Q. 1 – Q. 25 carry one mark each.

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

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

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?

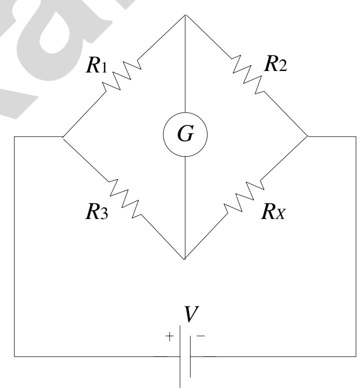
(A) $f(a) \cdot f(b) = 0$
(B) $f(a) \cdot f(b) < 0$
(C) $f(a) \cdot f(b) > 0$
(D) $f(a)/f(b) \leq 0$

Q.3 If the sum of the diagonal elements of a 2×2 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) 2π (C) 4π (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) $[120.25, 139.75]$

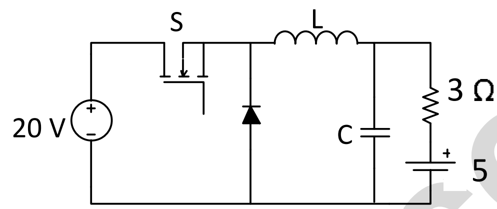
Q.6 A (0-50 A) moving coil ammeter has a voltage drop of 0.1 V across its terminals at full scale deflection. The external shunt resistance (in milliohms) needed to extend its range to (0 – 500 A) is _______.

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

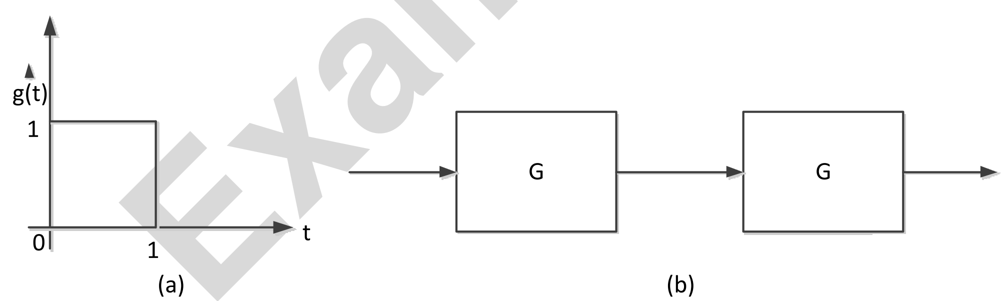
(A) P, Q and R only
(B) P and R only
(C) P, Q and S only
(D) Q, R and S only

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_____.



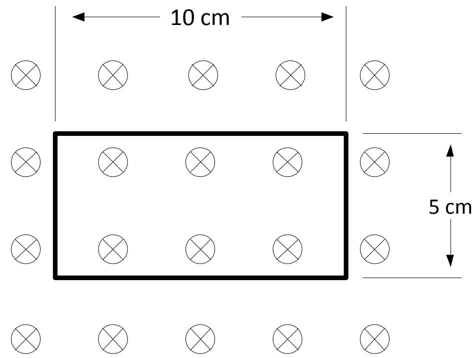
Q.9 A moving average function is given by $y(t) = \frac{1}{T}\int_{t-T}^{t} u(\tau)d\tau$. If the input u is a sinusoidal signal of frequency $\frac{1}{2T}$ Hz, then in steady state, the output y will lag u (in degree) by ______ .

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)?

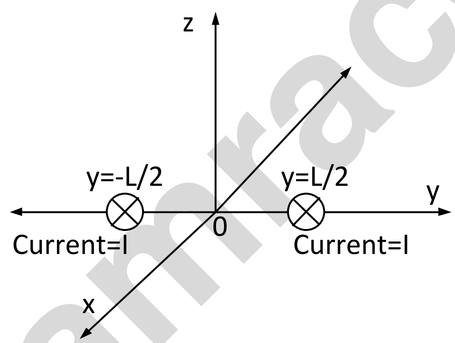


(A) $\frac{2}{3}$
(B) $\frac{3}{4}$
(C) $\frac{4}{5}$
(D) 1

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 0.4Ω, 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 ________.

