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

(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.

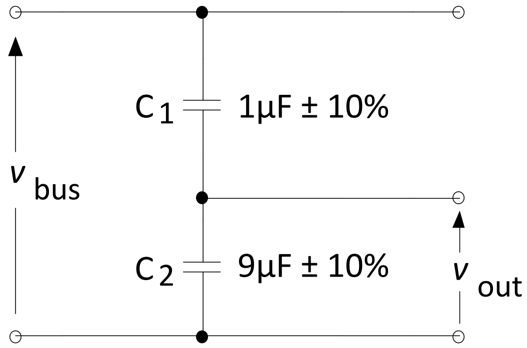
Instrument Type	**Used for**
P. Permanent magnet moving coil	1. DC Only
Q. Moving iron connected through current transformer	2. AC Only
R. Rectifier	3. AC and DC
S. Electrodynamometer	

(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

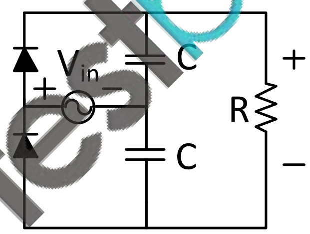
Q.6 A 3-phase balanced load which has a power factor of 0.707 is connected to a balanced supply. The power consumed by the load is 5 kW. The power is measured by the two-wattmeter method. The readings of the two wattmeters are

(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

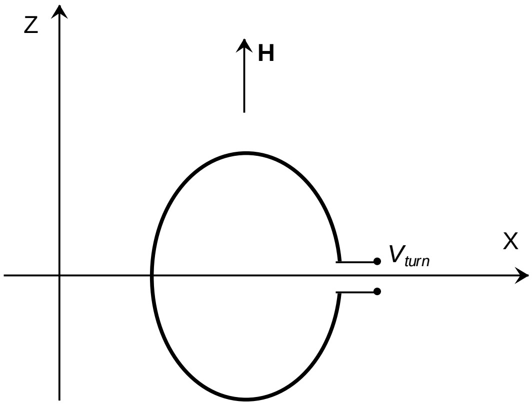


(A) 100 (B) 31.8 (C) 200 (D) 63.6

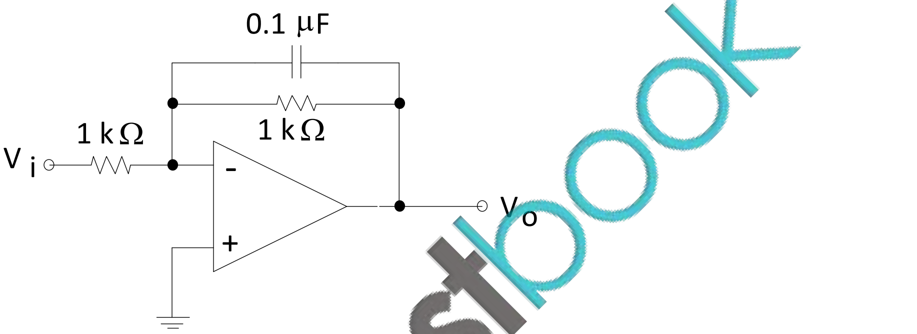
Q.9 Two semi-infinite dielectric regions are separated by a plane boundary at $y = 0$. The dielectric constants of region 1 ($y < 0$) and region 2 ($y > 0$) are 2 and 5, respectively. Region 1 has uniform electric field $\vec{E} = 3\hat{a}_x + 4\hat{a}_y + 2\hat{a}_z$, where $\hat{a}_x$, $\hat{a}_y$, 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) $3\hat{a}_x + 10\hat{a}_y + 0.8\hat{a}_z$

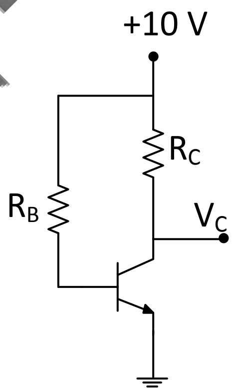
Q.10 A circular turn of radius 1 m revolves at 60 rpm about its diameter aligned with the x-axis as shown in the figure. The value of μ_0 is $4\pi \times 10^{-7}$ in SI unit. If a uniform magnetic field intensity $\vec{H} = 10^7\,\hat{z}$ A/m is applied, then the peak value of the induced voltage, V_{turn} (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 _______.



