# GATE Electrical Engineering

## Sample Paper – 6

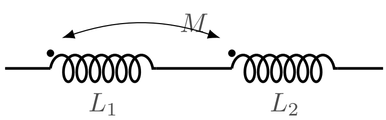
**Duration: 128 Minutes** **Maximum Marks: 72**

### Instructions

- This paper contains **46 questions** covering the core **Electrical Engineering** subject of the GATE paper conducted by the IITs and IISc (General Aptitude and Engineering Mathematics are provided as separate papers).
- **Q1–Q20 carry 1 mark each** and **Q21–Q46 carry 2 marks each**, for a total of **72 marks**.
- Each question carries **negative marking of one-third of its allotted marks**: a wrong 1-mark question costs **0.33** and a wrong 2-mark question costs **0.67**. Unattempted questions carry no penalty.
- Every question here is a single-correct **MCQ**. The real GATE paper also has Multiple Select (MSQ) and Numerical Answer Type (NAT) questions, and **those carry no negative marking**.
- Attempt this paper in one timed sitting of about **128 minutes**, the share this core subject earns at GATE's overall pace of 180 minutes for 65 questions. Unless stated otherwise take $\varepsilon_0 = 8.854 \times 10^{-12}$ F/m, $\mu_0 = 4\pi \times 10^{-7}$ H/m and $c = 3 \times 10^8$ m/s.

## Electric Circuits

**Q1.** Two magnetically coupled coils of self-inductances $L_1 = 4$ H and $L_2 = 6$ H, with a mutual inductance $M = 2$ H, are connected in **series-aiding** (their dots at the joined end), as shown. The equivalent inductance seen at the terminals is: **[1 mark]**




(A) 14 H

(B) 2 H

(C) 6 H

(D) 10 H

**Q2.** Two coils have self-inductances $L_1 = 8$ mH and $L_2 = 2$ mH and a mutual inductance $M = 3$ mH. The coefficient of coupling $k = \dfrac{M}{\sqrt{L_1 L_2}}$ is: **[1 mark]**

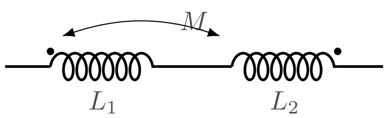
(A) 0.5

(B) 0.75

(C) 1

(D) 0.375

**Q3.** The same two coupled coils, now of $L_1 = 5$ H and $L_2 = 7$ H with $M = 1.5$ H, are connected in **series-opposing** (dots at opposite ends), as shown. The equivalent inductance is: **[1 mark]**




(A) 15 H

(B) 12 H

(C) 6 H

(D) 9 H

**Q4.** A series $RLC$ circuit has $L = 0.5$ H and $C = 200$ $\mu$F. Its undamped resonant angular frequency $\omega_0 = \dfrac{1}{\sqrt{LC}}$ is: **[1 mark]**

(A) 100 rad/s

(B) 200 rad/s

(C) 50 rad/s

(D) 10 rad/s

**Q5.** A series $RLC$ circuit has $R = 4\ \Omega$, $L = 40$ mH and $C = 100\ \mu$F. Its quality factor at resonance, $Q = \dfrac{1}{R}\sqrt{\dfrac{L}{C}}$, is: **[1 mark]**

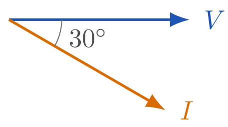
(A) $10$

(B) $2.5$

(C) $5$

(D) $20$

**Q6.** A single-phase load draws a current $I = 10\angle{-30^\circ}$ A when supplied with a voltage $V = 100\angle 0^\circ$ V, as the phasor diagram shows. The power factor of the load is: **[1 mark]**



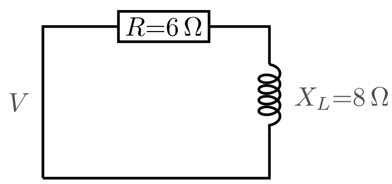

(A) $0.866$ lagging

(B) $0.5$ lagging

(C) $1$

(D) $0.707$ lagging

**Q7.** In the a.c. series circuit shown, a resistance $R = 6\ \Omega$ is in series with an inductive reactance $X_L = 8\ \Omega$. The magnitude of the total impedance $|Z| = \sqrt{R^2 + X_L^2}$ is: **[1 mark]**




(A) $14\ \Omega$

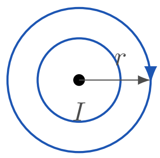
(B) $48\ \Omega$

(C) $10\ \Omega$

(D) $2\ \Omega$

## Electromagnetic Fields

**Q8.** A long straight conductor carries a steady current $I = 5$ A. By Ampere's law the magnetic flux density at a radial distance $r = 0.1$ m is $B = \dfrac{\mu_0 I}{2\pi r}$, as shown. Its value is: **[1 mark]**




(A) 5 $\mu$T

(B) 20 $\mu$T

(C) 10 $\mu$T

(D) 1 $\mu$T

**Q9.** An inductor of $L = 2$ H carries a steady current of $I = 3$ A. The energy stored in its magnetic field, $W = \frac{1}{2}LI^2$, is: **[1 mark]**

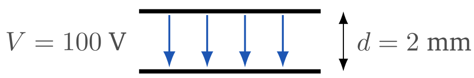
(A) 3 J

(B) 18 J

(C) 6 J

(D) 9 J

**Q10.** A parallel-plate capacitor is charged to $V = 100$ V and its plate separation is $d = 2$ mm, as shown. Assuming a uniform field, the electric field strength between the plates, $E = V/d$, is: **[1 mark]**




(A) 200 kV/m

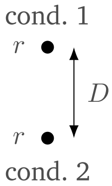
(B) 0.05 kV/m

(C) 50 kV/m

(D) 100 kV/m

**Q11.** A single-phase two-wire transmission line has its capacitance between the conductors given by $C_{ab} = \dfrac{\pi \varepsilon_0}{\ln(D/r)}$, with spacing $D$ and radius $r$

arranged so that $\ln(D/r) = 1$, as shown. The line-to-line capacitance per metre is nearest to: **[1 mark]**




(A) 8.85 pF/m

(B) 55.6 pF/m

(C) 13.9 pF/m

(D) 27.8 pF/m

## Signals and Systems

**Q12.** The discrete sequences $x[n] = \{1,\ 2,\ 3\}$ (for $n = 0, 1, 2$) and $h[n] = \{1,\ 1\}$ (for $n = 0, 1$) are linearly convolved to give $y[n] = x[n] * h[n]$. The sample $y[2]$ is: **[1 mark]**