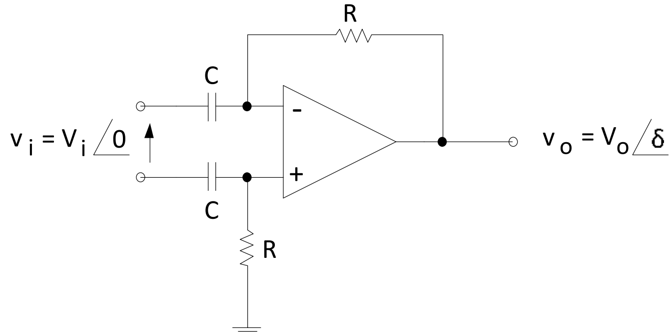


Q.12 A steady current I is flowing in the $-x$ direction through each of two infinitely long wires at $y = \pm \frac{L}{2}$ as shown in the figure. The permeability of the medium is μ_0. The $\vec{B}$-field at (0,L,0) is



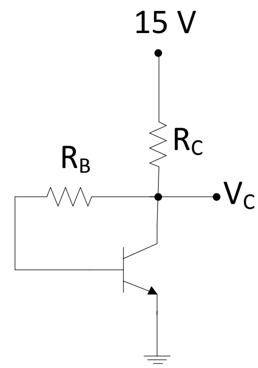
(A) $-\frac{4\mu_0 I}{3\pi L}\hat{z}$ (B) $+\frac{4\mu_0 I}{3\pi L}\hat{z}$ (C) 0 (D) $-\frac{3\mu_0 I}{4\pi L}\hat{z}$

Q.13 Consider the circuit shown in the figure. In this circuit R=1 kΩ, and C=1 μF. 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 δ radian. What is the value of the output phase angle δ (in radian) relative to the phase angle of the input voltage?

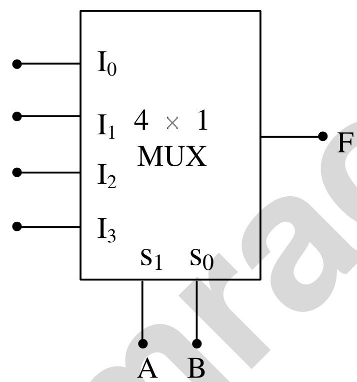


(A) 0 (B) π (C) $\pi/2$ (D) $-\pi/2$

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 ________.

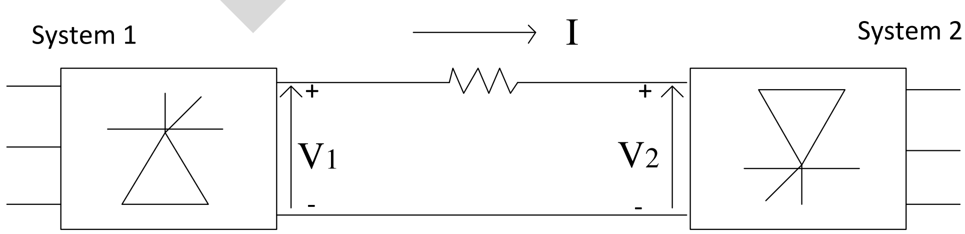


Q.15 In the 4 × 1 multiplexer, the output F is given by F = A ⊕ B. Find the required input '$I_3 I_2 I_1 I_0$'.



(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?