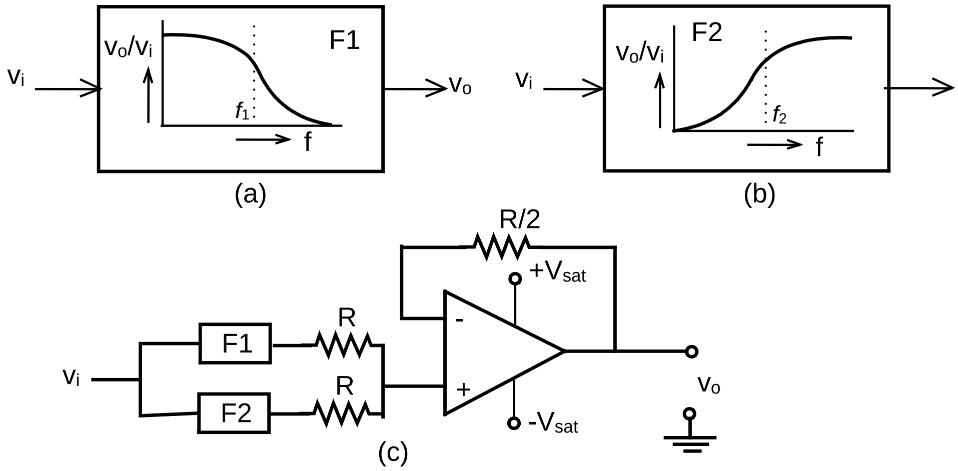
Q.13 Consider the following Sum of Products expression, F.

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

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).



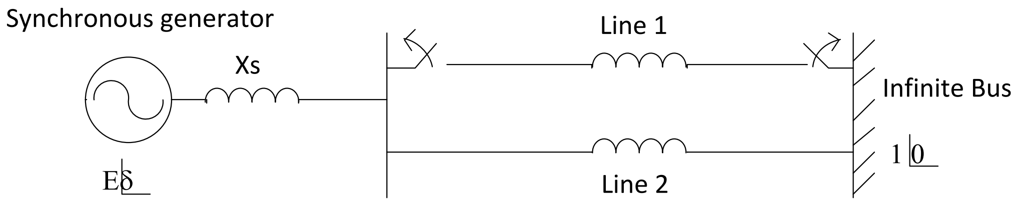
The cut-off frequencies of F1 and F2 are f_1 and f_2 respectively. If $f_1 < f_2$, the resultant circuit exhibits the characteristic of a

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

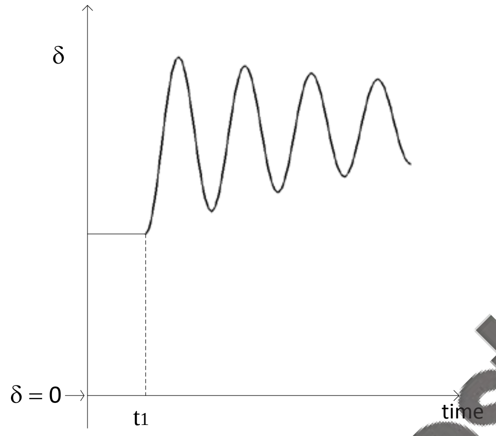
Q.15 When a bipolar junction transistor is operating in the saturation mode, which one of the following statements is TRUE about the state of its collector-base (CB) and the base-emitter (BE) junctions?

(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.

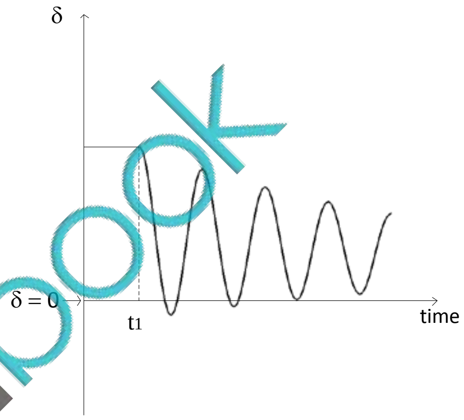
Q.16 The synchronous generator shown in the figure is supplying active power to an infinite bus via two short, lossless transmission lines, and is initially in steady state. The mechanical power input to the generator and the voltage magnitude E are constant. If one line is tripped at time t_1 by opening 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 δ shows the transient correctly?