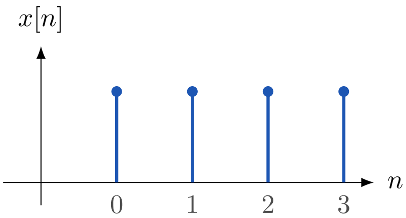
(A) 5

(B) 3

(C) 2

(D) 6

**Q13.** The 4-point DFT of the sequence $x[n] = \{1,\ 1,\ 1,\ 1\}$ (shown as a stem plot below) has a zero-frequency (d.c.) coefficient $X[0] = \sum_{n=0}^{3} x[n]$ equal to: **[1 mark]**




(A) 4

(B) 0

(C) 1

(D) 2

**Q14.** A band-limited continuous-time signal has a highest frequency component of 4 kHz. By the Nyquist sampling theorem the minimum sampling rate needed to avoid aliasing is: **[1 mark]**

(A) 4 kHz

(B) 2 kHz

(C) 8 kHz

(D) 16 kHz

**Q15.** Two finite discrete sequences of lengths 6 and 8 samples are convolved linearly. The number of samples in the resulting sequence is: **[1 mark]**

(A) 14

(B) 13

(C) 48

(D) 7

**Q16.** An $N = 8$ point DFT is computed by a radix-2 decimation-in-time FFT algorithm. The number of complex multiplications it requires, $\dfrac{N}{2}\log_2 N$, is: **[1 mark]**

(A) 64

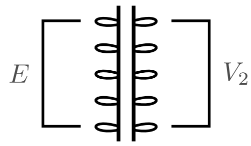
(B) 8

(C) 24

(D) 12

## Electrical Machines

**Q17.** A single-phase transformer has $N = 100$ primary turns and operates at $f = 50$ Hz with a maximum core flux $\phi_m = 0.02$ Wb, as shown. Its induced primary e.m.f., $E = 4.44\, f\, N\, \phi_m$, is: **[1 mark]**




$N = 100,\ \phi_m = 0.02$ Wb

(A) 222 V

(B) 111 V

(C) 888 V

(D) 444 V

**Q18.** A short-circuit (SC) test on a transformer records a full-load input power of 250 W, which equals the full-load copper loss. Since copper loss varies as the square of the load fraction, the copper loss at **half** load is: **[1 mark]**

(A) 125 W

(B) 62.5 W

(C) 250 W

(D) 500 W

**Q19.** An open-circuit (OC) test on a transformer records an input power of 150 W, which is essentially the constant core (iron) loss. The iron loss when the transformer runs at **half** its rated load is: **[1 mark]**

(A) 75 W

(B) 150 W

(C) 300 W

(D) 37.5 W

**Q20.** A 10 kVA single-phase transformer has a rated secondary voltage of 400 V. Its rated (full-load) secondary current, $I_2 = \dfrac{\text{kVA} \times 1000}{V_2}$, is: **[1 mark]**

(A) 40 A

(B) 10 A

(C) 25 A

(D) 4 A

**Q21.** A single-phase transformer delivers an output of 8 kW. Under this load its core loss is 120 W and its copper loss is 130 W. The efficiency $\eta = \dfrac{P_{out}}{P_{out} + P_{core} + P_{cu}}$ is nearest to: **[2 marks]**

(A) 90%

(B) 95%

(C) 98%

(D) 96.97%

**Q22.** A transformer has a constant iron loss of 200 W and a full-load copper loss of 800 W. Maximum efficiency occurs when the copper loss equals the iron loss; the corresponding fraction of full load is $x = \sqrt{P_i/P_{cu,\,fl}}$, which is: **[2 marks]**

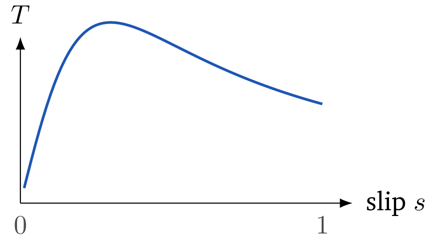
(A) 0.25

(B) 0.5

(C) 0.707

(D) 1

**Q23.** A 6-pole, 50 Hz three-phase induction motor runs with a per-unit slip of $s = 0.04$; its torque–slip curve is sketched below. Using $N_s = \dfrac{120f}{P}$ and $N = N_s(1-s)$, the rotor speed is: **[2 marks]**




(A) 960 rpm

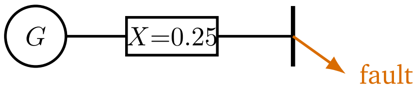
(B) 1000 rpm

(C) 950 rpm

(D) 1440 rpm

## Power Systems

**Q24.** A bus is fed from a source through a reactance of $X = 0.25$ pu on a base of 100 MVA, as the single-line diagram shows. For a three-phase symmetrical fault at the bus the short-circuit level $\text{MVA}_{fault} = \dfrac{\text{MVA}_{base}}{X_{pu}}$ is: **[2 marks]**




(A) 250 MVA

(B) 400 MVA

(C) 100 MVA

(D) 25 MVA

**Q25.** The fault level at an 11 kV bus is 400 MVA. The symmetrical short-circuit current $I_{sc} = \dfrac{\text{MVA}_{fault} \times 10^6}{\sqrt{3} \times V_L}$, which a switchgear at the bus must interrupt, is nearest to: **[2 marks]**

(A) 21 kA

(B) 36 kA

(C) 12 kA

(D) 400 kA

**Q26.** A circuit breaker is to interrupt a symmetrical fault current of 20 kA at a system voltage of 11 kV. Its three-phase symmetrical breaking capacity $S = \sqrt{3}\, V_L\, I_{sc}$ is nearest to: **[2 marks]**

(A) 381 MVA

(B) 220 MVA

(C) 660 MVA

(D) 127 MVA

**Q27.** A generator reactance is specified as $0.15$ pu on a base of $50$ MVA. Referred to a new base of $100$ MVA at the same voltage, using $X_{new} = X_{old} \times \frac{\text{MVA}_{new}}{\text{MVA}_{old}}$, its value becomes: **[2 marks]**

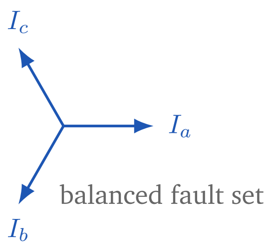
(A) $0.075$ pu

(B) $0.15$ pu

(C) $0.30$ pu

(D) $0.60$ pu

**Q28.** An unloaded generator with pre-fault e.m.f. $E = 1.0$ pu and reactance $X = 0.2$ pu experiences a bolted three-phase symmetrical fault at its terminals; the balanced fault-current phasors are indicated below. The fault current $I_f = \frac{E}{X}$ is: **[2 marks]**




(A) $0.2$ pu

(B) $10$ pu

(C) $2$ pu

(D) $5$ pu

**Q29.** Per-unit calculations use a base of $100$ MVA and a base voltage of $220$ kV. The base impedance $Z_{base} = \frac{(kV_{base})^2}{\text{MVA}_{base}}$ is: **[2 marks]**