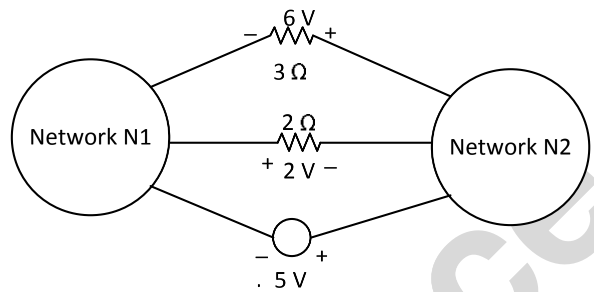
(A) $V_1 = -500$ kV, $V_2 = -485$ kV and $I = 1.5$ kA
(B) $V_1 = -485$ kV, $V_2 = -500$ kV and $I = 1.5$ kA
(C) $V_1 = 500$ kV, $V_2 = 485$ kV and $I = -1.5$ kA
(D) $V_1 = -500$ kV, $V_2 = -485$ kV and $I = -1.5$ kA

Q.17 Base load power plants are

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

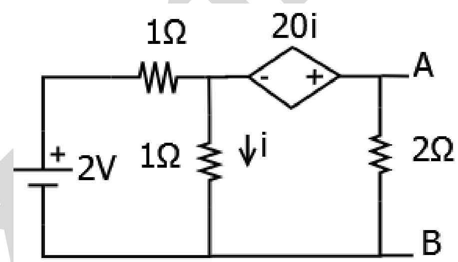
(A) P, Q and S only
(B) P, R and S only
(C) P, Q and R only
(D) Q and R only

Q.18 The voltages developed across the 3 Ω and 2 Ω 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?

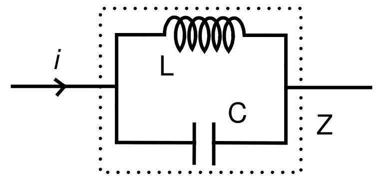


(A) 5
(B) 7
(C) 10
(D) 14

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 __________.

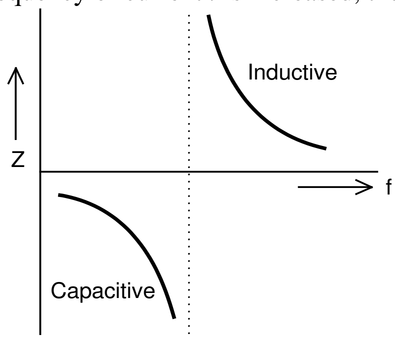


Q.20 An inductor is connected in parallel with a capacitor as shown in the figure.

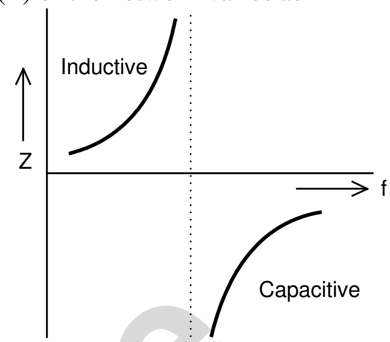


As the frequency of current *i* is increased, the impedance (Z) of the network varies as

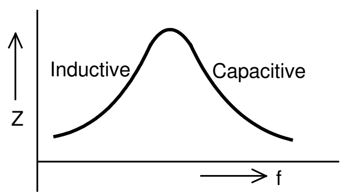
(A)



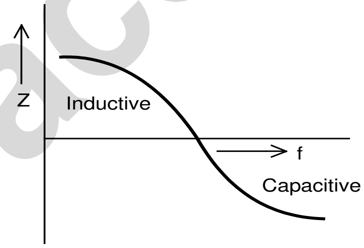
(B)



(C)



(D)



Q.21 A separately excited DC generator has an armature resistance of 0.1Ω 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 un-charged 1000 μF 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

