

**Q. 1 – Q. 25 carry one mark each.**

Q.1 A random variable  $X$  has probability density function  $f(x)$  as given below:

$$f(x) = \begin{cases} a + bx & \text{for } 0 < x < 1 \\ 0 & \text{otherwise} \end{cases}$$

If the expected value  $E[X] = 2/3$ , then  $Pr[X < 0.5]$  is \_\_\_\_\_.

Q.2 If a continuous function  $f(x)$  does not have a root in the interval  $[a, b]$ , then which one of the following statements is TRUE?

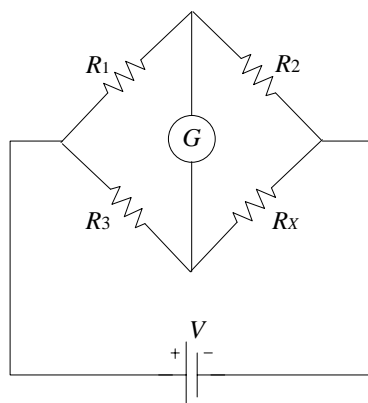
- (A)  $f(a) \cdot f(b) = 0$
- (B)  $f(a) \cdot f(b) < 0$
- (C)  $f(a) \cdot f(b) > 0$
- (D)  $f(a)/f(b) \leq 0$

Q.3 If the sum of the diagonal elements of a  $2 \times 2$  matrix is  $-6$ , then the maximum possible value of determinant of the matrix is \_\_\_\_\_.

Q.4 Consider a function  $\vec{f} = \frac{1}{r^2} \hat{r}$ , where  $r$  is the distance from the origin and  $\hat{r}$  is the unit vector in the radial direction. The divergence of this function over a sphere of radius  $R$ , which includes the origin, is

- (A) 0
- (B)  $2\pi$
- (C)  $4\pi$
- (D)  $R\pi$

Q.5 When the Wheatstone bridge shown in the figure is used to find the value of resistor  $R_x$ , the galvanometer  $G$  indicates zero current when  $R_1 = 50 \Omega$ ,  $R_2 = 65 \Omega$  and  $R_3 = 100 \Omega$ . If  $R_3$  is known with  $\pm 5\%$  tolerance on its nominal value of  $100 \Omega$ , what is the range of  $R_x$  in Ohms?



- (A) [123.50, 136.50]
- (B) [125.89, 134.12]
- (C) [117.00, 143.00]
- (D) [120.25, 139.75]

Q.6 A (0-50 A) moving coil ammeter has a voltage drop of 0.1 V across its terminals at full scale deflection. The external shunt resistance (in milliohms) needed to extend its range to (0 – 500 A) is \_\_\_\_\_.

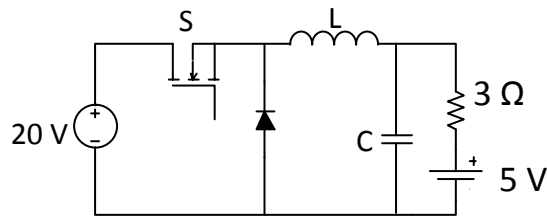
Q.7 Of the four characteristics given below, which are the major requirements for an instrumentation amplifier?

- P. High common mode rejection ratio
- Q. High input impedance
- R. High linearity
- S. High output impedance

(A) P, Q and R only  
(C) P, Q and S only

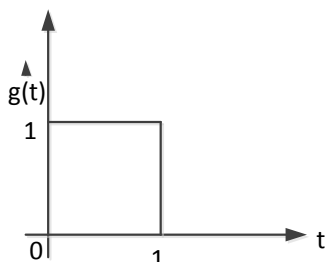
(B) P and R only  
(D) Q, R and S only

Q.8 In the following chopper, the duty ratio of switch S is 0.4. If the inductor and capacitor are sufficiently large to ensure continuous inductor current and ripple free capacitor voltage, the charging current (in Ampere) of the 5 V battery, under steady-state, is \_\_\_\_\_.

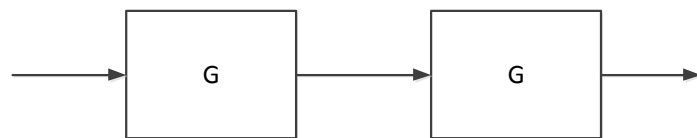


Q.9 A moving average function is given by  $y(t) = \frac{1}{T} \int_{t-T}^t u(\tau) d\tau$ . If the input  $u$  is a sinusoidal signal of frequency  $\frac{1}{2T}$  Hz, then in steady state, the output  $y$  will lag  $u$  (in degree) by \_\_\_\_\_.

Q.10 The impulse response  $g(t)$  of a system,  $G$ , is as shown in Figure (a). What is the maximum value attained by the impulse response of two cascaded blocks of  $G$  as shown in Figure (b)?



(a)



(b)

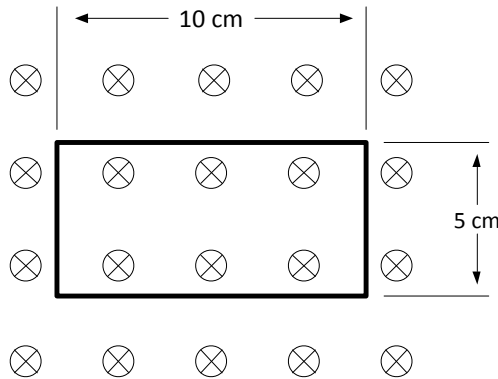
(A)  $\frac{2}{3}$

(B)  $\frac{3}{4}$

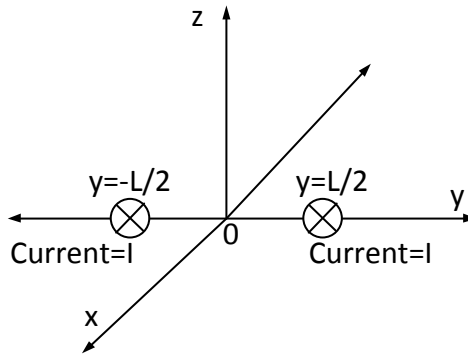
(C)  $\frac{4}{5}$

(D) 1

Q.11 Consider a one-turn rectangular loop of wire placed in a uniform magnetic field as shown in the figure. The plane of the loop is perpendicular to the field lines. The resistance of the loop is  $0.4\Omega$ , and its inductance is negligible. The magnetic flux density (in Tesla) is a function of time, and is given by  $B(t) = 0.25 \sin \omega t$ , where  $\omega = 2\pi \times 50$  radian/second. The power absorbed (in Watt) by the loop from the magnetic field is \_\_\_\_\_.

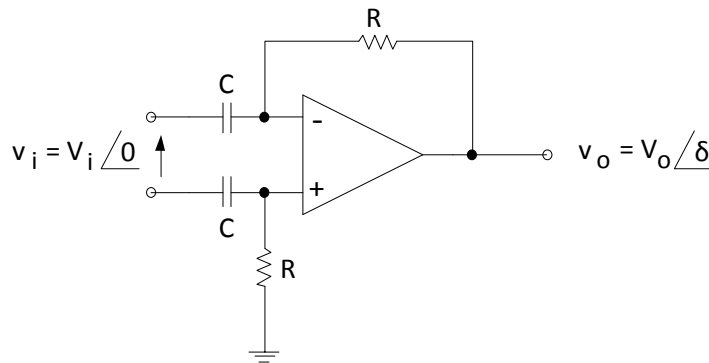


Q.12 A steady current  $I$  is flowing in the  $-x$  direction through each of two infinitely long wires at  $y = \pm \frac{L}{2}$  as shown in the figure. The permeability of the medium is  $\mu_0$ . The  $\vec{B}$ -field at  $(0,L,0)$  is



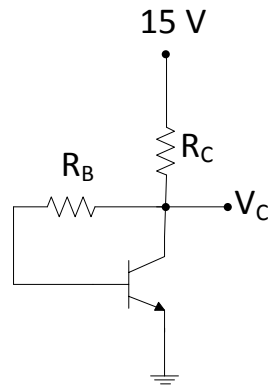
- (A)  $-\frac{4\mu_0 I}{3\pi L} \hat{z}$       (B)  $+\frac{4\mu_0 I}{3\pi L} \hat{z}$       (C) 0      (D)  $-\frac{3\mu_0 I}{4\pi L} \hat{z}$

Q.13 Consider the circuit shown in the figure. In this circuit  $R=1\text{ k}\Omega$ , and  $C=1\text{ }\mu\text{F}$ . The input voltage is sinusoidal with a frequency of 50 Hz, represented as a phasor with magnitude  $V_i$  and phase angle 0 radian as shown in the figure. The output voltage is represented as a phasor with magnitude  $V_o$  and phase angle  $\delta$  radian. What is the value of the output phase angle  $\delta$  (in radian) relative to the phase angle of the input voltage?

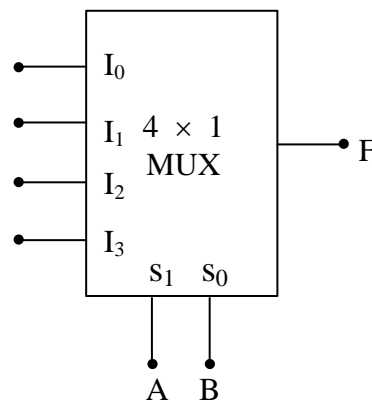


- (A) 0      (B)  $\pi$       (C)  $\pi/2$       (D)  $-\pi/2$

- Q.14 In the given circuit, the silicon transistor has  $\beta = 75$  and a collector voltage  $V_C = 9$  V. Then the ratio of  $R_B$  and  $R_C$  is \_\_\_\_\_.

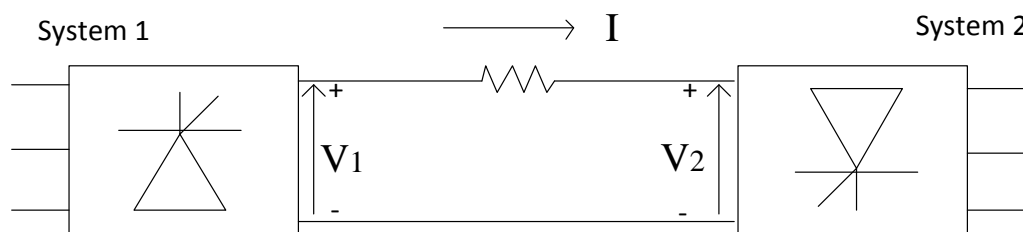


- Q.15 In the  $4 \times 1$  multiplexer, the output F is given by  $F = A \oplus B$ . Find the required input ' $I_3 I_2 I_1 I_0$ '.