(A) $484\ \Omega$

(B) $48.4\ \Omega$

(C) $242\ \Omega$

(D) $121\ \Omega$

**Q30.** A 132 kV (line) transmission line, 100 km long, has a capacitance to neutral of 0.02 $\mu$F/km and operates at 50 Hz. Its per-phase charging current $I_c = V_{ph}\,\omega C$ (with $V_{ph} = 132/\sqrt{3}$ kV and $C$ the total per-phase capacitance) is nearest to: **[2 marks]**

(A) 76 A

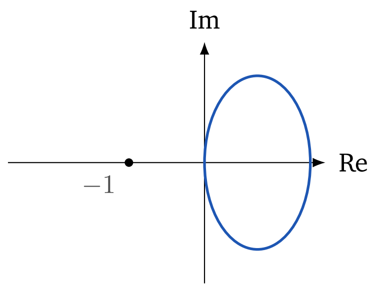
(B) 24 A

(C) 48 A

(D) 96 A

## Control Systems

**Q31.** A unity-feedback system has an open-loop transfer function with **no** poles in the right half of the $s$-plane ($P = 0$). Its Nyquist plot is sketched below and does not enclose the critical point $-1 + j0$. For closed-loop stability the required number of encirclements of $-1$ (by the Nyquist criterion $N = P - Z$ with $Z = 0$) is: **[2 marks]**




(A) 1

(B) 2

(C) $-1$

(D) 0

**Q32.** At its phase-crossover frequency (phase $= -180^\circ$) the open-loop gain magnitude of a system is $|G(j\omega_{pc})| = 0.25$. The gain margin, GM $= 20\log_{10}\dfrac{1}{|G|}$ dB, is: **[2 marks]**

(A) 6 dB

(B) 3 dB

(C) 0 dB

(D) 12 dB

**Q33.** A PID controller is tuned to $G_c(s) = K_p\left(1 + \frac{1}{T_i s} + T_d s\right)$ with $K_p = 5$, $T_i = 0.5$ s and $T_d = 0.1$ s. Its derivative gain, $K_d = K_p T_d$, is: **[2 marks]**

(A) 5

(B) 2.5

(C) 0.5

(D) 10

**Q34.** A unity-feedback system has the open-loop transfer function $G(s) = \frac{10}{s+5}$ (a type-0 system). For a unit-step input the steady-state error, $e_{ss} = \frac{1}{1+K_p}$ with $K_p = \lim_{s\to 0} G(s)$, is: **[2 marks]**

(A) 0

(B) 0.333

(C) 0.5

(D) 1

**Q35.** A closed-loop system has the characteristic equation $s^2 + 4s + 16 = 0$. Comparing with the standard form $s^2 + 2\zeta\omega_n s + \omega_n^2 = 0$, the damping ratio $\zeta$ is: **[2 marks]**

(A) 0.25

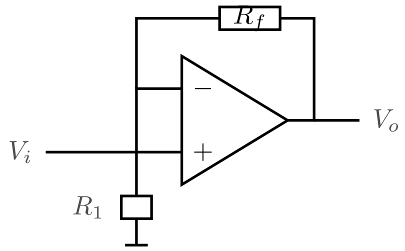
(B) 0.5

(C) 1

(D) 0.75

## Analog, Digital and Measurements

**Q36.** For the ideal-op-amp **non-inverting** amplifier shown, $R_1 = 10$ kΩ (to ground) and $R_f = 90$ kΩ (feedback). Its closed-loop voltage gain $\frac{V_o}{V_i} = 1 + \frac{R_f}{R_1}$ is: [2 marks]



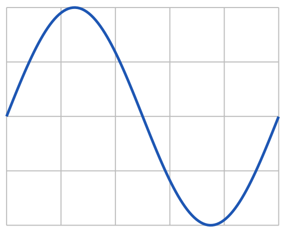

(A) 10

(B) 9

(C) 0.1

(D) 11

**Q37.** On an oscilloscope a sine wave spans 4 vertical divisions from peak to peak, with the vertical sensitivity set to 2 V/div (see the trace). The peak-to-peak voltage, $V_{pp} = (\text{divisions}) \times (\text{V/div})$, is: [2 marks]



(A) 2 V

(B) 4 V

(C) 16 V

(D) 8 V

**Q38.** On an oscilloscope one full cycle of a periodic signal occupies 4 horizontal divisions, with the time base set to 0.5 ms/div. The signal frequency, $f = \frac{1}{(\text{divisions}) \times (\text{time/div})}$, is: [2 marks]

(A) 500 Hz

(B) 250 Hz

(C) 1 kHz

(D) 2 kHz

**Q39.** A decade (mod-10) counter must pass through 10 distinct states. The minimum number of flip-flops required, the smallest $n$ with $2^n \geq 10$, is: **[2 marks]**

(A) 3

(B) 4

(C) 10

(D) 5

**Q40.** A 3-bit binary ripple counter is clocked at 8 kHz. Each flip-flop halves the frequency, so the most-significant-bit output appears at $\dfrac{8\text{ kHz}}{2^3}$, which is: **[2 marks]**

(A) 1 kHz

(B) 4 kHz

(C) 8 kHz

(D) 2 kHz

**Q41.** The hexadecimal number $(2\text{A})_{16}$ has the decimal (base-10) value: **[2 marks]**

(A) 26

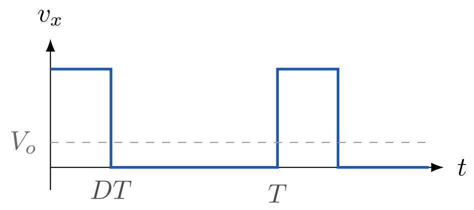
(B) 20

(C) 32

(D) 42

## Power Electronics

**Q42.** A step-down (buck) DC-DC converter operates from an input of $V_s = 48$ V at a duty ratio $D = 0.25$; its switch-node waveform is shown. In continuous conduction the average output voltage $V_o = D\,V_s$ is: **[2 marks]**




(A) 48 V

(B) 12 V

(C) 24 V

(D) 6 V

**Q43.** A step-up (boost) DC-DC converter operates from $V_s = 20$ V at a duty ratio $D = 0.5$. In continuous conduction its average output voltage is $V_o = \dfrac{V_s}{1-D}$, which is: **[2 marks]**

(A) 20 V

(B) 10 V

(C) 40 V

(D) 80 V

**Q44.** A buck-boost DC-DC converter operates from $V_s = 24$ V at a duty ratio $D = 0.6$. The magnitude of its average output voltage is $|V_o| = V_s \dfrac{D}{1-D}$, which is: **[2 marks]**

(A) 16 V

(B) 24 V

(C) 36 V

(D) 14.4 V

**Q45.** An SMPS uses a buck converter that must produce an average output of 5 V from a 20 V input. The required duty ratio, $D = \dfrac{V_o}{V_s}$, is: **[2 marks]**

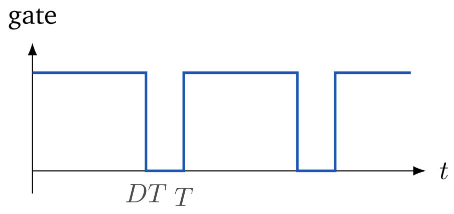
(A) 0.5

(B) 0.25

(C) $0.75$

(D) $2$

**Q46.** A boost converter in an SMPS must step $V_s = 12$ V up to $V_o = 48$ V, producing the pulse-train switch waveform shown. Using $V_o = \dfrac{V_s}{1-D}$, the required duty ratio $D$ is: **[2 marks]**




(A) $0.25$

(B) $0.75$

(C) $0.5$

(D) $0.9$

# Detailed Solutions

## Q1.

**Solution**

**Concept – series-aiding coupled inductors:** When two mutually coupled coils are connected in series so that their fluxes add (series-aiding), the equivalent inductance is $L_{eq} = L_1 + L_2 + 2M$.