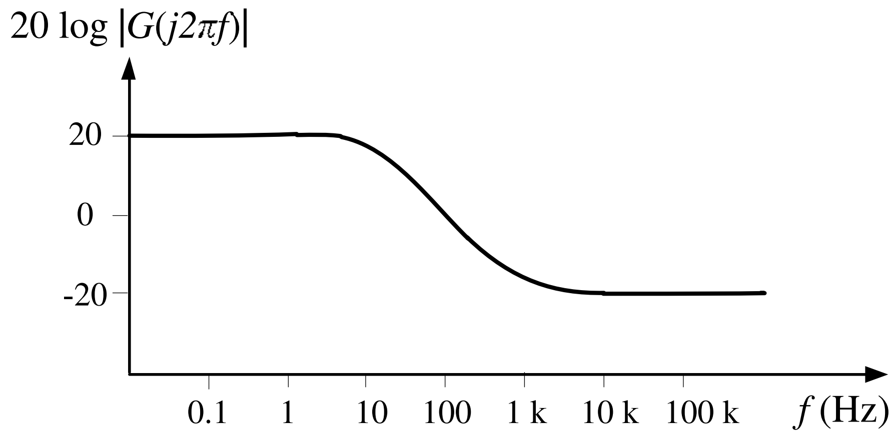
Q.22 The self inductance of the primary winding of a single phase, 50 Hz, transformer is 800 mH, and that of the secondary winding is 600 mH. The mutual inductance between these two windings is 480 mH. The secondary winding of this transformer is short circuited and the primary winding is connected to 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

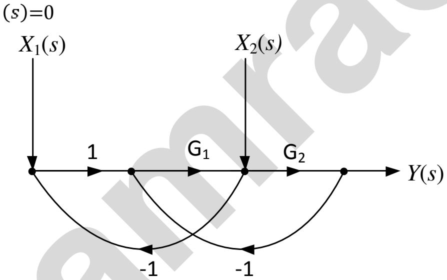
(A) power transformer.
(B) potential transformer.
(C) current transformer.
(D) distribution transformer.

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 $\left.\frac{Y(s)}{X_2(s)}\right|_{X_1(s)=0}$?



(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

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

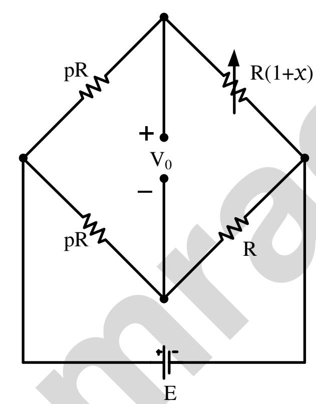
The Fourier series expansion of $sgn(\cos(t))$ has

(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

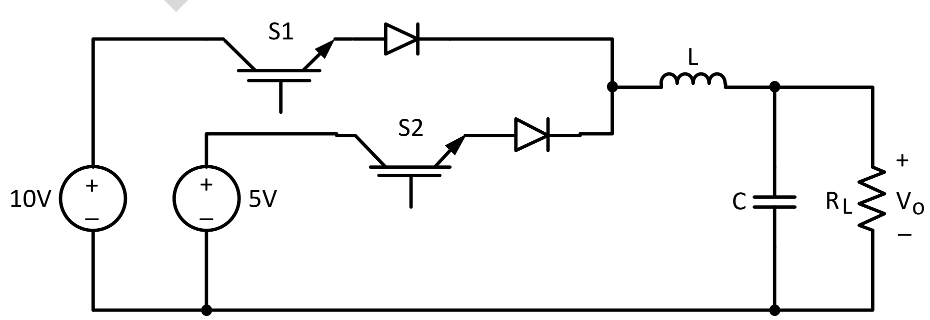
(A) 5/11 (B) 1/2 (C) 7/13 (D) 6/11

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?

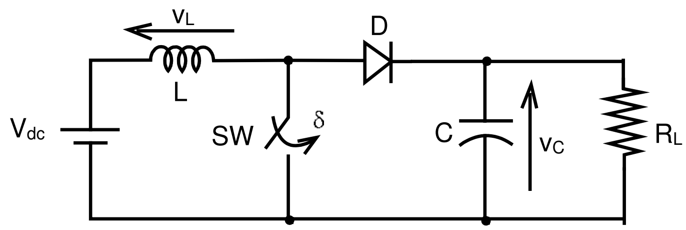


(A) $\sqrt{(1+x)}$ (B) $(1+x)$ (C) $1/\sqrt{(1+x)}$ (D) $\sqrt{(1-x)}$

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_O (in Volt) across R_L is ___________.