- (A) 1010                      (B) 0110                      (C) 1000                      (D) 1110

- Q.16 Consider a HVDC link which uses thyristor based line-commutated converters as shown in the figure. For a power flow of 750 MW from System 1 to System 2, the voltages at the two ends, and the current, are given by:  $V_1 = 500$  kV,  $V_2 = 485$  kV and  $I = 1.5$  kA. If the direction of power flow is to be reversed (that is, from System 2 to System 1) without changing the electrical connections, then which one of the following combinations is feasible?



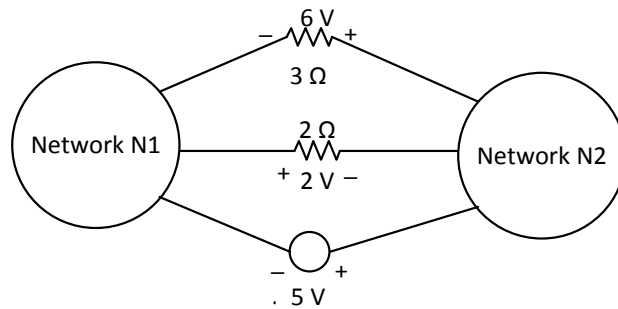
- (A)  $V_1 = -500$  kV,  $V_2 = -485$  kV and  $I = 1.5$  kA  
 (B)  $V_1 = -485$  kV,  $V_2 = -500$  kV and  $I = 1.5$  kA  
 (C)  $V_1 = 500$  kV,  $V_2 = 485$  kV and  $I = -1.5$  kA  
 (D)  $V_1 = -500$  kV,  $V_2 = -485$  kV and  $I = -1.5$  kA

Q.17 Base load power plants are

- P: wind farms.
- Q: run-of-river plants.
- R: nuclear power plants.
- S: diesel power plants.

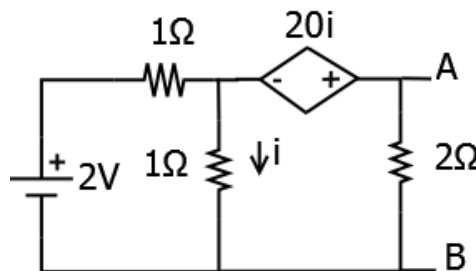
- (A) P, Q and S only
- (B) P, R and S only
- (C) P, Q and R only
- (D) Q and R only

Q.18 The voltages developed across the  $3\ \Omega$  and  $2\ \Omega$  resistors shown in the figure are  $6\ V$  and  $2\ V$  respectively, with the polarity as marked. What is the power (in Watt) delivered by the  $5\ V$  voltage source?

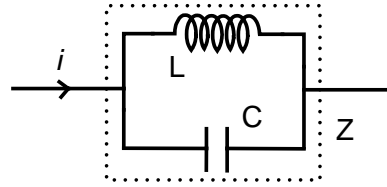


- (A) 5
- (B) 7
- (C) 10
- (D) 14

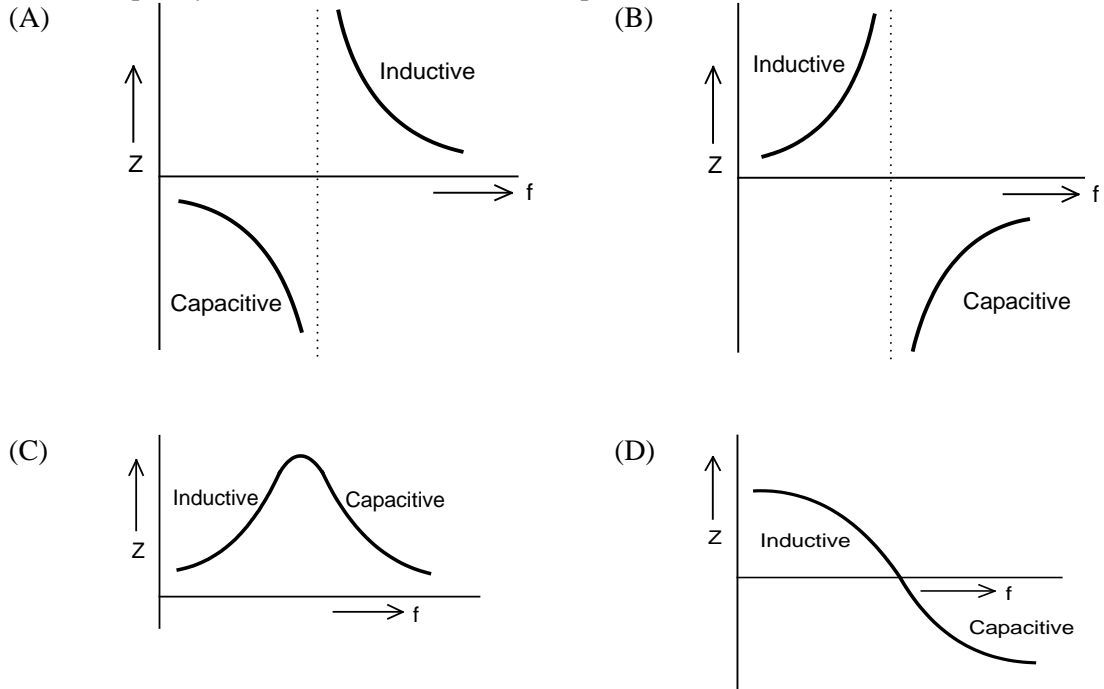
Q.19 For the given circuit, the Thevenin equivalent is to be determined. The Thevenin voltage,  $V_{Th}$  (in Volt), seen from terminal AB is \_\_\_\_\_.



Q.20 An inductor is connected in parallel with a capacitor as shown in the figure.



As the frequency of current  $i$  is increased, the impedance ( $Z$ ) of the network varies as



Q.21 A separately excited DC generator has an armature resistance of  $0.1\Omega$  and negligible armature inductance. At rated field current and rated rotor speed, its open-circuit voltage is 200 V. When this generator is operated at half the rated speed, with half the rated field current, an uncharged  $1000\ \mu\text{F}$  capacitor is suddenly connected across the armature terminals. Assume that the speed remains unchanged during the transient. At what time (in microsecond) after the capacitor is connected will the voltage across it reach 25 V?

- (A) 62.25                      (B) 69.3                      (C) 73.25                      (D) 77.3

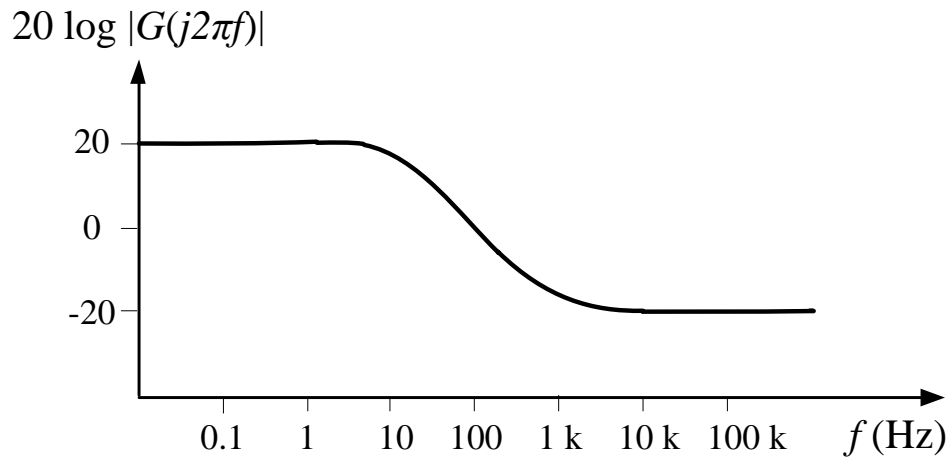
Q.22 The self inductance of the primary winding of a single phase, 50 Hz, transformer is 800 mH, and that of the secondary winding is 600 mH. The mutual inductance between these two windings is 480 mH. The secondary winding of this transformer is short circuited and the primary winding is connected to a 50 Hz, single phase, sinusoidal voltage source. The current flowing in both the windings is less than their respective rated currents. The resistance of both windings can be neglected. In this condition, what is the effective inductance (in mH) seen by the source?

- (A) 416                      (B) 440                      (C) 200                      (D) 920

Q.23 The primary mmf is least affected by the secondary terminal conditions in a

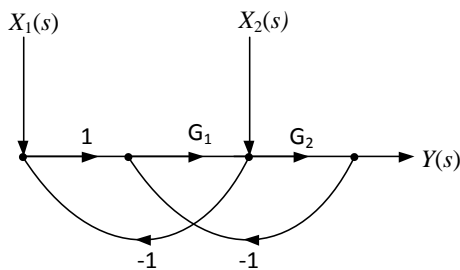
- (A) power transformer.                      (B) potential transformer.  
 (C) current transformer.                      (D) distribution transformer.

- Q.24 A Bode magnitude plot for the transfer function  $G(s)$  of a plant is shown in the figure. Which one of the following transfer functions best describes the plant?



- (A)  $\frac{1000(s+10)}{s+1000}$  (B)  $\frac{10(s+10)}{s(s+1000)}$  (C)  $\frac{s+1000}{10s(s+10)}$  (D)  $\frac{s+1000}{10(s+10)}$

- Q.25 For the signal-flow graph shown in the figure, which one of the following expressions is equal to the transfer function  $\frac{Y(s)}{X_2(s)} \Big|_{X_1(s)=0}$  ?



- (A)  $\frac{G_1}{1+G_2(1+G_1)}$  (B)  $\frac{G_2}{1+G_1(1+G_2)}$  (C)  $\frac{G_1}{1+G_1G_2}$  (D)  $\frac{G_2}{1+G_1G_2}$

**Q. 26 – Q. 55 carry two mark each.**

- Q.26 The maximum value of “ $a$ ” such that the matrix  $\begin{pmatrix} -3 & 0 & -2 \\ 1 & -1 & 0 \\ 0 & a & -2 \end{pmatrix}$  has three linearly independent real eigenvectors is

- (A)  $\frac{2}{3\sqrt{3}}$  (B)  $\frac{1}{3\sqrt{3}}$  (C)  $\frac{1+2\sqrt{3}}{3\sqrt{3}}$  (D)  $\frac{1+\sqrt{3}}{3\sqrt{3}}$

- Q.27 A solution of the ordinary differential equation  $\frac{d^2y}{dt^2} + 5\frac{dy}{dt} + 6y = 0$  is such that  $y(0) = 2$  and  $y(1) = -\frac{1-3e}{e^3}$ . The value of  $\frac{dy}{dt}(0)$  is \_\_\_\_\_.