**Step 1 – list the data:** $L_1 = 4$ H, $L_2 = 6$ H, $M = 2$ H.

**Step 2 – add the two self-inductances:** $L_1 + L_2 = 4 + 6 = 10$ H

**Step 3 – form the mutual term:** $2M = 2 \times 2 = 4$ H

**Step 4 – add the mutual term (aiding is $+$):** $L_{eq} = 10 + 4$

$L_{eq} = 14$ H

**Step 5 – sanity check:** Series-aiding must exceed the plain series sum of $10$ H, and $14 > 10$, so the sign is right.

**Final Answer:** $L_{eq} = 14 \text{ H} \Rightarrow \boxed{\text{A}}$

**Answer: (A)** Go Back to Q1

## Q2.

**Solution**

**Concept – coefficient of coupling:** The coupling coefficient links the mutual inductance to the two self-inductances through $k = \dfrac{M}{\sqrt{L_1 L_2}}$, and always satisfies $0 \le k \le 1$.

**Step 1 – list the data:** $L_1 = 8$ mH, $L_2 = 2$ mH, $M = 3$ mH.

**Step 2 – form the product of self-inductances:** $L_1 L_2 = 8 \times 2 = 16 \text{ mH}^2$

**Step 3 – take the square root:** $\sqrt{L_1 L_2} = \sqrt{16} = 4$ mH

**Step 4 – divide the mutual inductance by that root:** $k = \dfrac{3}{4}$

$k = 0.75$

**Step 5 – validity check:** $0.75$ lies between $0$ and $1$, so it is a physically valid coupling.

**Final Answer:** $k = 0.75 \Rightarrow \boxed{\text{B}}$

**Answer: (B)** Go Back to Q2

## Q3.

**Solution**

**Concept – series-opposing coupled inductors:** When the two coil fluxes oppose (series-opposing), the mutual term is subtracted: $L_{eq} = L_1 + L_2 - 2M$.

**Step 1 – list the data:** $L_1 = 5$ H, $L_2 = 7$ H, $M = 1.5$ H.

**Step 2 – add the self-inductances:** $L_1 + L_2 = 5 + 7 = 12$ H

**Step 3 – form the mutual term:** $2M = 2 \times 1.5 = 3$ H

**Step 4 – subtract the mutual term (opposing is $-$):** $L_{eq} = 12 - 3$

$L_{eq} = 9$ H

**Step 5 – sanity check:** Series-opposing must be less than the plain series sum of 12 H, and $9 < 12$, so the sign is right.

**Final Answer:** $L_{eq} = 9 \text{ H} \Rightarrow \boxed{\text{D}}$

Answer: (D) Go Back to Q3

## Q4.

**Solution**

**Concept – resonant frequency of a series $RLC$:** At resonance the inductive and capacitive reactances cancel, giving $\omega_0 = \dfrac{1}{\sqrt{LC}}$.

**Step 1 – convert the data to base units:** $L = 0.5$ H

$C = 200\ \mu\text{F} = 200 \times 10^{-6}$ F

**Step 2 – form the product $LC$:** $LC = 0.5 \times 200 \times 10^{-6}$

$LC = 100 \times 10^{-6} = 1 \times 10^{-4}$

**Step 3 – take the square root:** $\sqrt{LC} = \sqrt{1 \times 10^{-4}} = 1 \times 10^{-2}$

**Step 4 – take the reciprocal:** $\omega_0 = \dfrac{1}{1 \times 10^{-2}}$

$\omega_0 = 100$ rad/s

**Final Answer:** $\omega_0 = 100 \text{ rad/s} \Rightarrow \boxed{\text{A}}$

Answer: (A) Go Back to Q4

## Q5.

### Solution

**Concept – quality factor of a series $RLC$:** The sharpness of resonance is measured by $Q = \frac{1}{R}\sqrt{\frac{L}{C}}$.

**Step 1 – convert the data to base units:** $R = 4\ \Omega$, $L = 40$ mH $= 0.04$ H, $C = 100\ \mu\text{F} = 100 \times 10^{-6}$ F.

**Step 2 – form the ratio $L/C$:** $\frac{L}{C} = \frac{0.04}{100 \times 10^{-6}}$

$\frac{L}{C} = \frac{0.04}{1 \times 10^{-4}} = 400$

**Step 3 – take the square root:** $\sqrt{L/C} = \sqrt{400} = 20$

**Step 4 – divide by the resistance:** $Q = \frac{1}{4} \times 20$

$Q = 5$

**Final Answer:** $Q = 5 \Rightarrow \boxed{\text{C}}$

Answer: (C) Go Back to Q5

## Q6.

### Solution

**Concept – power factor from the current angle:** The power factor is the cosine of the phase angle between voltage and current, pf $= \cos\phi$, and it is lagging when the current lags the voltage.

**Step 1 – identify the phase angle:** $V = 100\angle 0°$ V and $I = 10\angle{-30°}$ A, so the current lags the voltage by $\phi = 30°$.

**Step 2 – take the cosine of the angle:** $\cos 30° = \frac{\sqrt{3}}{2}$

**Step 3 – evaluate:** $\cos 30° = 0.866$

**Step 4 – state the sense:** Because the current lags the voltage, the power factor is $0.866$ *lagging*.

**Why the other options are wrong:**

- B, $0.5$: this is $\cos 60°$, the wrong angle.
- C, $1$: unity would need $\phi = 0°$ (a purely resistive load).
- D, $0.707$: this is $\cos 45°$, not $\cos 30°$.

**Final Answer:** pf $= 0.866$ lagging $\Rightarrow \boxed{\text{A}}$

Answer: (A) Go Back to Q6

## Q7.

**Solution**

**Concept – magnitude of a series $R$–$L$ impedance:** The resistance and reactance add as perpendicular components, so $|Z| = \sqrt{R^2 + X_L^2}$.