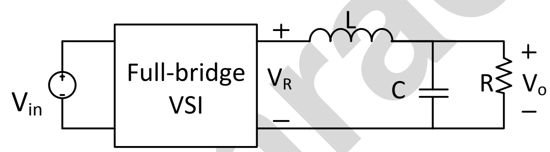
Q.32 A self commutating switch SW, operated at duty cycle δ is used to control the load voltage as shown in the figure



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, $C = 63.66$ μF, 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^{th} 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^{th} harmonic component of voltage is _________.

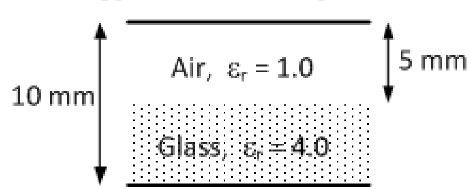
Q.35 Consider a discrete time signal given by

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

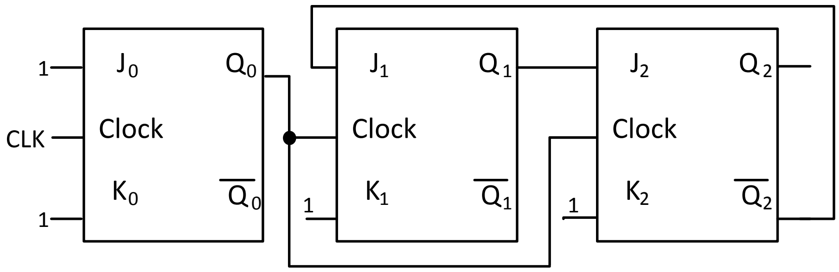
The region of convergence of its Z-transform would be

(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 ______.



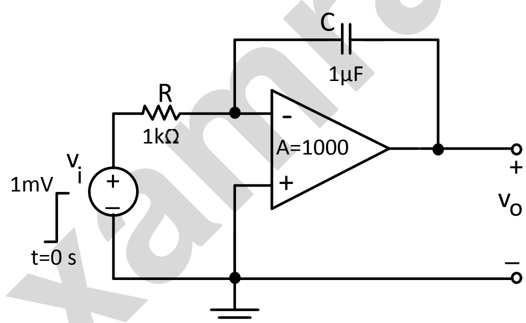
Q.37 The figure shows a digital circuit constructed using negative edge triggered J-K flip flops. Assume a starting state of $Q_2Q_1Q_0$=000. This state $Q_2Q_1Q_0$=000 will repeat after _______ number of cycles of the clock CLK.



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) $\bar{A}C\bar{D} + A\bar{B}C\bar{D} + A\bar{B}\bar{C}\bar{D}$
(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 $V_i = 1\ mV$ 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:

$$C_1(P_1) = 0.01P_1^2 + 30P_1 + 10 \quad ; \quad 100\text{ MW} \le P_1 \le 150\text{ MW}$$
$$C_2(P_2) = 0.05P_2^2 + 10P_2 + 10 \quad ; \quad 100\text{ MW} \le P_2 \le 180\text{ MW}$$

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].

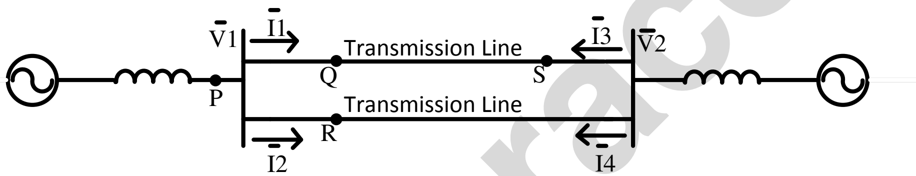
Assertion: Fast decoupled load flow method gives approximate load flow solution because it uses several assumptions.