Q.28 The signum function is given by

$$\text{sgn}(x) = \begin{cases} \frac{x}{|x|}; & x \neq 0 \\ 0; & x = 0 \end{cases}$$

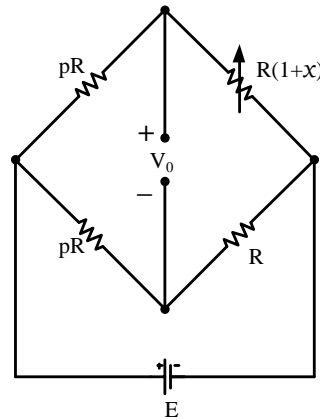
The Fourier series expansion of  $\text{sgn}(\cos(t))$  has

- (A) only sine terms with all harmonics.
- (B) only cosine terms with all harmonics.
- (C) only sine terms with even numbered harmonics.
- (D) only cosine terms with odd numbered harmonics.

Q.29 Two players, A and B, alternately keep rolling a fair dice. The person to get a six first wins the game. Given that player A starts the game, the probability that A wins the game is

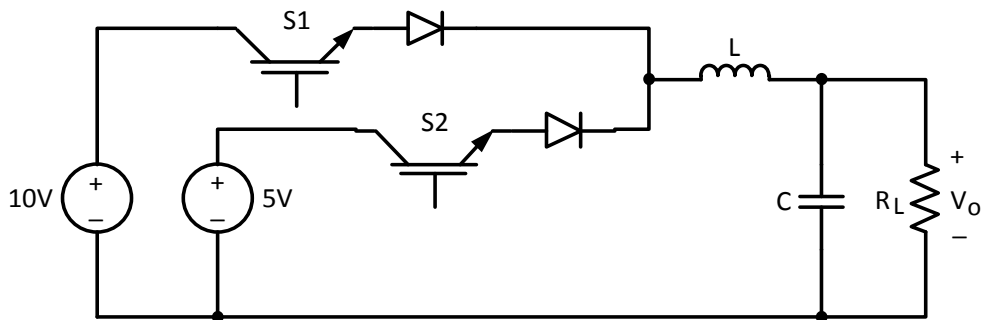
- (A) 5/11
- (B) 1/2
- (C) 7/13
- (D) 6/11

Q.30 An unbalanced DC Wheatstone bridge is shown in the figure. At what value of  $p$  will the magnitude of  $V_0$  be maximum?



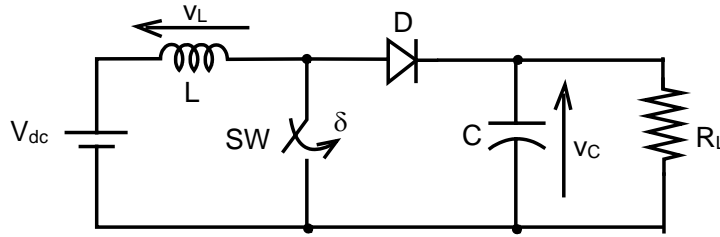
- (A)  $\sqrt{1+x}$
- (B)  $(1+x)$
- (C)  $1/\sqrt{1+x}$
- (D)  $\sqrt{1-x}$

Q.31 The circuit shown is meant to supply a resistive load  $R_L$  from two separate DC voltage sources. The switches S1 and S2 are controlled so that only one of them is ON at any instant. S1 is turned on for 0.2 ms and S2 is turned on for 0.3 ms in a 0.5 ms switching cycle time period. Assuming continuous conduction of the inductor current and negligible ripple on the capacitor voltage, the output voltage  $V_0$  (in Volt) across  $R_L$  is \_\_\_\_\_.





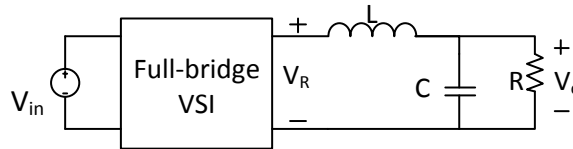
Q.32 A self commutating switch SW, operated at duty cycle  $\delta$  is used to control the load voltage as shown in the figure



Under steady state operating conditions, the average voltage across the inductor and the capacitor respectively, are

- (A)  $V_L = 0$  and  $V_C = \frac{1}{1-\delta} V_{dc}$
- (B)  $V_L = \frac{\delta}{2} V_{dc}$  and  $V_C = \frac{1}{1-\delta} V_{dc}$
- (C)  $V_L = 0$  and  $V_C = \frac{\delta}{1-\delta} V_{dc}$
- (D)  $V_L = \frac{\delta}{2} V_{dc}$  and  $V_C = \frac{\delta}{1-\delta} V_{dc}$

Q.33 The single-phase full-bridge voltage source inverter (VSI), shown in figure, has an output frequency of 50 Hz. It uses unipolar pulse width modulation with switching frequency of 50 kHz and modulation index of 0.7. For  $V_{in} = 100$  V DC,  $L = 9.55$  mH,  $C = 63.66$   $\mu$ F, and  $R = 5$   $\Omega$ , the amplitude of the fundamental component in the output voltage  $V_o$  (in Volt) under steady-state is \_\_\_\_\_.



Q.34 A 3-phase 50 Hz square wave (6-step) VSI feeds a 3-phase, 4 pole induction motor. The VSI line voltage has a dominant 5<sup>th</sup> harmonic component. If the operating slip of the motor with respect to fundamental component voltage is 0.04, the slip of the motor with respect to 5<sup>th</sup> harmonic component of voltage is \_\_\_\_\_.

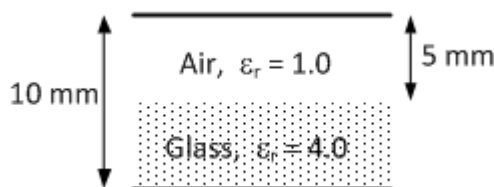
Q.35 Consider a discrete time signal given by

$$x[n] = (-0.25)^n u[n] + (0.5)^n u[-n - 1]$$

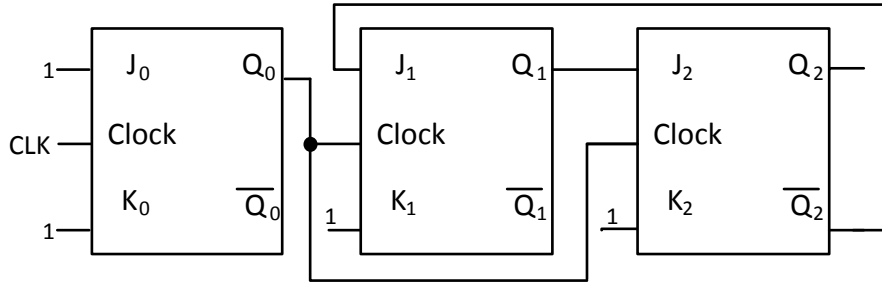
The region of convergence of its Z-transform would be

- (A) the region inside the circle of radius 0.5 and centered at origin
- (B) the region outside the circle of radius 0.25 and centered at origin
- (C) the annular region between the two circles, both centered at origin and having radii 0.25 and 0.5
- (D) the entire Z plane.

Q.36 A parallel plate capacitor is partially filled with glass of dielectric constant 4.0 as shown below. The dielectric strengths of air and glass are 30 kV/cm and 300 kV/cm, respectively. The maximum voltage (in kilovolts), which can be applied across the capacitor without any breakdown, is \_\_\_\_\_.



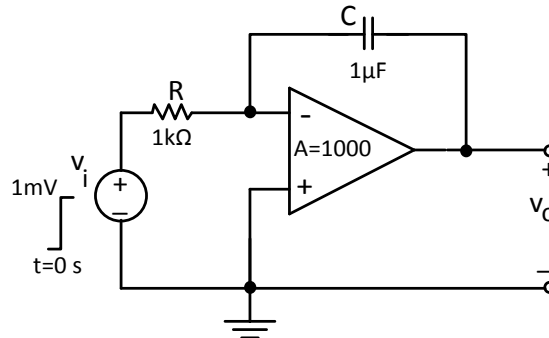
Q.37 The figure shows a digital circuit constructed using negative edge triggered J-K flip flops. Assume a starting state of  $Q_2Q_1Q_0=000$ . This state  $Q_2Q_1Q_0=000$  will repeat after \_\_\_\_\_ number of cycles of the clock CLK.



Q.38  $f(A, B, C, D) = \Pi M(0,1,3,4,5,7,9,11,12,13,14,15)$  is a maxterm representation of a Boolean function  $f(A, B, C, D)$  where  $A$  is the MSB and  $D$  is the LSB. The equivalent minimized representation of this function is

- (A)  $(A + \bar{C} + D)(\bar{A} + B + D)$
- (B)  $A\bar{C}D + \bar{A}BD$
- (C)  $\bar{A}\bar{C}\bar{D} + A\bar{B}C\bar{D} + A\bar{B}\bar{C}\bar{D}$
- (D)  $(B + \bar{C} + D)(A + \bar{B} + \bar{C} + D)(\bar{A} + B + C + D)$

Q.39 The op-amp shown in the figure has a finite gain  $A = 1000$  and an infinite input resistance. A step-voltage  $V_i = 1\text{ mV}$  is applied at the input at time  $t = 0$  as shown. Assuming that the operational amplifier is not saturated, the time constant (in millisecond) of the output voltage  $V_o$  is



- (A) 1001
- (B) 101
- (C) 11
- (D) 1

Q.40 An 8-bit, unipolar Successive Approximation Register type ADC is used to convert 3.5 V to digital equivalent output. The reference voltage is +5 V. The output of the ADC, at the end of 3rd clock pulse after the start of conversion, is

- (A) 1010 0000
- (B) 1000 0000
- (C) 0000 0001
- (D) 0000 0011

Q.41 Consider the economic dispatch problem for a power plant having two generating units. The fuel costs in Rs/MWh along with the generation limits for the two units are given below:

$$C_1(P_1) = 0.01P_1^2 + 30P_1 + 10 \quad ; \quad 100 \text{ MW} \leq P_1 \leq 150 \text{ MW}$$

$$C_2(P_2) = 0.05P_2^2 + 10P_2 + 10 \quad ; \quad 100 \text{ MW} \leq P_2 \leq 180 \text{ MW}$$

The incremental cost (in Rs/MWh) of the power plant when it supplies 200 MW is \_\_\_\_\_ .

Q.42 Determine the correctness or otherwise of the following Assertion [a] and the Reason [r].

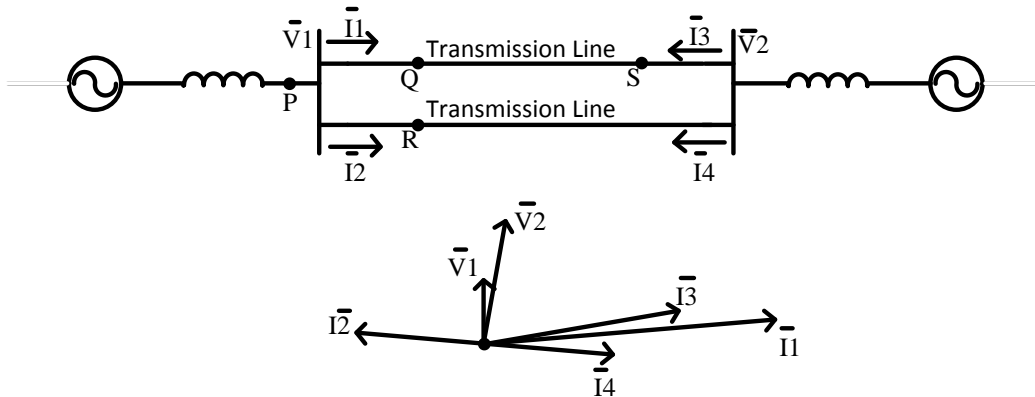
Assertion: Fast decoupled load flow method gives approximate load flow solution because it uses several assumptions.