**Step 1 – list the data:** $R = 6\ \Omega$, $X_L = 8\ \Omega$.

**Step 2 – square each component:** $R^2 = 6^2 = 36$

$X_L^2 = 8^2 = 64$

**Step 3 – add the squares:** $R^2 + X_L^2 = 36 + 64 = 100$

**Step 4 – take the square root:** $|Z| = \sqrt{100}$

$|Z| = 10\ \Omega$

**Step 5 – recognise the pattern:** This is the 6–8–10 right triangle, confirming the result.

**Final Answer:** $|Z| = 10\ \Omega \Rightarrow \boxed{\text{C}}$

Answer: (C) Go Back to Q7

## Q8.

**Solution**

**Concept – field of a long straight current-carrying wire:** By Ampere's law the magnetic flux density around a long straight conductor is $B = \dfrac{\mu_0 I}{2\pi r}$.

**Step 1 – list the data:** $\mu_0 = 4\pi \times 10^{-7}$ H/m, $I = 5$ A, $r = 0.1$ m.

**Step 2 – form the numerator $\mu_0 I$:** $\mu_0 I = (4\pi \times 10^{-7}) \times 5 = 20\pi \times 10^{-7}$

**Step 3 – form the denominator $2\pi r$:** $2\pi r = 2\pi \times 0.1 = 0.2\pi$

**Step 4 – divide (the $\pi$ cancels):** $B = \dfrac{20\pi \times 10^{-7}}{0.2\pi} = 100 \times 10^{-7}$

**Step 5 – express in convenient units:** $B = 1 \times 10^{-5}$ T $= 10\ \mu$T

**Final Answer:** $B = 10\ \mu\text{T} \Rightarrow \boxed{\text{C}}$

Answer: (C) Go Back to Q8

## Q9.

**Solution**

**Concept – energy stored in an inductor:** The energy held in the magnetic field of an inductor is $W = \frac{1}{2}LI^2$.

**Step 1 – list the data:** $L = 2$ H, $I = 3$ A.

**Step 2 – square the current:** $I^2 = 3^2 = 9$ A$^2$

**Step 3 – multiply by the inductance:** $LI^2 = 2 \times 9 = 18$

**Step 4 – take one-half:** $W = \frac{1}{2} \times 18$

$W = 9$ J

**Final Answer:** $W = 9 \text{ J} \Rightarrow \boxed{\text{D}}$

Answer: (D) Go Back to Q9

## Q10.

**Solution**

**Concept – uniform field between parallel plates:** For closely spaced parallel plates the field is uniform and equals the voltage divided by the gap, $E = \dfrac{V}{d}$.

**Step 1 – convert the data to base units:** $V = 100$ V, $d = 2 \text{ mm} = 2 \times 10^{-3}$ m.

**Step 2 – substitute into the field equation:** $E = \dfrac{100}{2 \times 10^{-3}}$

**Step 3 – divide the numbers:** $E = \dfrac{100}{0.002} = 50000$ V/m

**Step 4 – express in kV/m:** $E = 50$ kV/m

**Final Answer:** $E = 50 \text{ kV/m} \Rightarrow \boxed{\text{C}}$

Answer: (C) Go Back to Q10

## Q11.

**Solution**

**Concept – capacitance of a two-wire line:** The capacitance between the two conductors of a single-phase line is $C_{ab} = \dfrac{\pi\varepsilon_0}{\ln(D/r)}$.

**Step 1 – list the data:** $\varepsilon_0 = 8.854 \times 10^{-12}$ F/m and $\ln(D/r) = 1$.

**Step 2 – substitute the logarithm:** $C_{ab} = \dfrac{\pi\varepsilon_0}{1} = \pi\varepsilon_0$

**Step 3 – multiply out:** $C_{ab} = 3.1416 \times 8.854 \times 10^{-12}$

**Step 4 – evaluate:** $C_{ab} = 27.8 \times 10^{-12}$ F/m

**Step 5 – express in picofarads:** $C_{ab} = 27.8$ pF/m

**Final Answer:** $C_{ab} \approx 27.8$ pF/m $\Rightarrow \boxed{\text{D}}$

Answer: (D) Go Back to Q11

## Q12.

### Solution

**Concept – discrete linear convolution:** The convolution sum is $y[n] = \sum_k x[k]\,h[n-k]$; each output sample gathers the products whose indices add up to $n$.

**Step 1 – list the two sequences:** $x[0] = 1,\ x[1] = 2,\ x[2] = 3$ and $h[0] = 1,\ h[1] = 1$.

**Step 2 – write the terms contributing to $y[2]$ (indices $k$ and $2-k$):** $y[2] = x[0]h[2] + x[1]h[1] + x[2]h[0]$

**Step 3 – note that $h[2]$ does not exist (it is $0$):** $x[0]h[2] = 1 \times 0 = 0$

**Step 4 – evaluate the remaining products:** $x[1]h[1] = 2 \times 1 = 2$

$x[2]h[0] = 3 \times 1 = 3$

**Step 5 – add the contributions:** $y[2] = 0 + 2 + 3 = 5$

**Final Answer:** $y[2] = 5 \Rightarrow \boxed{\text{A}}$

Answer: (A) Go Back to Q12

## Q13.

### Solution

**Concept – d.c. (zero-frequency) DFT coefficient:** The first DFT sample is the plain sum of all the time samples, $X[0] = \sum_{n=0}^{N-1} x[n]$, because the twiddle factor is unity at $k = 0$.

**Step 1 – list the sequence:** $x[0] = 1,\ x[1] = 1,\ x[2] = 1,\ x[3] = 1$.

**Step 2 – write the $X[0]$ sum:** $X[0] = x[0] + x[1] + x[2] + x[3]$

**Step 3 – add the samples:** $X[0] = 1 + 1 + 1 + 1$

$X[0] = 4$

**Step 4 – interpret:** A constant sequence has all its energy at d.c., so only $X[0]$ is non-zero, consistent with the value found.

**Final Answer:** $X[0] = 4 \Rightarrow \boxed{\text{A}}$

Answer: (A) Go Back to Q13

## Q14.

**Solution**

**Concept – Nyquist sampling theorem:** To reconstruct a band-limited signal without aliasing, it must be sampled at a rate of at least twice its highest frequency, $f_s \geq 2f_{max}$.

**Step 1 – identify the highest frequency:** $f_{max} = 4$ kHz.

**Step 2 – apply the Nyquist criterion:** $f_{s,\min} = 2f_{max}$

**Step 3 – substitute the value:** $f_{s,\min} = 2 \times 4$ kHz

$f_{s,\min} = 8$ kHz

**Final Answer:** $f_{s,\min} = 8$ kHz $\Rightarrow \boxed{\text{C}}$

Answer: (C) Go Back to Q14

## Q15.

**Solution**

**Concept – length of a linear convolution:** Convolving sequences of lengths $L_1$ and $L_2$ produces an output of length $L_1 + L_2 - 1$.

