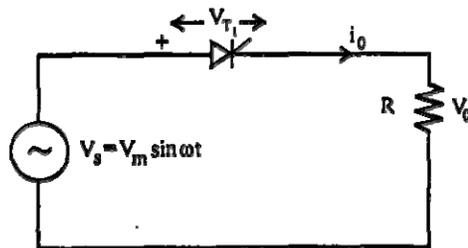
- (i) an Integrator, and
- (ii) a differentiator using operational amplifier circuits. How the offset voltage can be minimized in an Integrator at the

8. (a) Draw the symbols and characteristics of the following devices

- (i) Diode,
- (ii) Thyristor,
- (iii) GTO,
- (iv) Triac and
- (v) IGBT.

10

(b) A single-phase thyristor converter with a resistive load is shown below:



Supply voltage  $V_s$  is sinusoidal at a fixed frequency.

(i) Draw the waveforms of  $V_s$ ,  $V_o$  and  $V_{T1}$  at the firing angle  $\alpha = 45^\circ$ . Neglect leakage current.

10

(ii) If the supply voltage is 230 V (rms) at 50 Hz, calculate for  $\alpha = 45^\circ$  and  $R$  100 ohms.

- (a) Average output voltage and current.
- (b) R.M.S. value of supply current.
- (c) Ripple factor.

Derive the formulae used.

**SECTION D**

9. (a) Draw the circuit diagram of a single-phase semi converter and derive an expression for the average voltage across the load in terms of supply voltage and firing angle  $\alpha$ . Explain the semi converter operation and show the waveforms for the input voltage, output voltage and current through different diodes and thyristors. 18
- (b) A semi converter is connected to a 240 V 50 Hz supply. The load current  $I_a$  can be assumed to be continuous and its ripple current is negligible. Calculate the harmonic factor of input current for  $\alpha = \pi/2$ . Derive all the relevant formulae used using Fourier series analysis. Obtain also expressions for r.m.s. value of supply current and r.m.s. value of fundamental current in terms of  $I_a$  and  $\alpha$ . 22
10. (a) Define “amplitude modulation” and “modulation index”. Write down the equations for (i) amplitude, and (ii) the instantaneous voltage of the amplitude modulated wave. Sketch the graph of an amplitude modulated wave. 10
- (b) The current in an Antenna of an AM transmitter is 8.0 A when only the carrier is sent, but it increases to 9.0 A, when the carrier is sinusoidally modulated. Find the percentage modulation. Determine also the Antenna current when the depth of modulation is 0.77. 15
- (c) An 18 MHz carrier is modulated by a 400 Hz audio sine wave if the carrier voltage is 50 V and the maximum deviation is 12 KHz. Write down the equations of this modulated wave for (a) F.M., (b) P.M. If the modulating frequency is only changed to 1.6 KHz all other data remaining constant, write down the new equations for (c) F.M. and (d) P.M. 15