Reason: Accuracy depends on the power mismatch vector tolerance.

- (A) Both [a] and [r] are true and [r] is the correct reason for [a].
- (B) Both [a] and [r] are true but [r] is not the correct reason for [a].
- (C) Both [a] and [r] are false.
- (D) [a] is false and [r] is true.

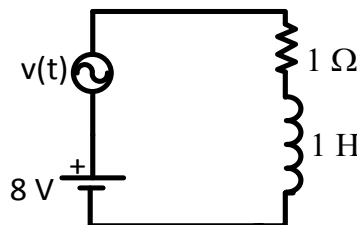
Q.43 A 50 Hz generating unit has  $H$ -constant of 2 MJ/MVA. The machine is initially operating in steady state at synchronous speed, and producing 1 pu of real power. The initial value of the rotor angle  $\delta$  is  $5^\circ$ , when a bolted three phase to ground short circuit fault occurs at the terminal of the generator. Assuming the input mechanical power to remain at 1 pu, the value of  $\delta$  in degrees, 0.02 second after the fault is \_\_\_\_\_.

Q.44 A sustained three-phase fault occurs in the power system shown in the figure. The current and voltage phasors during the fault (on a common reference), after the natural transients have died down, are also shown. Where is the fault located?



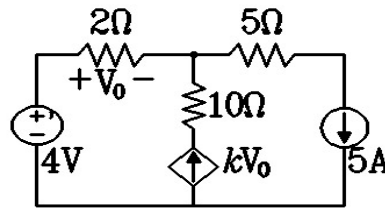
- (A) Location P
- (B) Location Q
- (C) Location R
- (D) Location S

Q.45 The circuit shown in the figure has two sources connected in series. The instantaneous voltage of the AC source (in Volt) is given by  $v(t) = 12 \sin t$ . If the circuit is in steady state, then the rms value of the current (in Ampere) flowing in the circuit is \_\_\_\_\_.



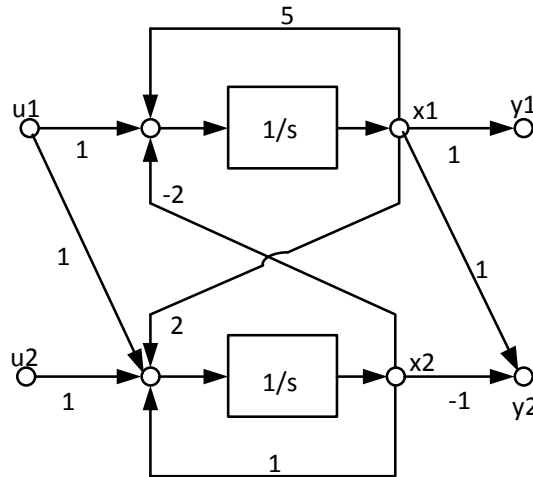
Q.46 In a linear two-port network, when 10 V is applied to Port 1, a current of 4 A flows through Port 2 when it is short-circuited. When 5 V is applied to Port 1, a current of 1.25 A flows through a  $1 \Omega$  resistance connected across Port 2. When 3 V is applied to Port 1, the current (in Ampere) through a  $2 \Omega$  resistance connected across Port 2 is \_\_\_\_\_.

- Q.47 In the given circuit, the parameter  $k$  is positive, and the power dissipated in the  $2\ \Omega$  resistor is  $12.5\text{W}$ . The value of  $k$  is \_\_\_\_\_.



- Q.48 A separately excited DC motor runs at 1000 rpm on no load when its armature terminals are connected to a 200V DC source and the rated voltage is applied to the field winding. The armature resistance of this motor is  $1\ \Omega$ . The no-load armature current is negligible. With the motor developing its full load torque, the armature voltage is set so that the rotor speed is 500 rpm. When the load torque is reduced to 50% of the full load value under the same armature voltage conditions, the speed rises to 520 rpm. Neglecting the rotational losses, the full load armature current (in Ampere) is \_\_\_\_\_.
- Q.49 A DC motor has the following specifications: 10 hp, 37.5 A, 230 V; flux/pole = 0.01 Wb, number of poles = 4, number of conductors = 666, number of parallel paths = 2. Armature resistance =  $0.267\ \Omega$ . The armature reaction is negligible and rotational losses are 600 W. The motor operates from a 230 V DC supply. If the motor runs at 1000 rpm, the output torque produced (in Nm) is \_\_\_\_\_.
- Q.50 A 200/400 V, 50 Hz, two-winding transformer is rated at 20 kVA. Its windings are connected as an auto-transformer of rating 200/600 V. A resistive load of  $12\ \Omega$  is connected to the high voltage (600 V) side of the auto-transformer. The value of equivalent load resistance (in Ohm) as seen from low voltage side is \_\_\_\_\_.
- Q.51 Two single-phase transformers  $T_1$  and  $T_2$  each rated at 500 kVA are operated in parallel. Percentage impedances of  $T_1$  and  $T_2$  are  $(1 + j6)$  and  $(0.8 + j4.8)$ , respectively. To share a load of 1000 kVA at 0.8 lagging power factor, the contribution of  $T_2$  (in kVA) is \_\_\_\_\_.

Q.52 In the signal flow diagram given in the figure,  $u_1$  and  $u_2$  are possible inputs whereas  $y_1$  and  $y_2$  are possible outputs. When would the SISO system derived from this diagram be controllable and observable?

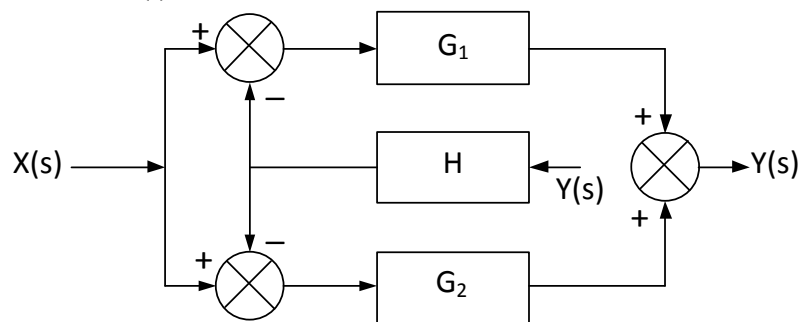


- (A) When  $u_1$  is the only input and  $y_1$  is the only output.
- (B) When  $u_2$  is the only input and  $y_1$  is the only output.
- (C) When  $u_1$  is the only input and  $y_2$  is the only output.
- (D) When  $u_2$  is the only input and  $y_2$  is the only output.

Q.53 The transfer function of a second order real system with a perfectly flat magnitude response of unity has a pole at  $(2 - j3)$ . List all the poles and zeroes.

- (A) Poles at  $(2 \pm j3)$ , no zeroes.
- (B) Poles at  $(\pm 2 - j3)$ , one zero at origin.
- (C) Poles at  $(2 - j3)$ ,  $(-2 + j3)$ , zeroes at  $(-2 - j3)$ ,  $(2 + j3)$ .
- (D) Poles at  $(2 \pm j3)$ , zeroes at  $(-2 \pm j3)$ .

Q.54 Find the transfer function  $\frac{Y(s)}{X(s)}$  of the system given below.



- |   |   |
|---|---|
| (A) $\frac{G_1}{1-HG_1} + \frac{G_2}{1-HG_2}$ | (B) $\frac{G_1}{1+HG_1} + \frac{G_2}{1+HG_2}$ |
| (C) $\frac{G_1+G_2}{1+H(G_1+G_2)}$            | (D) $\frac{G_1+G_2}{1-H(G_1+G_2)}$            |

- Q.55 The open loop poles of a third order unity feedback system are at  $0, -1, -2$ . Let the frequency corresponding to the point where the root locus of the system transits to unstable region be  $K$ . Now suppose we introduce a zero in the open loop transfer function at  $-3$ , while keeping all the earlier open loop poles intact. Which one of the following is TRUE about the point where the root locus of the modified system transits to unstable region?
- (A) It corresponds to a frequency greater than  $K$
  - (B) It corresponds to a frequency less than  $K$
  - (C) It corresponds to a frequency  $K$
  - (D) Root locus of modified system never transits to unstable region

**END OF THE QUESTION PAPER**

**Q. 1 – Q. 25 carry one mark each.**

Q.1 Given  $f(z) = g(z) + h(z)$ , where  $f, g, h$  are complex valued functions of a complex variable  $z$ . Which one of the following statements is TRUE?

- (A) If  $f(z)$  is differentiable at  $z_0$ , then  $g(z)$  and  $h(z)$  are also differentiable at  $z_0$ .
- (B) If  $g(z)$  and  $h(z)$  are differentiable at  $z_0$ , then  $f(z)$  is also differentiable at  $z_0$ .
- (C) If  $f(z)$  is continuous at  $z_0$ , then it is differentiable at  $z_0$ .
- (D) If  $f(z)$  is differentiable at  $z_0$ , then so are its real and imaginary parts.

Q.2 We have a set of 3 linear equations in 3 unknowns. ' $X \equiv Y$ ' means  $X$  and  $Y$  are equivalent statements and ' $X \not\equiv Y$ ' means  $X$  and  $Y$  are not equivalent statements.

- P: There is a unique solution.
- Q: The equations are linearly independent.
- R: All eigenvalues of the coefficient matrix are nonzero.
- S: The determinant of the coefficient matrix is nonzero.

Which one of the following is TRUE?

- (A)  $P \equiv Q \equiv R \equiv S$
- (B)  $P \equiv R \not\equiv Q \equiv S$
- (C)  $P \equiv Q \not\equiv R \equiv S$
- (D)  $P \not\equiv Q \not\equiv R \not\equiv S$

Q.3 Match the following.