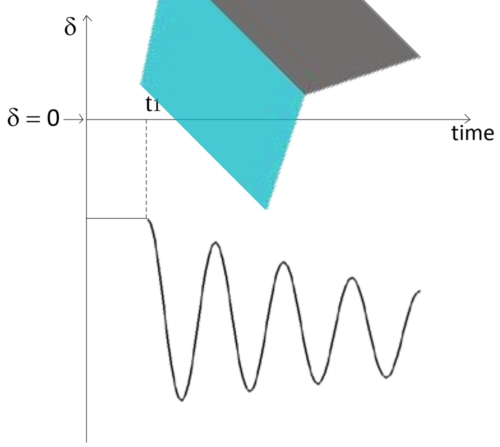
(A)



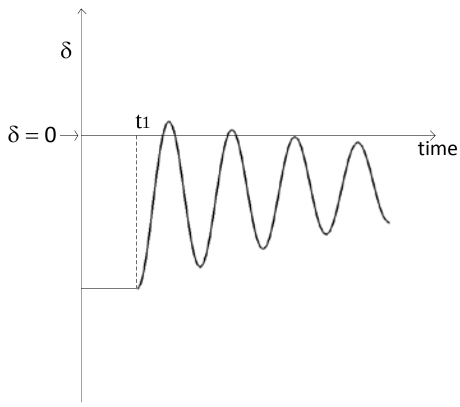
(B)



(C)



(D)



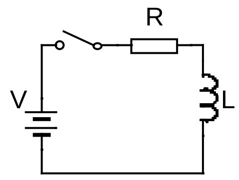
Q.17 A 3-bus power system network consists of 3 transmission lines. The bus admittance matrix of the uncompensated system is

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

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

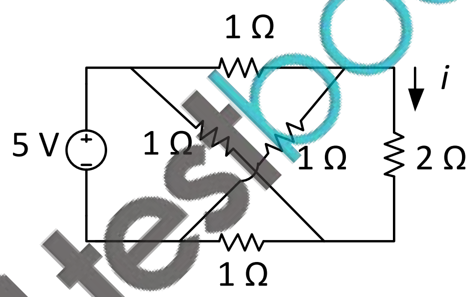
(A) $-j7.0$ (B) $-j8.5$ (C) $-j7.5$ (D) $-j9.0$

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

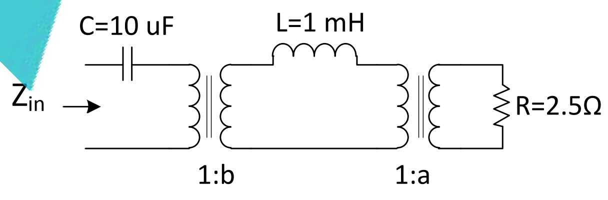


(A) $\frac{V}{L}$ (B) $\frac{-V}{R}$ (C) 0 (D) $\frac{-RV}{L^2}$

Q.19 The current i (in Ampere) in the 2 Ω resistor of the given network is _______.



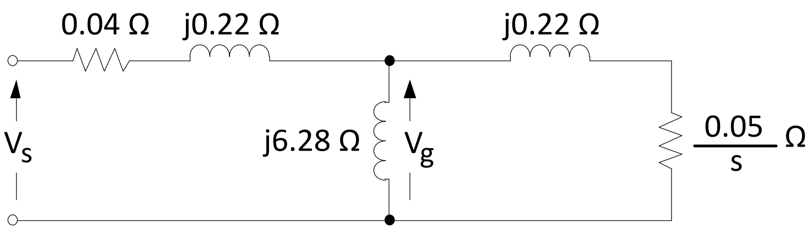
Q.20 Find the transformer ratios a and b such that the impedance (Z_{in}) is resistive and equals 2.5 Ω when the network is excited with a sine wave voltage of angular frequency of 5000 rad/s.



(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 radian/second. At its rated torque of 500 Nm, its speed is 180 radian/second. The motor is used to directly drive a load whose load torque T_L depends on its rotational speed ω_r (in radian/second), such that $T_L = 2.78$ ⍰ ω_r. Neglecting rotational losses, the steady-state speed (in 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 ?