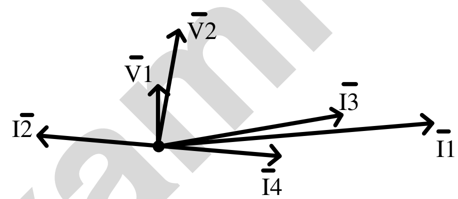
Reason: Accuracy depends on the power mismatch vector tolerance.

(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 δ is 5°, 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 δ in degrees, 0.02 second after the fault is _________.

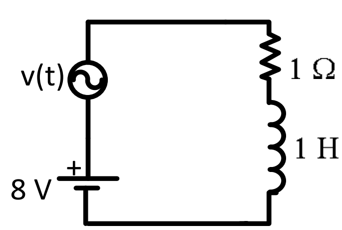
Q.44 A sustained three-phase fault occurs in the power system shown in the figure. The current and voltage phasors during the fault (on a common reference), after the natural transients have died down, are also shown. Where is the fault located?





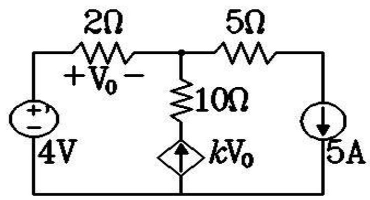
(A) Location P (B) Location Q (C) Location R (D) Location S

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 Ω resistance connected across Port 2. When 3 V is applied to Port 1, the current (in Ampere) through a 2 Ω resistance connected across Port 2 is _______.

Q.47 In the given circuit, the parameter k is positive, and the power dissipated in the 2 Ω resistor is 12.5W. The value of k is _________.



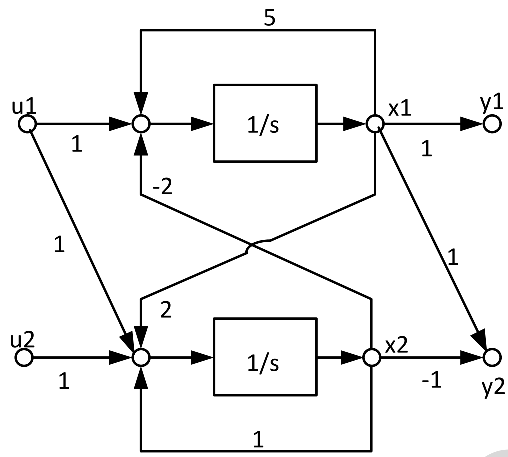
Q.48 A separately excited DC motor runs at 1000 rpm on no load when its armature terminals are connected to a 200V DC source and the rated voltage is applied to the field winding. The armature resistance of this motor is 1 Ω. The no-load armature current is negligible. With the motor developing its full 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 Ω. 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 Ω 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?

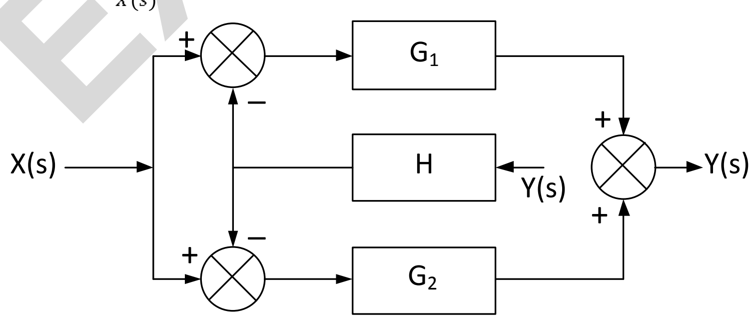


(A) When u_1 is the only input and y_1 is the only output.
(B) When u_2 is the only input and y_1 is the only output.
(C) When u_1 is the only input and y_2 is the only output.
(D) When u_2 is the only input and y_2 is the only output.

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