- |                              |  |
|------------------------------|--|
| P. Stokes's Theorem          | 1. $\oiint \mathbf{D} \cdot d\mathbf{s} = Q$   |
| Q. Gauss's Theorem           | 2. $\oint f(z)dz = 0$  |
| R. Divergence Theorem        | 3. $\iiint (\nabla \cdot \mathbf{A})dv = \oiint \mathbf{A} \cdot d\mathbf{s}$                |
| S. Cauchy's Integral Theorem | 4. $\iint (\nabla \times \mathbf{A}) \cdot d\mathbf{s} = \oint \mathbf{A} \cdot d\mathbf{l}$ |

- |     |     |     |     |
|-----|-----|-----|-----|
| (A) | (B) | (C) | (D) |
| P-2 | P-4 | P-4 | P-3 |
| Q-1 | Q-1 | Q-3 | Q-4 |
| R-4 | R-3 | R-1 | R-2 |
| S-3 | S-2 | S-2 | S-1 |

Q.4 The Laplace transform of  $f(t) = 2\sqrt{t/\pi}$  is  $s^{-3/2}$ . The Laplace transform of  $g(t) = \sqrt{1/\pi t}$  is

- (A)  $3s^{-5/2}/2$
- (B)  $s^{-1/2}$
- (C)  $s^{1/2}$
- (D)  $s^{3/2}$

Q.5 Match the following.

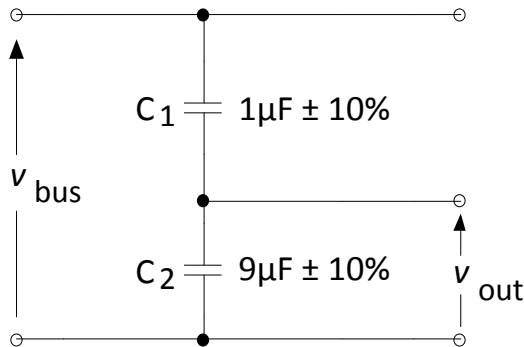
- |  |                        |
|--|------------------------|
| <b><u>Instrument Type</u></b>                        | <b><u>Used for</u></b> |
| P. Permanent magnet moving coil                      | 1. DC Only             |
| Q. Moving iron connected through current transformer | 2. AC Only             |
| R. Rectifier   | 3. AC and DC           |
| S. Electrodynamometer                                |                        |

- |     |     |     |     |
|-----|-----|-----|-----|
| (A) | (B) | (C) | (D) |
| P-1 | P-1 | P-1 | P-3 |
| Q-2 | Q-3 | Q-2 | Q-1 |
| R-1 | R-1 | R-3 | R-2 |
| S-3 | S-2 | S-3 | S-1 |

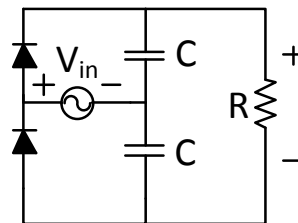
Q.6 A 3-phase balanced load which has a power factor of 0.707 is connected to a balanced supply. The power consumed by the load is 5 kW. The power is measured by the two-wattmeter method. The readings of the two wattmeters are

- (A) 3.94 kW and 1.06 kW (B) 2.50 kW and 2.50 kW  
(C) 5.00 kW and 0.00 kW (D) 2.96 kW and 2.04 kW

Q.7 A capacitive voltage divider is used to measure the bus voltage  $V_{bus}$  in a high-voltage 50 Hz AC system as shown in the figure. The measurement capacitors  $C_1$  and  $C_2$  have tolerances of  $\pm 10\%$  on their nominal capacitance values. If the bus voltage  $V_{bus}$  is 100 kV rms, the maximum rms output voltage  $V_{out}$  (in kV), considering the capacitor tolerances, is \_\_\_\_\_.



Q.8 In the following circuit, the input voltage  $V_{in}$  is  $100 \sin(100\pi t)$ . For  $100\pi RC = 50$ , the average voltage across  $R$  (in Volts) under steady-state is nearest to



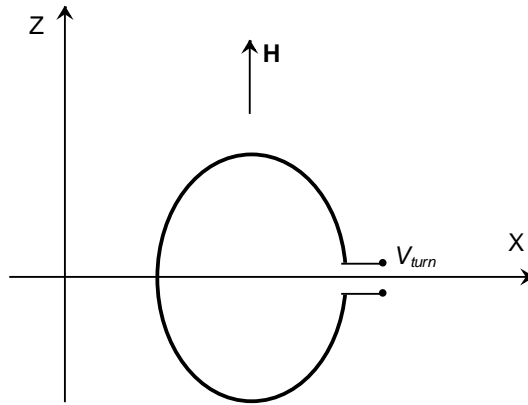
- (A) 100 (B) 31.8 (C) 200 (D) 63.6

Q.9 Two semi-infinite dielectric regions are separated by a plane boundary at  $y = 0$ . The dielectric constants of region 1 ( $y < 0$ ) and region 2 ( $y > 0$ ) are 2 and 5, respectively. Region 1 has uniform electric field  $\vec{E} = 3\hat{a}_x + 4\hat{a}_y + 2\hat{a}_z$ , where  $\hat{a}_x$ ,  $\hat{a}_y$ , and  $\hat{a}_z$  are unit vectors along the  $x$ ,  $y$  and  $z$  axes, respectively. The electric field in region 2 is

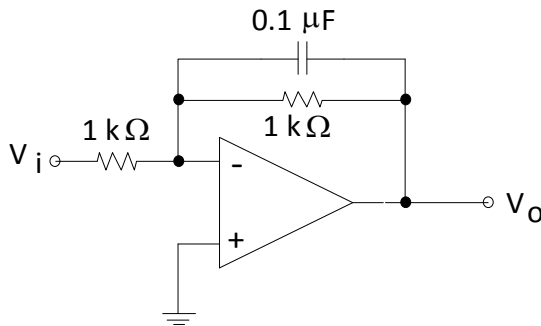
- (A)  $3\hat{a}_x + 1.6\hat{a}_y + 2\hat{a}_z$  (B)  $1.2\hat{a}_x + 4\hat{a}_y + 2\hat{a}_z$   
(C)  $1.2\hat{a}_x + 4\hat{a}_y + 0.8\hat{a}_z$  (D)  $3\hat{a}_x + 10\hat{a}_y + 0.8\hat{a}_z$



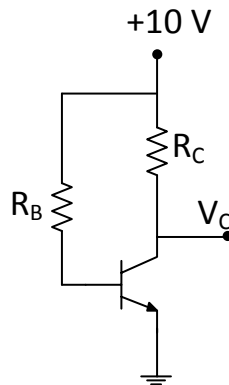
Q.10 A circular turn of radius 1 m revolves at 60 rpm about its diameter aligned with the x-axis as shown in the figure. The value of  $\mu_0$  is  $4\pi \times 10^{-7}$  in SI unit. If a uniform magnetic field intensity  $\vec{H} = 10^7 \hat{z}$  A/m is applied, then the peak value of the induced voltage,  $V_{turn}$  (in Volts), is \_\_\_\_\_.



Q.11 The operational amplifier shown in the figure is ideal. The input voltage (in Volt) is  $V_i = 2 \sin(2\pi \times 2000t)$ . The amplitude of the output voltage  $V_o$  (in Volt) is \_\_\_\_\_.



Q.12 In the following circuit, the transistor is in active mode and  $V_C = 2$  V. To get  $V_C = 4$  V, we replace  $R_C$  with  $R'_C$ . Then the ratio  $R'_C/R_C$  is \_\_\_\_\_.



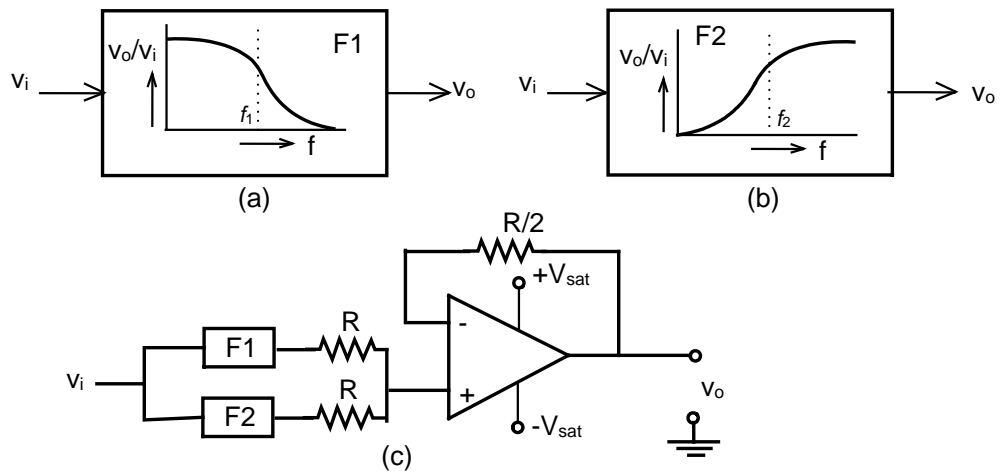
Q.13 Consider the following Sum of Products expression,  $F$ .

$$F = ABC + \bar{A}\bar{B}C + A\bar{B}C + \bar{A}BC + \bar{A}\bar{B}\bar{C}$$

The equivalent Product of Sums expression is

- (A)  $F = (A + \bar{B} + C)(\bar{A} + B + C)(\bar{A} + \bar{B} + C)$
- (B)  $F = (A + \bar{B} + \bar{C})(A + B + C)(\bar{A} + \bar{B} + \bar{C})$
- (C)  $F = (\bar{A} + B + \bar{C})(A + \bar{B} + \bar{C})(A + B + C)$
- (D)  $F = (\bar{A} + \bar{B} + C)(A + B + \bar{C})(A + B + C)$

Q.14 The filters F1 and F2 having characteristics as shown in Figures (a) and (b) are connected as shown in Figure (c).



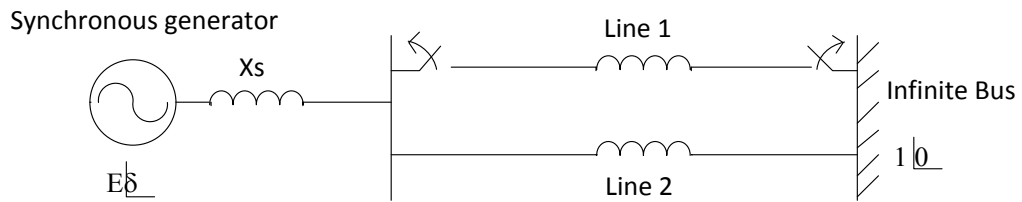
The cut-off frequencies of F1 and F2 are  $f_1$  and  $f_2$  respectively. If  $f_1 < f_2$ , the resultant circuit exhibits the characteristic of a

- (A) Band-pass filter  
 (B) Band-stop filter  
 (C) All pass filter  
 (D) High-Q filter

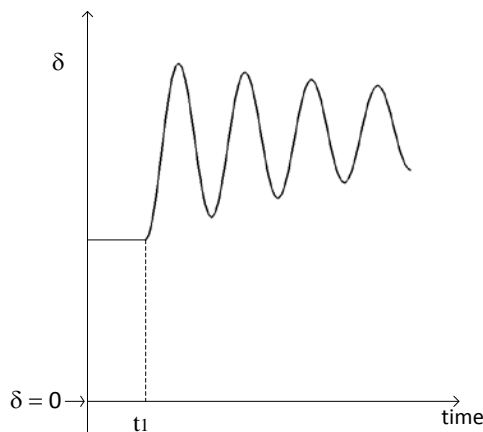
Q.15 When a bipolar junction transistor is operating in the saturation mode, which one of the following statements is TRUE about the state of its collector-base (CB) and the base-emitter (BE) junctions?