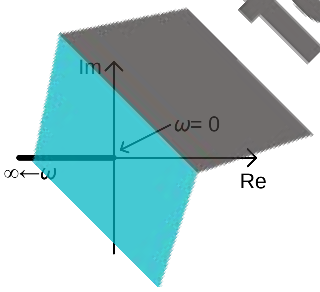
(A) 230 and 5 (B) 115 and 5 (C) 115 and 2.5 (D) 230 and 2.5

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 ______.

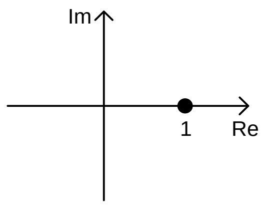
Q.25 Nyquist plots of two functions $G_1(s)$ and $G_2(s)$ are shown in figure.

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

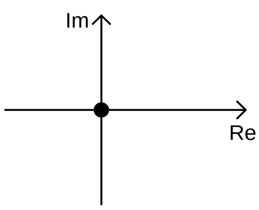
(A)



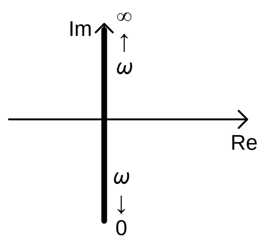
(B)



(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

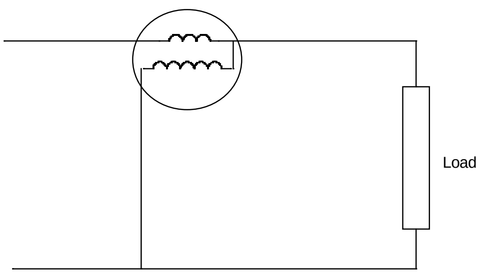
$$x(t) = \begin{cases} e^{j10t} & \text{for } |t| \le 1 \\ 0 & \text{for } |t| > 1 \end{cases}$$

Its Fourier Transform is

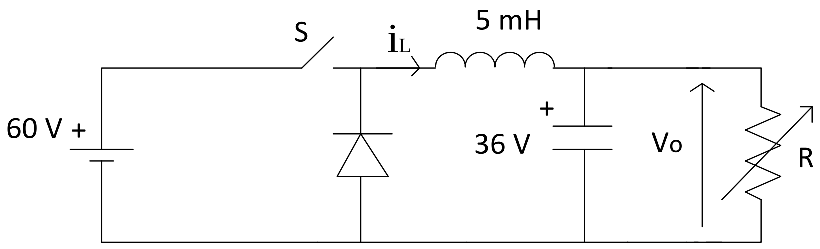
(A) $\frac{2\sin(\omega-10)}{\omega-10}$ (B) $2e^{j10}\frac{\sin(\omega-10)}{\omega-10}$

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

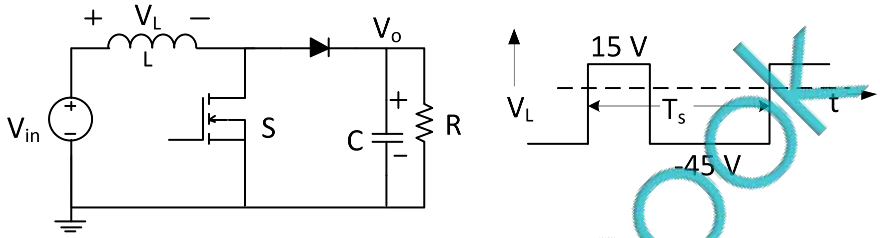
Q.30 The coils of a wattmeter have resistances 0.01 Ω and 1000 Ω; their inductances may be neglected. The wattmeter is connected as shown in the figure, to measure the power consumed by a load, which draws 25 A at power factor 0.8. The voltage across the load terminals is 30 V. The percentage error on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



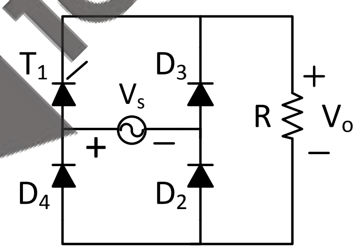
Q.31 A buck converter feeding a variable resistive load is shown in the figure. The switching frequency of the switch S is 100 kHz and the duty ratio is 0.6. The output voltage V_O is 36 V. Assume that all the components are ideal, and that the output voltage is ripple-free. The value of R (in Ohm) that 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°. If the input voltage V_s is $100\sin(100\pi t)$ V, the average voltage across R (in Volt) under steady-state is _______.