**Step 1 – list the lengths:** $L_1 = 6$, $L_2 = 8$.

**Step 2 – add the lengths:** $L_1 + L_2 = 6 + 8 = 14$

**Step 3 – subtract one:** $L = 14 - 1$

$L = 13$

**Step 4 – sanity check:** The output must be longer than either input, and $13 > 8$, which is consistent.

**Final Answer:** $L = 13$ samples $\Rightarrow \boxed{\text{B}}$

Answer: (B) Go Back to Q15

## Q16.

**Solution**

**Concept – complex multiplications in a radix-2 FFT:** A radix-2 FFT reduces the DFT cost from $N^2$ to $\frac{N}{2}\log_2 N$ complex multiplications.

**Step 1 – list the transform size:** $N = 8$.

**Step 2 – form $N/2$:** $\dfrac{N}{2} = \dfrac{8}{2} = 4$

**Step 3 – form $\log_2 N$:** $\log_2 8 = 3$

**Step 4 – multiply the two factors:** $\dfrac{N}{2}\log_2 N = 4 \times 3$

$= 12$

**Step 5 – contrast with the direct DFT:** A direct DFT would need $N^2 = 64$; the FFT's 12 shows the saving.

**Final Answer:** 12 complex multiplications $\Rightarrow \boxed{\text{D}}$

Answer: (D) Go Back to Q16

## Q17.

### Solution

**Concept – e.m.f. equation of a transformer:** The r.m.s. induced e.m.f. in a winding is $E = 4.44\, f\, N\, \phi_m$, where $\phi_m$ is the peak core flux.

**Step 1 – list the data:** $f = 50$ Hz, $N = 100$ turns, $\phi_m = 0.02$ Wb.

**Step 2 – multiply the constant by the frequency:** $4.44 \times 50 = 222$

**Step 3 – multiply by the number of turns:** $222 \times 100 = 22200$

**Step 4 – multiply by the peak flux:** $E = 22200 \times 0.02$

$E = 444$ V

**Final Answer:** $E = 444$ V $\Rightarrow \boxed{\text{D}}$

Answer: (D) Go Back to Q17

## Q18.

### Solution

**Concept – copper loss and the short-circuit test:** The short-circuit test is done at rated current, so its input power equals the full-load copper loss. Because copper loss follows $I^2$, at a load fraction $x$ it becomes $P_{cu} = x^2\, P_{cu,\,fl}$.

**Step 1 – identify the full-load copper loss:** $P_{cu,\,fl} = 250$ W (the SC test reading).

**Step 2 – set the load fraction:** Half load means $x = 0.5$.

**Step 3 – square the load fraction:** $x^2 = (0.5)^2 = 0.25$

**Step 4 – scale the copper loss:** $P_{cu} = 0.25 \times 250$

$P_{cu} = 62.5$ W

**Final Answer:** $P_{cu} = 62.5$ W $\Rightarrow \boxed{\text{B}}$

Answer: (B) Go Back to Q18

## Q19.

### Solution

**Concept – core loss and the open-circuit test:** The open-circuit test applies rated voltage, so its input power is the core (iron) loss. Iron loss depends on voltage and frequency, *not* on load, so it stays constant as the load changes.

**Step 1 – identify the core loss from the OC test:** $P_{core} = 150$ W at rated voltage.

**Step 2 – note the load dependence:** Core loss is independent of the load current.

**Step 3 – evaluate at half load:** Since the supply voltage is unchanged, $P_{core}$ at half load is still 150 W.

**Step 4 – contrast with copper loss:** Only the copper loss would fall with load; the iron loss does not.

**Final Answer:** $P_{core} = 150 \text{ W} \Rightarrow \boxed{\text{B}}$

Answer: (B) Go Back to Q19

## Q20.

### Solution

**Concept – rated current from the kVA rating:** The apparent power fixes the current through $S = V\,I$, so $I = \dfrac{S}{V}$.

**Step 1 – convert the rating to volt-amperes:** $S = 10 \text{ kVA} = 10000 \text{ VA}$.

**Step 2 – list the secondary voltage:** $V_2 = 400$ V.

**Step 3 – divide to get the current:** $I_2 = \dfrac{10000}{400}$

**Step 4 – evaluate:** $I_2 = 25$ A

**Final Answer:** $I_2 = 25 \text{ A} \Rightarrow \boxed{\text{C}}$

Answer: (C) Go Back to Q20

## Q21.

### Solution

**Concept – transformer efficiency:** Efficiency is output power divided by input power, where input is output plus the total loss: $\eta = \dfrac{P_{out}}{P_{out} + P_{core} + P_{cu}}$.

**Step 1 – list the data:** $P_{out} = 8000$ W, $P_{core} = 120$ W, $P_{cu} = 130$ W.

**Step 2 – add the losses:** $P_{loss} = 120 + 130 = 250$ W

**Step 3 – form the input power:** $P_{in} = 8000 + 250 = 8250$ W

**Step 4 – divide output by input:** $\eta = \dfrac{8000}{8250}$

**Step 5 – evaluate and convert to per cent:** $\eta = 0.9697 = 96.97\%$

**Final Answer:** $\eta \approx 96.97\% \Rightarrow \boxed{\text{D}}$

**Answer: (D)** Go Back to Q21

## Q22.

### Solution

**Concept – load for maximum efficiency:** Maximum efficiency occurs when the variable copper loss equals the fixed iron loss. Setting $x^2 P_{cu,\,fl} = P_i$ gives the load fraction $x = \sqrt{\dfrac{P_i}{P_{cu,\,fl}}}$.

**Step 1 – list the data:** $P_i = 200$ W, $P_{cu,\,fl} = 800$ W.

**Step 2 – form the loss ratio:** $\dfrac{P_i}{P_{cu,\,fl}} = \dfrac{200}{800} = 0.25$

**Step 3 – take the square root:** $x = \sqrt{0.25}$

$x = 0.5$

**Step 4 – interpret:** Maximum efficiency occurs at half (50%) of full load.

**Final Answer:** $x = 0.5 \Rightarrow \boxed{\text{B}}$

**Answer: (B)** Go Back to Q22

## Q23.

### Solution

**Concept – slip and rotor speed of an induction motor:** The synchronous speed is $N_s = \dfrac{120f}{P}$ and the rotor runs slower by the slip, $N = N_s(1 - s)$.

**Step 1 – compute the synchronous speed:** $N_s = \dfrac{120 \times 50}{6}$

$N_s = \dfrac{6000}{6} = 1000$ rpm

**Step 2 – form the running factor:** $1 - s = 1 - 0.04 = 0.96$

**Step 3 – multiply to get the rotor speed:** $N = 1000 \times 0.96$

$N = 960$ rpm

**Step 4 – sanity check:** The rotor speed must be just below the synchronous $1000$

rpm, and $960 < 1000$, which is consistent.