- (A) The CB junction is forward biased and the BE junction is reverse biased.  
 (B) The CB junction is reverse biased and the BE junction is forward biased.  
 (C) Both the CB and BE junctions are forward biased.  
 (D) Both the CB and BE junctions are reverse biased.

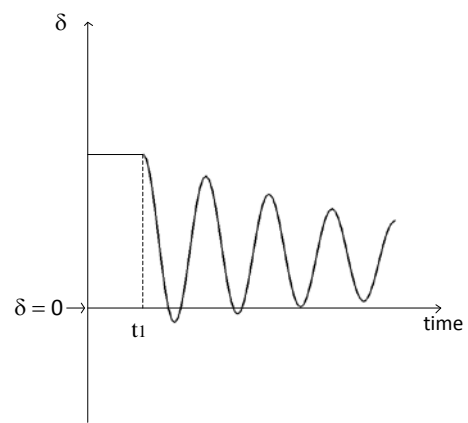
Q.16 The synchronous generator shown in the figure is supplying active power to an infinite bus via two short, lossless transmission lines, and is initially in steady state. The mechanical power input to the generator and the voltage magnitude  $E$  are constant. If one line is tripped at time  $t_1$  by opening the circuit breakers at the two ends (although there is no fault), then it is seen that the generator undergoes a stable transient. Which one of the following waveforms of the rotor angle  $\delta$  shows the transient correctly?



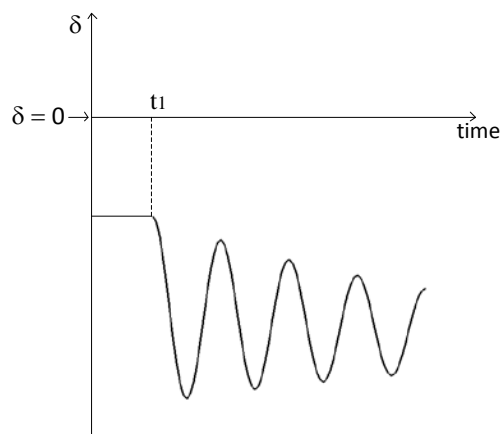
(A)



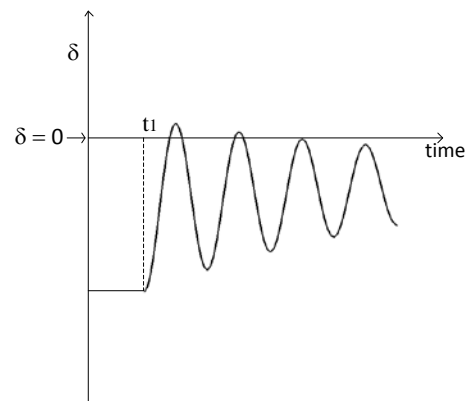
(B)



(C)



(D)

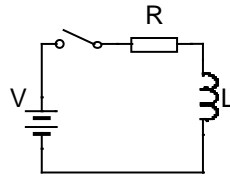


- Q.17 A 3-bus power system network consists of 3 transmission lines. The bus admittance matrix of the uncompensated system is

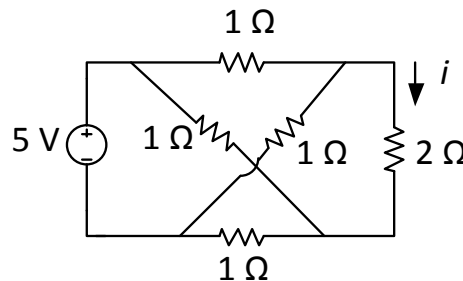
$$\begin{bmatrix} -j6 & j3 & j4 \\ j3 & -j7 & j5 \\ j4 & j5 & -j8 \end{bmatrix} \text{ pu.}$$

If the shunt capacitance of all transmission lines is 50% compensated, the imaginary part of the 3<sup>rd</sup> row 3<sup>rd</sup> column element (in pu) of the bus admittance matrix after compensation is

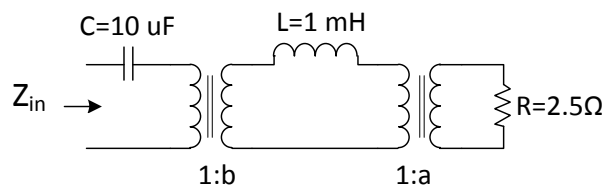
- (A)  $-j7.0$       (B)  $-j8.5$       (C)  $-j7.5$       (D)  $-j9.0$
- Q.18 A series RL circuit is excited at  $t = 0$  by closing a switch as shown in the figure. Assuming zero initial conditions, the value of  $\frac{d^2i}{dt^2}$  at  $t = 0^+$  is



- (A)  $\frac{V}{L}$       (B)  $\frac{-V}{R}$       (C) 0      (D)  $\frac{-RV}{L^2}$
- Q.19 The current  $i$  (in Ampere) in the  $2\ \Omega$  resistor of the given network is \_\_\_\_\_.

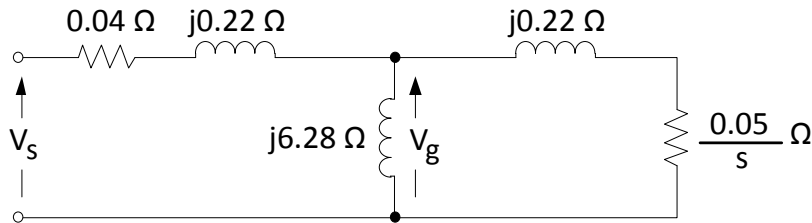


- Q.20 Find the transformer ratios  $a$  and  $b$  such that the impedance ( $Z_{in}$ ) is resistive and equals  $2.5\ \Omega$  when the network is excited with a sine wave voltage of angular frequency of  $5000\ \text{rad/s}$ .



- (A)  $a = 0.5, b = 2.0$       (B)  $a = 2.0, b = 0.5$   
 (C)  $a = 1.0, b = 1.0$       (D)  $a = 4.0, b = 0.5$
- Q.21 A shunt-connected DC motor operates at its rated terminal voltage. Its no-load speed is  $200\ \text{radian/second}$ . At its rated torque of  $500\ \text{Nm}$ , its speed is  $180\ \text{radian/second}$ . The motor is used to directly drive a load whose load torque  $T_L$  depends on its rotational speed  $\omega_r$  (in  $\text{radian/second}$ ), such that  $T_L = 2.78 \times \omega_r$ . Neglecting rotational losses, the steady-state speed (in  $\text{radian/second}$ ) of the motor, when it drives this load, is \_\_\_\_\_.

Q.22 The figure shows the per-phase equivalent circuit of a two-pole three-phase induction motor operating at 50 Hz. The “air-gap” voltage,  $V_g$  across the magnetizing inductance, is 210 V rms, and the slip,  $s$ , is 0.05. The torque (in Nm) produced by the motor is \_\_\_\_\_.

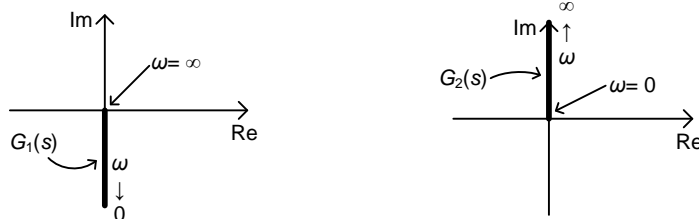


Q.23 A 4-pole, separately excited, wave wound DC machine with negligible armature resistance is rated for 230 V and 5 kW at a speed of 1200 rpm. If the same armature coils are reconnected to form a lap winding, what is the rated voltage (in volts) and power (in kW) respectively at 1200 rpm of the reconnected machine if the field circuit is left unchanged ?

- (A) 230 and 5                      (B) 115 and 5                      (C) 115 and 2.5                      (D) 230 and 2.5

Q.24 An open loop control system results in a response of  $e^{-2t}(\sin 5t + \cos 5t)$  for a unit impulse input. The DC gain of the control system is \_\_\_\_\_.

Q.25 Nyquist plots of two functions  $G_1(s)$  and  $G_2(s)$  are shown in figure.



Nyquist plot of the product of  $G_1(s)$  and  $G_2(s)$  is

- (A) (B) (C) (D)

**Q. 26 – Q. 55 carry two mark each.**

Q.26 The volume enclosed by the surface  $f(x, y) = e^x$  over the triangle bounded by the lines  $x = y$ ;  $x = 0$ ;  $y = 1$  in the  $xy$  plane is \_\_\_\_\_.

Q.27 Two coins R and S are tossed. The 4 joint events  $H_R H_S, T_R T_S, H_R T_S, T_R H_S$  have probabilities 0.28, 0.18, 0.30, 0.24, respectively, where  $H$  represents head and  $T$  represents tail. Which one of the following is TRUE?

- (A) The coin tosses are independent.
- (B) R is fair, S is not.
- (C) S is fair, R is not.
- (D) The coin tosses are dependent.

Q.28 A differential equation  $\frac{di}{dt} - 0.2i = 0$  is applicable over  $-10 < t < 10$ . If  $i(4) = 10$ , then  $i(-5)$  is \_\_\_\_\_.