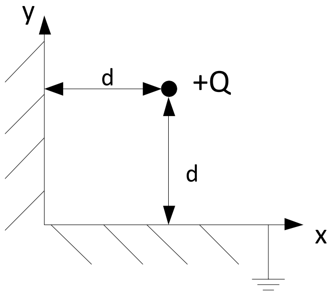
Q.34 For linear time invariant systems, that are Bounded Input Bounded Output stable, which one of the following statements is TRUE?

(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

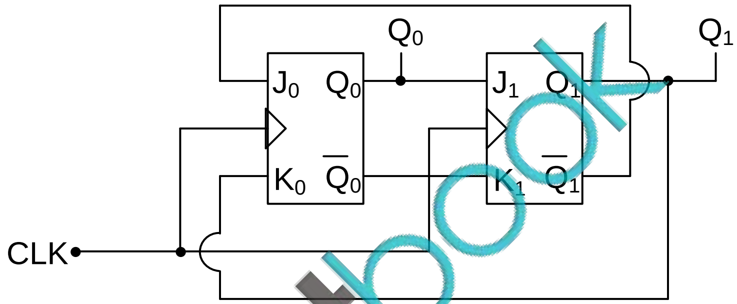
(A) $2z + 2 - 8/z + 7/z^2 - 3/z^3$
(B) $-2z + 2 - 6/z + 1/z^2 - 3/z^3$
(C) $-2z - 2 + 8/z - 7/z^2 + 3/z^3$
(D) $4z - 2 - 8/z - 1/z^2 + 3/z^3$

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



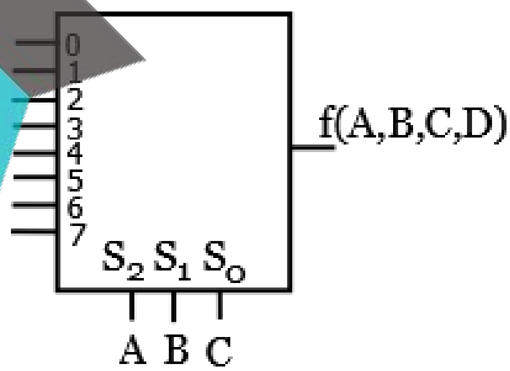
(A) 0 (B) $-\frac{1}{4}\hat{\imath}-\frac{1}{4}\hat{\jmath}$ (C) $-\frac{1}{8}\hat{\imath}-\frac{1}{8}\hat{\jmath}$ (D) $\frac{1-2\sqrt{2}}{8\sqrt{2}}\hat{\imath}+\frac{1-2\sqrt{2}}{8\sqrt{2}}\hat{\jmath}$

Q.37 In the following sequential circuit, the initial state (before the first clock pulse) of the circuit is $Q_1Q_o = 00$. The state (Q_1Q_o), immediately after the 333rd clock pulse is



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

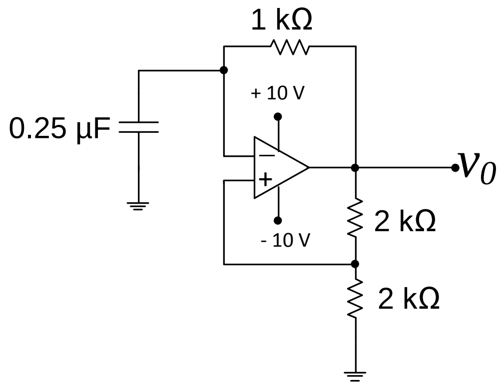
Q.38 A Boolean function $f(A,B,C,D) = \prod(1,5,12,15)$ is to be implemented using an 8 × 1 multiplexer (A is MSB). The inputs ABC are connected to the select inputs S_2 S_1 S_0 of the multiplexer respectively.



