**2023**

ELECTRICAL ENGINEERING

PAPER-I

*Time Allowed — 3 Hours* *Full Marks — 200*

*If the questions attempted are in excess of the prescribed number, only the questions attempted first up to the prescribed number shall be valued and the remaining ones ignored.*

*Answer may be written either in* ***English*** *or in* ***Bengali*** *but all answers must be in one and the same language.*

*All symbols have their usual significance.*

Answer *any five* questions.

1. (a) A two-phase load draws the following current:

$$I_1(t) = I_m \sin(\omega t - \phi_1),\ I_2(t) = I_m \cos(\omega t - \phi_2)$$

If these currents are balanced then find the value of $\phi_1$.

(b) The three circuit elements shown in figure (Fig. 1) are part of an electric circuit. Calculate the total power absorbed by the three circuit elements in watts.

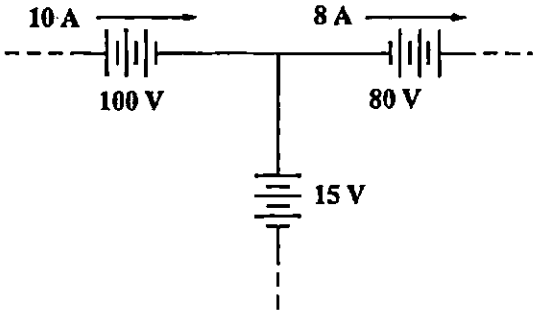


Fig. 1

(c) In the circuit shown in figure (Fig. 2), determine the value of the current I.

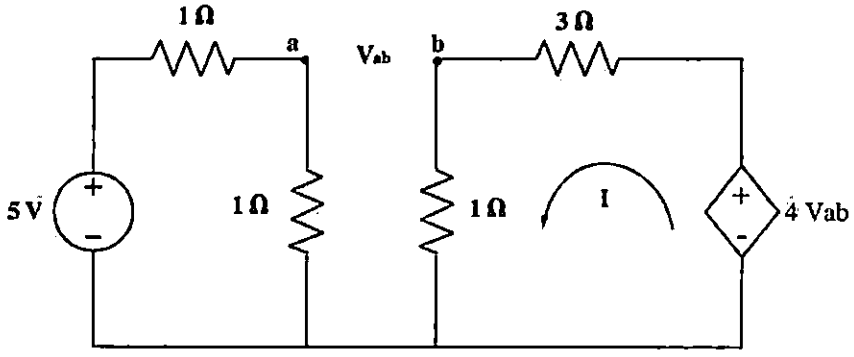


Fig. 2 10+10+20

2. (a) Find the driving point impedance Z(s) for the circuit shown below (in Fig. 3):

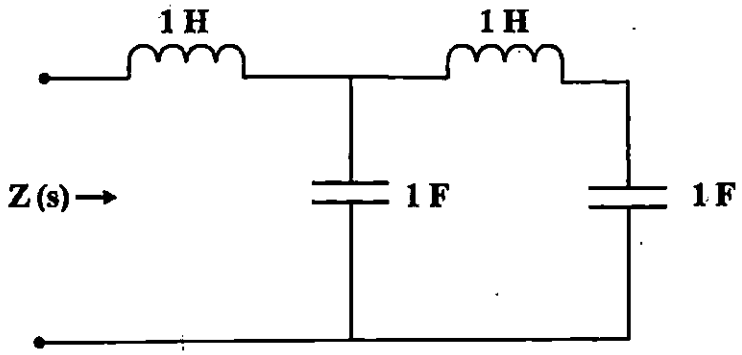


Fig. 3

(b) Two identical couple inductors are connected in series. The measured inductances for the two possible series connections are 380 μH and 240 μH. Calculate their mutual inductance in μH.

(c) A coil (which can be modelled as a series RL circuit) has been designed for high Q-performance at a rated voltage and a specified frequency. If the frequency of operation is doubled and the coil operated at the same rated voltage then the Q-factor and the active power P consumed by the coil will be affected as follows:

(i) P is doubled, Q is halved.

(ii) P is halved, Q is doubled.

(iii) P remains constant, Q is doubled.

(iv) P is decreased four times, Q is doubled.

Justify your answer in details. 10+10+20

3. (a) A single-phase load is connected between R and Y terminals of a 415 V, symmetrical, 3-phase, 4-wire system with phase sequence RYB. A wattmeter is connected in the system as shown in figure (Fig. 4). The power factor of the load is 0.8 lagging. What will be the reading of the wattmeter?

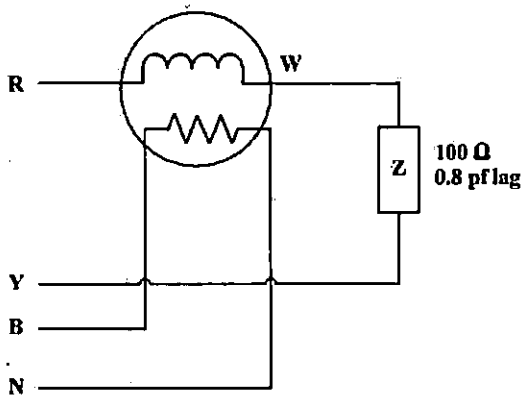


Fig. 4

(b) A water boiler at home is switched ON to the ac mains supplying power at 230 V, 50 Hz. Find the frequency of instantaneous power consumed by the boiler.