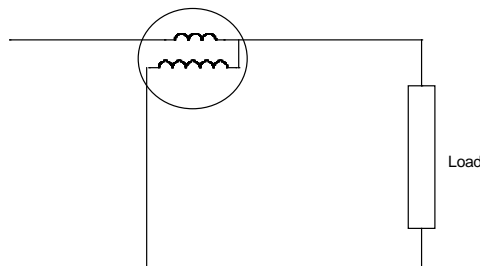
Q.29 Consider a signal defined by

$$x(t) = \begin{cases} e^{j10t} & \text{for } |t| \leq 1 \\ 0 & \text{for } |t| > 1 \end{cases}$$

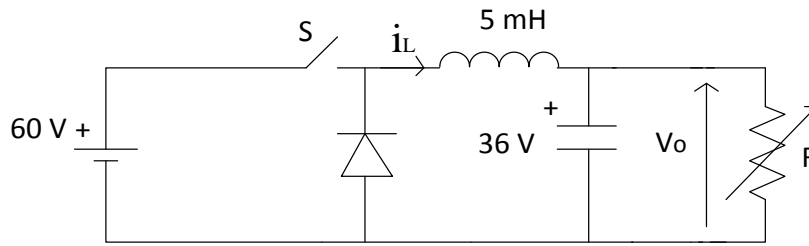
Its Fourier Transform is

- (A)  $\frac{2 \sin(\omega-10)}{\omega-10}$
- (B)  $2 e^{j10} \frac{\sin(\omega-10)}{\omega-10}$
- (C)  $\frac{2 \sin \omega}{\omega-10}$
- (D)  $e^{j10\omega} \frac{2 \sin \omega}{\omega}$

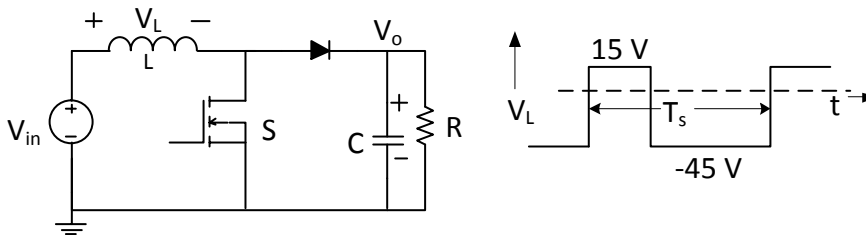
Q.30 The coils of a wattmeter have resistances  $0.01 \Omega$  and  $1000 \Omega$ ; their inductances may be neglected. The wattmeter is connected as shown in the figure, to measure the power consumed by a load, which draws 25 A at power factor 0.8. The voltage across the load terminals is 30 V. The percentage error on the wattmeter reading is \_\_\_\_\_.



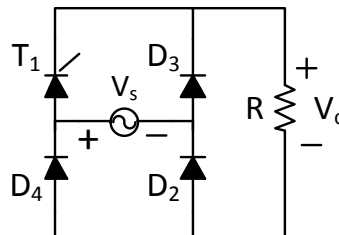
Q.31 A buck converter feeding a variable resistive load is shown in the figure. The switching frequency of the switch S is 100 kHz and the duty ratio is 0.6. The output voltage  $V_O$  is 36 V. Assume that all the components are ideal, and that the output voltage is ripple-free. The value of R (in Ohm) that will make the inductor current ( $i_L$ ) just continuous is \_\_\_\_\_.



Q.32 For the switching converter shown in the following figure, assume steady-state operation. Also assume that the components are ideal, the inductor current is always positive and continuous and switching period is  $T_s$ . If the voltage  $V_L$  is as shown, the duty cycle of the switch S is \_\_\_\_\_.



Q.33 In the given rectifier, the delay angle of the thyristor  $T_1$  measured from the positive going zero crossing of  $V_s$  is  $30^\circ$ . If the input voltage  $V_s$  is  $100 \sin(100\pi t)$  V, the average voltage across R (in Volt) under steady-state is \_\_\_\_\_.



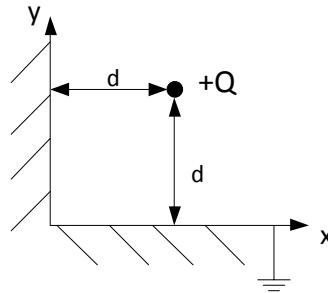
Q.34 For linear time invariant systems, that are Bounded Input Bounded Output stable, which one of the following statements is TRUE?

- (A) The impulse response will be integrable, but may not be absolutely integrable.
- (B) The unit impulse response will have finite support.
- (C) The unit step response will be absolutely integrable.
- (D) The unit step response will be bounded.

Q.35 The z-Transform of a sequence  $x[n]$  is given as  $X(z) = 2z + 4 - 4/z + 3/z^2$ . If  $y[n]$  is the first difference of  $x[n]$ , then  $Y(z)$  is given by

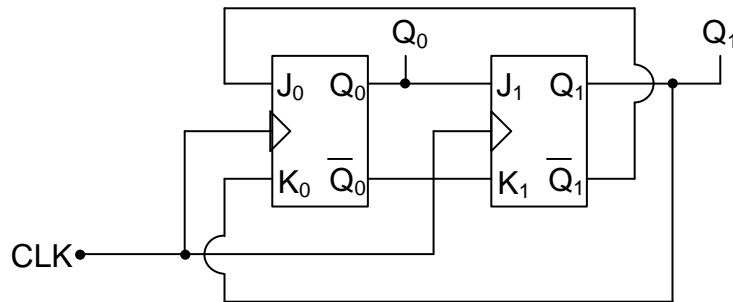
- (A)  $2z + 2 - 8/z + 7/z^2 - 3/z^3$
- (B)  $-2z + 2 - 6/z + 1/z^2 - 3/z^3$
- (C)  $-2z - 2 + 8/z - 7/z^2 + 3/z^3$
- (D)  $4z - 2 - 8/z - 1/z^2 + 3/z^3$

Q.36 Two semi-infinite conducting sheets are placed at right angles to each other as shown in the figure. A point charge of  $+Q$  is placed at a distance of  $d$  from both sheets. The net force on the charge is  $\frac{Q^2}{4\pi\epsilon_0} \frac{K}{d^2}$ , where  $K$  is given by



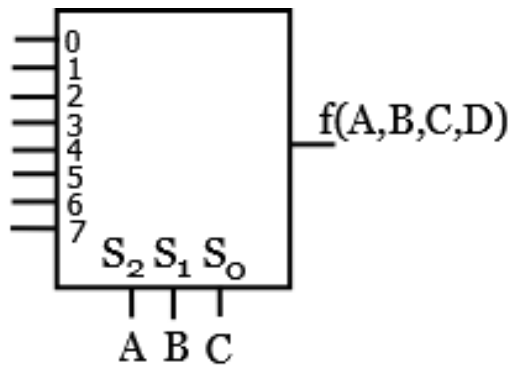
- (A) 0                      (B)  $-\frac{1}{4} \hat{i} - \frac{1}{4} \hat{j}$                       (C)  $-\frac{1}{8} \hat{i} - \frac{1}{8} \hat{j}$                       (D)  $\frac{1-2\sqrt{2}}{8\sqrt{2}} \hat{i} + \frac{1-2\sqrt{2}}{8\sqrt{2}} \hat{j}$

Q.37 In the following sequential circuit, the initial state (before the first clock pulse) of the circuit is  $Q_1Q_0 = 00$ . The state  $(Q_1Q_0)$ , immediately after the 333<sup>rd</sup> clock pulse is



- (A) 00                      (B) 01                      (C) 10                      (D) 11

Q.38 A Boolean function  $f(A, B, C, D) = \prod(1,5,12,15)$  is to be implemented using an  $8 \times 1$  multiplexer (A is MSB). The inputs ABC are connected to the select inputs  $S_2 S_1 S_0$  of the multiplexer respectively.

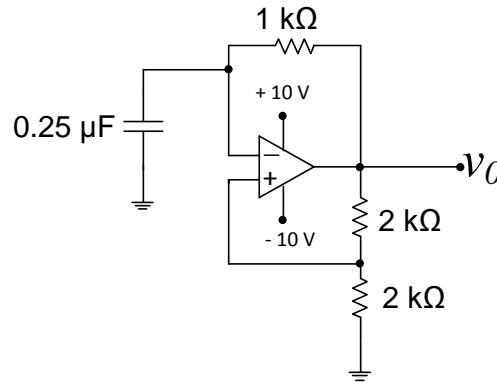


Which one of the following options gives the correct inputs to pins 0,1,2,3,4,5,6,7 in order?

- (A)  $D, 0, D, 0, 0, 0, \bar{D}, D$   
 (B)  $\bar{D}, 1, \bar{D}, 1, 1, 1, D, \bar{D}$   
 (C)  $D, 1, D, 1, 1, 1, \bar{D}, D$   
 (D)  $\bar{D}, 0, \bar{D}, 0, 0, 0, D, \bar{D}$



- Q.39 The saturation voltage of the ideal op-amp shown below is  $\pm 10$  V. The output voltage  $v_0$  of the following circuit in the steady-state is



- (A) square wave of period 0.55 ms.                      (B) triangular wave of period 0.55 ms.  
 (C) square wave of period 0.25 ms.                      (D) triangular wave of period 0.25 ms.
- Q.40 The incremental costs (in Rupees/MWh) of operating two generating units are functions of their respective powers  $P_1$  and  $P_2$  in MW, and are given by

$$\frac{dC_1}{dP_1} = 0.2P_1 + 50$$

$$\frac{dC_2}{dP_2} = 0.24P_2 + 40$$

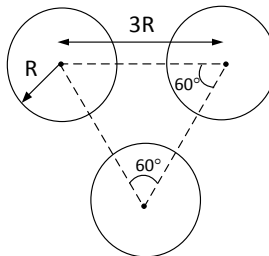
where

$$20 \text{ MW} \leq P_1 \leq 150 \text{ MW}$$

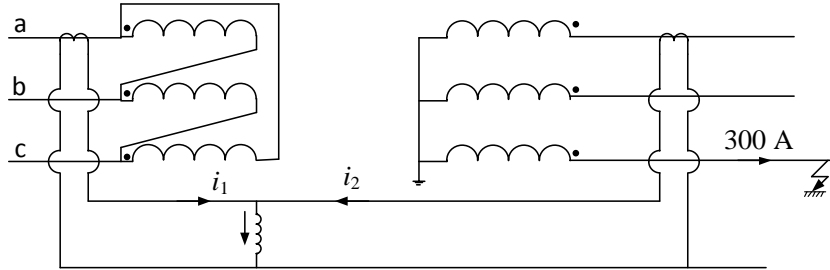
$$20 \text{ MW} \leq P_2 \leq 150 \text{ MW}.$$

For a certain load demand,  $P_1$  and  $P_2$  have been chosen such that  $dC_1/dP_1 = 76$  Rs/MWh and  $dC_2/dP_2 = 68.8$  Rs/MWh. If the generations are rescheduled to minimize the total cost, then  $P_2$  is \_\_\_\_\_.

- Q.41 A composite conductor consists of three conductors of radius  $R$  each. The conductors are arranged as shown below. The geometric mean radius (GMR) (in cm) of the composite conductor is  $kR$ . The value of  $k$  is \_\_\_\_\_.

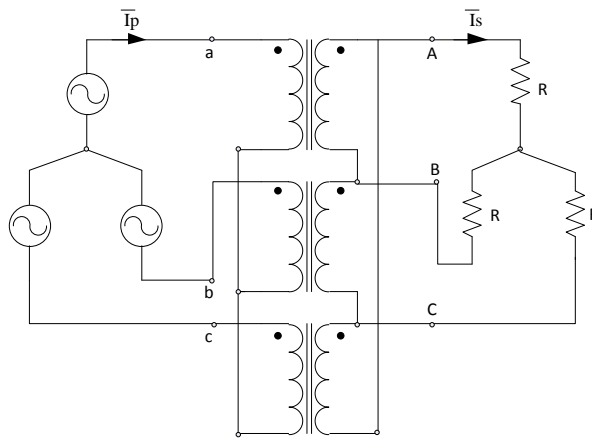


Q.42 A 3-phase transformer rated for 33 kV/11 kV is connected in delta/star as shown in figure. The current transformers (CTs) on low and high voltage sides have a ratio of 500/5. Find the currents  $i_1$  and  $i_2$ , if the fault current is 300 A as shown in figure.