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

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

Q.39 The saturation voltage of the ideal op-amp shown below is ± 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

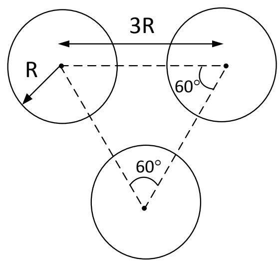
$$\frac{dC_1}{dP_1} = 0.2P_1 + 50$$
$$\frac{dC_2}{dP_2} = 0.24P_2 + 40$$

where

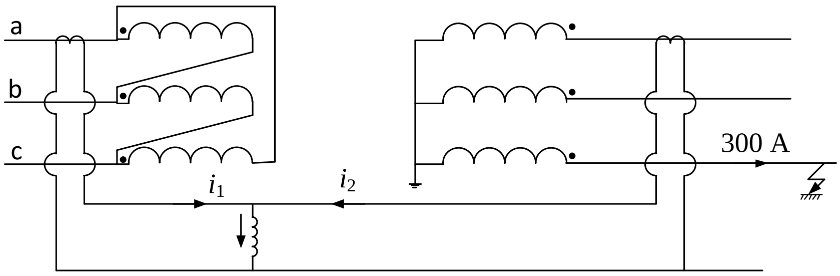
$$20 \text{ MW} \le P_1 \le 150 \text{ MW}$$
$$20 \text{ MW} \le P_2 \le 150 \text{ MW}.$$

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 _______.

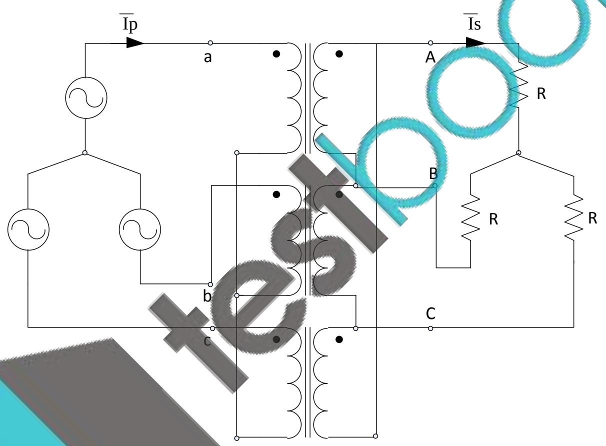


Q.42 A 3-phase transformer rated for 33 kV/11 kV is connected in delta/star as shown in figure. The current transformers (CTs) on low and high voltage sides have a ratio of $500/5$. Find the currents i_1 and i_2, if the fault current is 300 A as shown in figure.



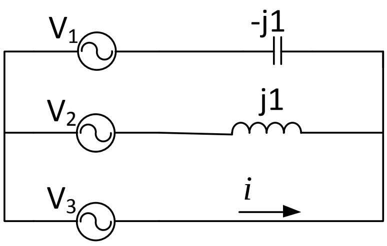
(A) $i_1 = 1/\sqrt{3}\,A, i_2 = 0\,A$
(B) $i_1 = 0\,A, i_2 = 0\,A$
(C) $i_1 = 0\,A, i_2 = 1/\sqrt{3}\,A$
(D) $i_1 = 1/\sqrt{3}\,A, i_2 = 1/\sqrt{3}\,A$

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 $\overline{I_s} = 100\angle 0°$ A, then what is the value of $\overline{I_p}$ in Ampere?



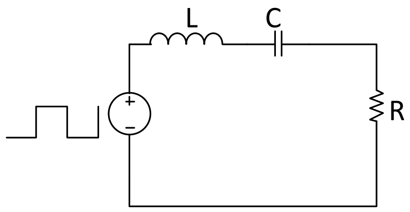
(A) $50\angle 30°$
(B) $50\angle -30°$
(C) $50\sqrt{3}\angle 30°$
(D) $200\angle 30°$

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



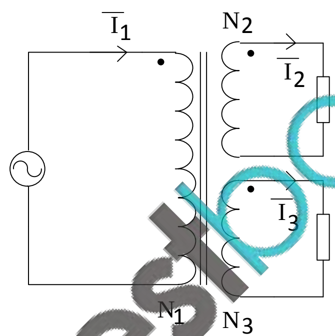
(A) $173.2\angle -60°$
(B) $173.2\angle 120°$
(C) $100.0\angle -60°$
(D) $100.0\angle 120°$

Q.45 A symmetrical square wave of 50% duty cycle has amplitude of ± 15 V and time period of 0.4π ms. This square wave is applied across a series RLC circuit with $R = 5\ \Omega, L = 10$ mH, and $C = 4$ μF. 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 αL is obtained by interconnecting these two coils, the minimum value of α 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 $\overline{I_2} = 2\angle 30^\circ$A and $\overline{I_3} = 2\angle 150^\circ$A, then what is the value of the current $\overline{I_1}$ in Ampere?