**Final Answer:** $N = 960$ rpm $\Rightarrow \boxed{\text{A}}$

**Answer: (A)** Go Back to Q23

## Q24.

### Solution

**Concept – short-circuit (fault) MVA:** For a fault fed through a per-unit reactance, the fault level is $\text{MVA}_{fault} = \dfrac{\text{MVA}_{base}}{X_{pu}}$.

**Step 1 – list the data:** $\text{MVA}_{base} = 100$, $X_{pu} = 0.25$.

**Step 2 – substitute into the fault-level equation:** $\text{MVA}_{fault} = \dfrac{100}{0.25}$

**Step 3 – evaluate the division:** $\text{MVA}_{fault} = 400$

**Step 4 – interpret:** A smaller reactance would give a larger fault level; $0.25$ pu yields $400$ MVA.

**Final Answer:** $\text{MVA}_{fault} = 400$ MVA $\Rightarrow \boxed{\text{B}}$

**Answer: (B)** Go Back to Q24

## Q25.

### Solution

**Concept – fault current from fault MVA:** For a three-phase system the short-circuit current is $I_{sc} = \dfrac{\text{MVA}_{fault} \times 10^6}{\sqrt{3}\,V_L}$.

**Step 1 – list the data:** $\text{MVA}_{fault} = 400$, $V_L = 11$ kV $= 11000$ V.

**Step 2 – form the denominator:** $\sqrt{3} \times 11000 = 1.732 \times 11000 = 19052$

**Step 3 – form the numerator:** $400 \times 10^6 = 4 \times 10^8$

**Step 4 – divide:** $I_{sc} = \dfrac{4 \times 10^8}{19052}$

**Step 5 – evaluate:** $I_{sc} \approx 20990$ A $\approx 21$ kA

**Final Answer:** $I_{sc} \approx 21$ kA $\Rightarrow \boxed{\text{A}}$

**Answer: (A)** Go Back to Q25

## Q26.

**Solution**

**Concept – breaking capacity of a circuit breaker:** The three-phase symmetrical breaking capacity is the apparent power at the interrupted current, $S = \sqrt{3}\,V_L\,I_{sc}$.

**Step 1 – list the data:** $V_L = 11$ kV $= 11000$ V, $I_{sc} = 20$ kA $= 20000$ A.

**Step 2 – multiply voltage and current:** $V_L\,I_{sc} = 11000 \times 20000 = 2.2 \times 10^8$

**Step 3 – multiply by $\sqrt{3}$:** $S = 1.732 \times 2.2 \times 10^8$

**Step 4 – evaluate:** $S = 3.81 \times 10^8$ VA $= 381$ MVA

**Final Answer:** $S \approx 381$ MVA $\Rightarrow \boxed{\text{A}}$

Answer: (A) Go Back to Q26

## Q27.

**Solution**

**Concept – changing the MVA base of a per-unit reactance:** At the same voltage base a per-unit reactance scales directly with the MVA base, $X_{new} = X_{old} \times \dfrac{\text{MVA}_{new}}{\text{MVA}_{old}}$.

**Step 1 – list the data:** $X_{old} = 0.15$ pu, $\text{MVA}_{old} = 50$, $\text{MVA}_{new} = 100$.

**Step 2 – form the MVA ratio:** $\dfrac{\text{MVA}_{new}}{\text{MVA}_{old}} = \dfrac{100}{50} = 2$

**Step 3 – multiply:** $X_{new} = 0.15 \times 2$

$X_{new} = 0.30$ pu

**Step 4 – interpret:** Doubling the MVA base doubles the per-unit reactance, as found.

**Final Answer:** $X_{new} = 0.30$ pu $\Rightarrow \boxed{\text{C}}$

Answer: (C) Go Back to Q27

## Q28.

**Solution**

**Concept – three-phase symmetrical fault current in per-unit:** For a bolted three-phase fault the per-unit current is the pre-fault voltage divided by the reactance, $I_f = \dfrac{E}{X}$.

**Step 1 – list the data:** $E = 1.0$ pu, $X = 0.2$ pu.

**Step 2 – substitute into the fault equation:** $I_f = \dfrac{1.0}{0.2}$

**Step 3 – evaluate:** $I_f = 5$ pu

**Step 4 – interpret:** A $0.2$ pu reactance permits five times rated current to flow during the fault.

**Final Answer:** $I_f = 5$ pu $\Rightarrow \boxed{\text{D}}$

Answer: (D) Go Back to Q28

## Q29.

**Solution**

**Concept – base impedance:** For a chosen voltage and power base the base impedance is $Z_{base} = \dfrac{(kV_{base})^2}{\text{MVA}_{base}}$.

**Step 1 – list the data:** $kV_{base} = 220$ kV, $\text{MVA}_{base} = 100$.

**Step 2 – square the base voltage:** $(220)^2 = 48400$

**Step 3 – divide by the base MVA:** $Z_{base} = \dfrac{48400}{100}$

**Step 4 – evaluate:** $Z_{base} = 484\ \Omega$

**Final Answer:** $Z_{base} = 484\ \Omega \Rightarrow \boxed{\text{A}}$

Answer: (A) Go Back to Q29

## Q30.

**Solution**

**Concept – charging current of a line's capacitance:** The shunt capacitance of a line draws a charging current $I_c = V_{ph}\,\omega C$, where $V_{ph}$ is the phase voltage and $C$ the total per-phase capacitance.

**Step 1 – find the total per-phase capacitance:** $C = 0.02\ \mu\text{F/km} \times 100\ \text{km} = 2\ \mu\text{F} = 2 \times 10^{-6}$ F

**Step 2 – find the angular frequency:** $\omega = 2\pi f = 2\pi \times 50 = 314.16$ rad/s

**Step 3 – find the phase voltage:** $V_{ph} = \dfrac{132000}{\sqrt{3}} = 76210$ V

**Step 4 – form the susceptance $\omega C$:** $\omega C = 314.16 \times 2 \times 10^{-6} = 6.283 \times 10^{-4}$ S

**Step 5 – multiply by the phase voltage:** $I_c = 76210 \times 6.283 \times 10^{-4}$

**Step 6 – evaluate:** $I_c \approx 47.9$ A $\approx 48$ A

**Final Answer:** $I_c \approx 48$ A $\Rightarrow \boxed{\text{C}}$

Answer: (C) Go Back to Q30

## Q31.

### Solution

**Concept – Nyquist stability criterion:** The criterion states $N = P - Z$, where $N$ is the number of clockwise encirclements of $-1$, $P$ the open-loop right-half-plane poles, and $Z$ the closed-loop right-half-plane poles. For stability we need $Z = 0$.