(c) A periodic voltage waveform observed on an oscilloscope across a load is shown in figure (Fig. 5). A permanent magnet moving coil (PMMC) meter is connected across the same load. Calculate the reading of the meter.

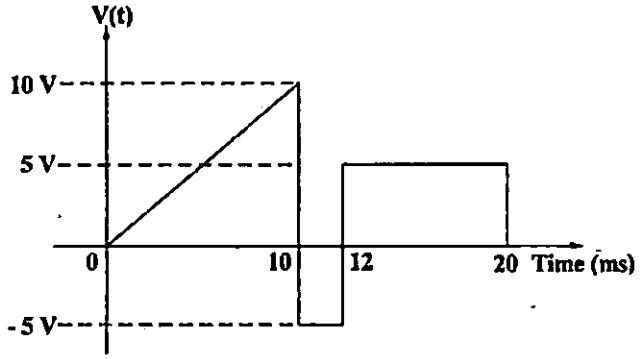


Fig. 5

10+10+20

4. (a) The transfer function of a system is given as

$$\frac{100}{s^2+20s+100}$$

Justify that the system is a critically damped system.

(b) Figure (Fig. 6) shows a feedback system where $K > 0$. Find the range of $K$ for which the system is stable.

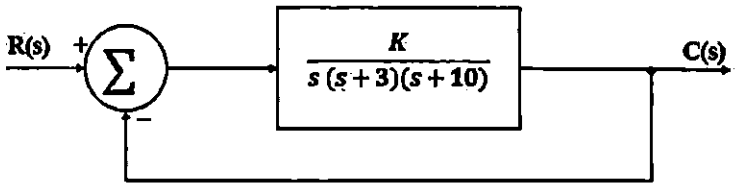


Fig. 6

(c) Consider the system described by following state space equations:

$$\begin{bmatrix}\dot{x}_1\\ \dot{x}_2\end{bmatrix}=\begin{bmatrix}0 & 1\\ -1 & -1\end{bmatrix}\begin{bmatrix}x_1\\ x_2\end{bmatrix}+\begin{bmatrix}0\\ 1\end{bmatrix}u;\quad y=\begin{bmatrix}1 & 0\end{bmatrix}\begin{bmatrix}x_1\\ x_2\end{bmatrix}$$

If $u$ is unit step input, then find the steady state error of the system. 10+10+20

5. (a) Let $x$ and $y$ be two vectors in three-dimensional space and $<x, y>$ denote their dot products. Then the determinant is

$$\det\begin{bmatrix}<x,x> & <x,y>\\ <y,x> & <y,y>\end{bmatrix}$$

(i) zero when $x$ and $y$ are linearly independent.

(ii) positive when $x$ and $y$ are linearly independent.

(iii) no-zero for all non-zero $x$ and $y$.

(iv) zero only when either $x$ or $y$ is zero.

Justify your answer in details.

(b) $x(t)$ is a positive rectangular pulse from t = –1 to t = +1 with unit height as shown in figure (Fig. 7). Find the value of $\int_{-\infty}^{\infty} |X(\omega)|^2 d\omega$ {where $X(\omega)$ is the Fourier transform of $x(t)$}.

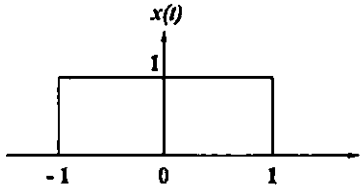


Fig. 7

(c) Calculate the rms value of the periodic waveform given in figure (Fig. 8).

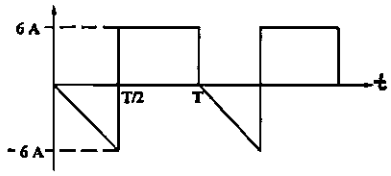


Fig. 8 10+10+20

6. (a) The second harmonic component of the periodic waveform is given in figure (Fig. 9). Calculate its amplitude.

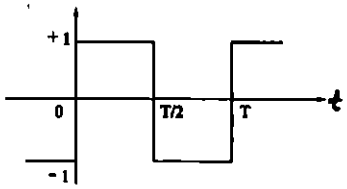


Fig. 9

(b) A three-phase, fully controlled thyristor bridge converter is used as line commutated inverter to feed 50 kW power at 420 V dc to a three-phase, 415 V (line), 50 Hz ac mains. Consider dc link current to be constant. Find the rms current of the thyristor.

(c) A single-phase fully controlled converter bridge is used for electrical braking of a separately excited dc motor. The dc motor load is represented by an equivalent circuit as shown in figure (Fig. 10).

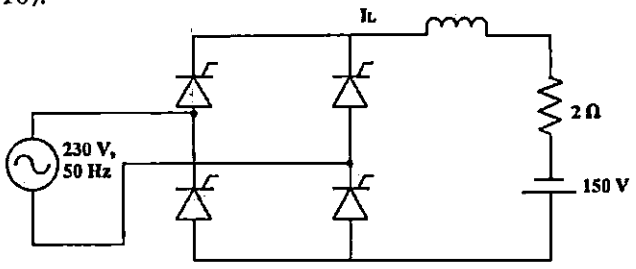


Fig. 10

Assume that the load inductance is sufficient to ensure continuous and ripple free load current. Find the firing angle of the bridge for a load current of $I_L = 10A$. 10+10+20

7. Write short notes on the following: 10×4=40
   (a) Nyquist's criterion
   (b) SMPS
   (c) Error in electro-dynamometer wattmeter
   (d) Brushless DC motor