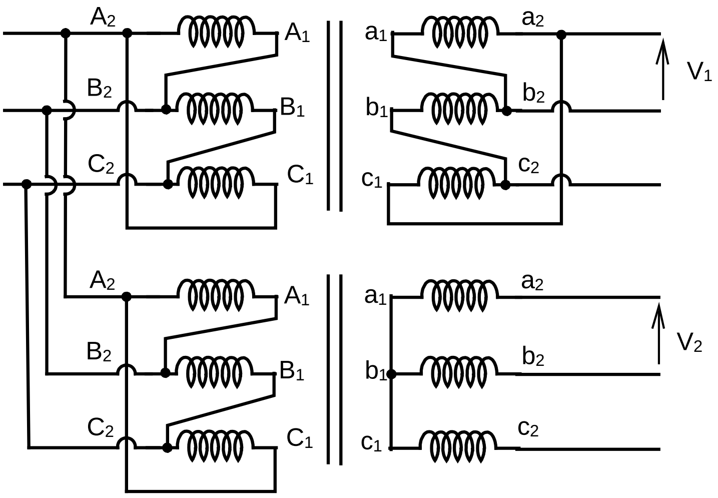
(A) $1\angle 90^\circ$ (B) $1\angle 270^\circ$ (C) $4\angle 90^\circ$ (D) $4\angle 270^\circ$

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 Ω. 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 Ω 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 Ω/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 $h > 0$

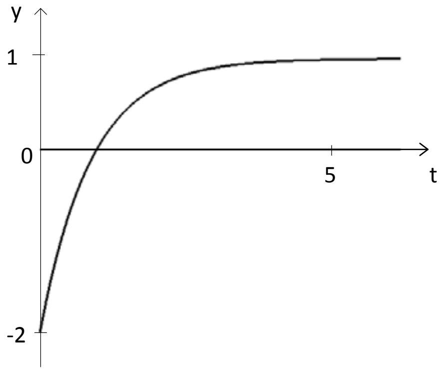
(B) The system is stable for $h > \frac{1}{\pi}$

(C) The system is stable for $0 < h < \frac{1}{2\pi}$

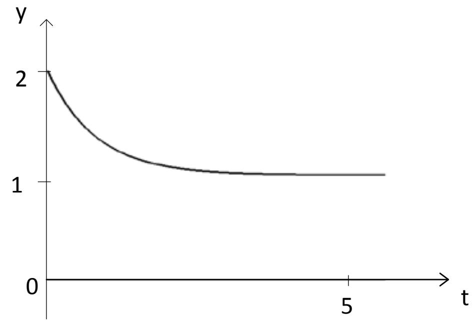
(D) The system is stable for $\frac{1}{2\pi} < h < \frac{1}{\pi}$

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?

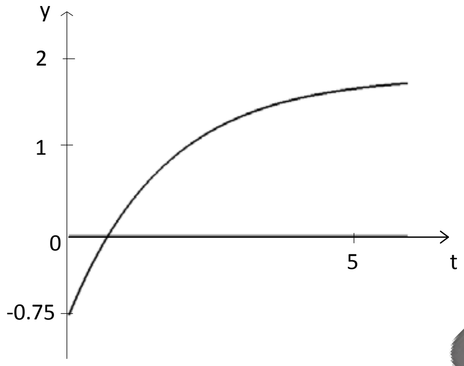
(A)



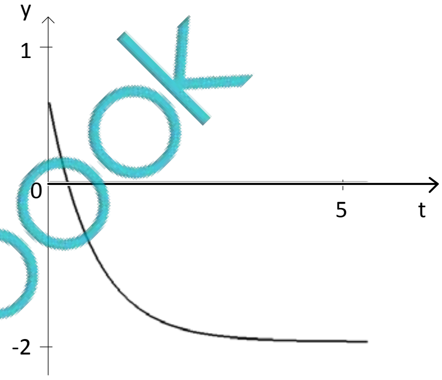
(B)



(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:

$$dx_1/\,dt = 2\,x_1 + x_2 + u$$
$$dx_2\,/\,dt = -\,2\,x_1 + u$$
$$y = 3\,x_1$$

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