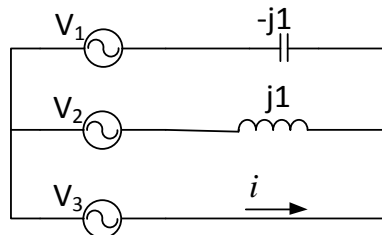
- (A)  $i_1 = 1/\sqrt{3} A, i_2 = 0 A$
- (B)  $i_1 = 0 A, i_2 = 0 A$
- (C)  $i_1 = 0 A, i_2 = 1/\sqrt{3} A$
- (D)  $i_1 = 1/\sqrt{3} A, i_2 = 1/\sqrt{3} A$

Q.43 A balanced (positive sequence) three-phase AC voltage source is connected to a balanced, star connected load through a star-delta transformer as shown in the figure. The line-to-line voltage rating is 230 V on the star side, and 115 V on the delta side. If the magnetizing current is neglected and  $\bar{I}_s = 100\angle 0^\circ A$ , then what is the value of  $\bar{I}_p$  in Ampere?



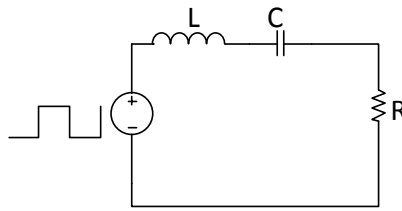
- (A)  $50 \angle 30^\circ$
- (B)  $50 \angle -30^\circ$
- (C)  $50\sqrt{3} \angle 30^\circ$
- (D)  $200 \angle 30^\circ$

Q.44 In the given network  $V_1 = 100\angle 0^\circ V, V_2 = 100\angle -120^\circ V, V_3 = 100\angle +120^\circ V$ . The phasor current  $i$  (in Ampere) is

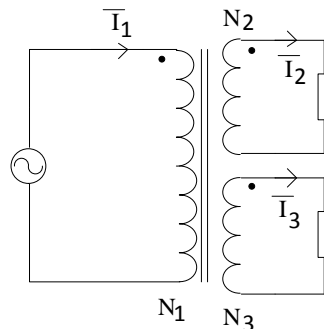


- (A)  $173.2\angle -60^\circ$
- (B)  $173.2\angle 120^\circ$
- (C)  $100.0\angle -60^\circ$
- (D)  $100.0\angle 120^\circ$

- Q.45 A symmetrical square wave of 50% duty cycle has amplitude of  $\pm 15$  V and time period of  $0.4\pi$  ms. This square wave is applied across a series RLC circuit with  $R = 5 \Omega$ ,  $L = 10$  mH, and  $C = 4 \mu\text{F}$ . The amplitude of the 5000 rad/s component of the capacitor voltage (in Volt) is \_\_\_\_\_.

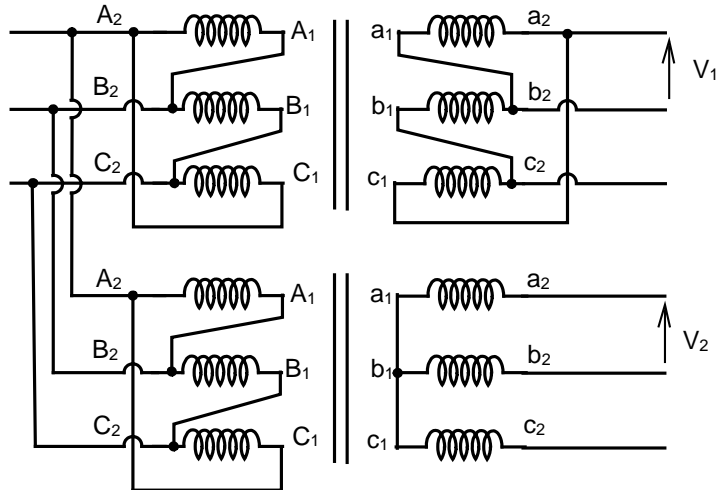


- Q.46 Two identical coils each having inductance  $L$  are placed together on the same core. If an overall inductance of  $\alpha L$  is obtained by interconnecting these two coils, the minimum value of  $\alpha$  is \_\_\_\_\_.
- Q.47 A three-winding transformer is connected to an AC voltage source as shown in the figure. The number of turns are as follows:  $N_1 = 100$ ,  $N_2 = 50$ ,  $N_3 = 50$ . If the magnetizing current is neglected, and the currents in two windings are  $\bar{I}_2 = 2 \angle 30^\circ$  A and  $\bar{I}_3 = 2 \angle 150^\circ$  A, then what is the value of the current  $\bar{I}_1$  in Ampere?



- (A)  $1 \angle 90^\circ$       (B)  $1 \angle 270^\circ$       (C)  $4 \angle 90^\circ$       (D)  $4 \angle 270^\circ$
- Q.48 With an armature voltage of 100 V and rated field winding voltage, the speed of a separately excited DC motor driving a fan is 1000 rpm, and its armature current is 10 A. The armature resistance is  $1 \Omega$ . The load torque of the fan load is proportional to the square of the rotor speed. Neglecting rotational losses, the value of the armature voltage (in Volt) which will reduce the rotor speed to 500 rpm is \_\_\_\_\_.
- Q.49 A three-phase, 11 kV, 50 Hz, 2 pole, star connected, cylindrical rotor synchronous motor is connected to an 11 kV, 50 Hz source. Its synchronous reactance is  $50 \Omega$  per phase, and its stator resistance is negligible. The motor has a constant field excitation. At a particular load torque, its stator current is 100 A at unity power factor. If the load torque is increased so that the stator current is 120 A, then the load angle (in degrees) at this load is \_\_\_\_\_.
- Q.50 A 220 V, 3-phase, 4-pole, 50 Hz inductor motor of wound rotor type is supplied at rated voltage and frequency. The stator resistance, magnetizing reactance, and core loss are negligible. The maximum torque produced by the rotor is 225 % of full load torque and it occurs at 15% slip. The actual rotor resistance is  $0.03 \Omega/\text{phase}$ . The value of external resistance (in Ohm) which must be inserted in a rotor phase if the maximum torque is to occur at start is \_\_\_\_\_.

Q.51 Two three-phase transformers are realized using single-phase transformers as shown in the figure.



The phase difference (in degree) between voltages  $V_1$  and  $V_2$  is \_\_\_\_\_.

Q.52 The following discrete-time equations result from the numerical integration of the differential equations of an un-damped simple harmonic oscillator with state variables  $x$  and  $y$ . The integration time step is  $h$ .

$$\frac{x_{k+1} - x_k}{h} = y_k$$

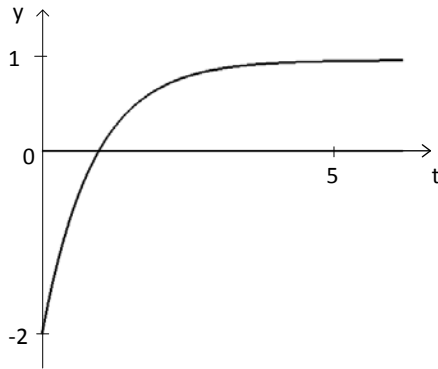
$$\frac{y_{k+1} - y_k}{h} = -x_k$$

For this discrete-time system, which one of the following statements is TRUE?

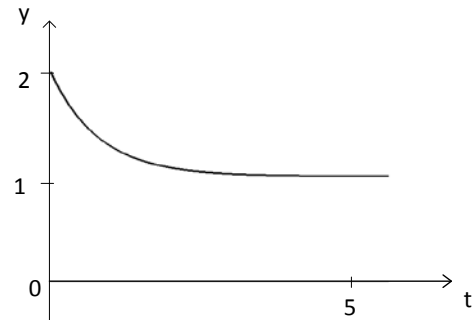
- (A) The system is not stable for  $h > 0$
- (B) The system is stable for  $h > \frac{1}{\pi}$
- (C) The system is stable for  $0 < h < \frac{1}{2\pi}$
- (D) The system is stable for  $\frac{1}{2\pi} < h < \frac{1}{\pi}$

Q.53 The unit step response of a system with the transfer function  $G(s) = \frac{1-2s}{1+s}$  is given by which one of the following waveforms?

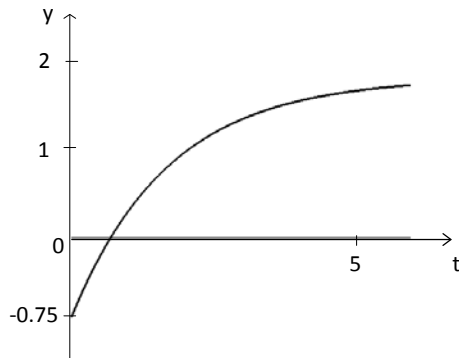
(A)



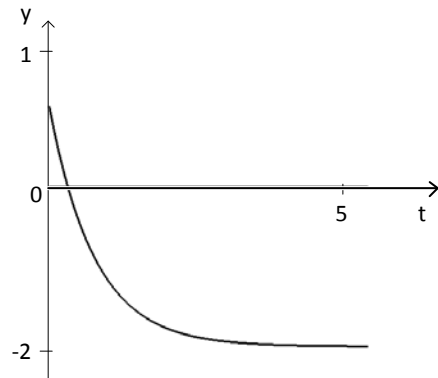
(B)



(C)



(D)



Q.54 An open loop transfer function  $G(s)$  of a system is

$$G(s) = \frac{K}{s(s+1)(s+2)}$$

For a unity feedback system, the breakaway point of the root loci on the real axis occurs at,

- (A)  $-0.42$  (B)  $-1.58$   
 (C)  $-0.42$  and  $-1.58$  (D) none of the above

Q.55 For the system governed by the set of equations:

$$\begin{aligned} dx_1/dt &= 2x_1 + x_2 + u \\ dx_2/dt &= -2x_1 + u \\ y &= 3x_1 \end{aligned}$$

the transfer function  $Y(s)/U(s)$  is given by

- (A)  $3(s+1)/(s^2 - 2s + 2)$  (B)  $3(2s+1)/(s^2 - 2s + 1)$   
 (C)  $(s+1)/(s^2 - 2s + 1)$  (D)  $3(2s+1)/(s^2 - 2s + 2)$

**END OF THE QUESTION PAPER**