**Step 1 – list what is given:** The open-loop system has $P = 0$ right-half-plane poles.

**Step 2 – impose stability:** Stability requires $Z = 0$.

**Step 3 – substitute into $N = P - Z$:** $N = 0 - 0$

$N = 0$

**Step 4 – interpret with the sketch:** The Nyquist plot must *not* encircle $-1$; the sketch shows the locus staying clear of $-1$, so the system is indeed stable.

**Final Answer:** $N = 0$ encirclements $\Rightarrow \boxed{\text{D}}$

**Answer: (D)** Go Back to Q31

## Q32.

### Solution

**Concept – gain margin:** The gain margin is the reciprocal of the open-loop gain at the phase-crossover frequency, expressed in decibels: $\text{GM} = 20\log_{10}\dfrac{1}{|G|}$.

**Step 1 – list the data:** $|G(j\omega_{pc})| = 0.25$.

**Step 2 – take the reciprocal:** $\dfrac{1}{|G|} = \dfrac{1}{0.25} = 4$

**Step 3 – take the base-10 logarithm:** $\log_{10} 4 = 0.602$

**Step 4 – multiply by 20:** $\text{GM} = 20 \times 0.602$

$\text{GM} = 12.04$ dB $\approx 12$ dB

**Step 5 – interpret:** A positive gain margin of 12 dB indicates a stable system with comfortable headroom.

**Final Answer:** $\text{GM} \approx 12$ dB $\Rightarrow \boxed{\text{D}}$

**Answer: (D)** Go Back to Q32

## Q33.

**Solution**

**Concept – derivative gain of a PID controller:** Writing the PID law as $G_c = K_p\left(1 + \frac{1}{T_i s} + T_d s\right)$, the derivative-path gain is $K_d = K_p T_d$.

**Step 1 – list the tuning constants:** $K_p = 5$, $T_d = 0.1$ s.

**Step 2 – form the product $K_pT_d$:** $K_d = 5 \times 0.1$

**Step 3 – evaluate:** $K_d = 0.5$

**Step 4 – note:** The integral time $T_i = 0.5$ s sets the integral gain and does not enter the derivative gain.

**Final Answer:** $K_d = 0.5 \Rightarrow \boxed{\text{C}}$

Answer: (C) Go Back to Q33

## Q34.

**Solution**

**Concept – steady-state error of a type-0 system to a step:** For a unit-step input the position error constant is $K_p = \lim_{s\to 0} G(s)$ and the steady-state error is $e_{ss} = \dfrac{1}{1+K_p}$.

**Step 1 – evaluate the position error constant:** $K_p = \lim_{s\to 0} \dfrac{10}{s+5} = \dfrac{10}{5} = 2$

**Step 2 – substitute into the error formula:** $e_{ss} = \dfrac{1}{1+2}$

**Step 3 – add in the denominator:** $e_{ss} = \dfrac{1}{3}$

**Step 4 – evaluate:** $e_{ss} = 0.333$

**Step 5 – note the type:** Since $G$ has no pole at the origin it is type-0, so a finite step error is expected.

**Final Answer:** $e_{ss} = 0.333 \Rightarrow \boxed{\text{B}}$

Answer: (B) Go Back to Q34

## Q35.

**Solution**

**Concept – damping ratio from the characteristic equation:** Comparing $s^2 + 2\zeta\omega_n s + \omega_n^2 = 0$ with the given equation, first read off $\omega_n$ from the constant term, then $\zeta$ from the middle term.

**Step 1 – read the constant term:** $\omega_n^2 = 16$

**Step 2 – take the square root:** $\omega_n = \sqrt{16} = 4$ rad/s

**Step 3 – match the middle coefficient:** $2\zeta\omega_n = 4$

**Step 4 – solve for $\zeta$:** $\zeta = \dfrac{4}{2\omega_n} = \dfrac{4}{2 \times 4}$

**Step 5 – evaluate:** $\zeta = \dfrac{4}{8} = 0.5$

**Step 6 – interpret:** $\zeta = 0.5 < 1$, so the system is underdamped.

**Final Answer:** $\zeta = 0.5 \Rightarrow \boxed{\text{B}}$

**Answer: (B)** Go Back to Q35

## Q36.

### Solution

**Concept – gain of a non-inverting amplifier:** For an ideal op-amp in the non-inverting configuration the closed-loop gain is $\dfrac{V_o}{V_i} = 1 + \dfrac{R_f}{R_1}$.

**Step 1 – list the data:** $R_f = 90$ k$\Omega$, $R_1 = 10$ k$\Omega$.

**Step 2 – form the resistor ratio:** $\dfrac{R_f}{R_1} = \dfrac{90}{10} = 9$

**Step 3 – add one:** $\dfrac{V_o}{V_i} = 1 + 9$

**Step 4 – evaluate:** $\dfrac{V_o}{V_i} = 10$

**Why the other options are wrong:**

- B, $9$: this is the inverting gain $R_f/R_1$, which drops the "1+".
- C, $0.1$: this is $R_1/R_f$, the ratio inverted.
- D, $11$: over-counts by adding an extra unit.

**Final Answer:** $\dfrac{V_o}{V_i} = 10 \Rightarrow \boxed{\text{A}}$

**Answer: (A)** Go Back to Q36

## Q37.

**Solution**

**Concept – reading a voltage on an oscilloscope:** The peak-to-peak voltage equals the number of vertical divisions the trace spans multiplied by the vertical sensitivity, $V_{pp} = (\text{div}) \times (\text{V/div})$.

**Step 1 – list the data:** Vertical span $= 4$ divisions, sensitivity $= 2$ V/div.

**Step 2 – multiply:** $V_{pp} = 4 \times 2$

**Step 3 – evaluate:** $V_{pp} = 8$ V

**Step 4 – cross-check the amplitude:** The amplitude is half of this, $4$ V, and the RMS would be $4/\sqrt{2} = 2.83$ V, all consistent.

**Final Answer:** $V_{pp} = 8 \text{ V} \Rightarrow \boxed{\text{D}}$

**Answer: (D)** Go Back to Q37

## Q38.

**Solution**

**Concept – measuring frequency on an oscilloscope:** The period equals the horizontal divisions per cycle times the time base; the frequency is its reciprocal, $f = \dfrac{1}{(\text{div}) \times (\text{time/div})}$.

**Step 1 – find the period:** $T = 4 \text{ div} \times 0.5 \text{ ms/div}$

$T = 2 \text{ ms} = 2 \times 10^{-3}$ s

**Step 2 – take the reciprocal:** $f = \dfrac{1}{2 \times 10^{-3}}$

**Step 3 – evaluate:** $f = 500$ Hz

**Final Answer:** $f = 500 \text{ Hz} \Rightarrow \boxed{\text{A}}$

**Answer: (A)** Go Back to Q38

## Q39.

**Solution**

**Concept – flip-flops for a counter modulus:** An $n$-bit counter has $2^n$ states, so the number of flip-flops needed for a modulus $M$ is the smallest $n$ with $2^n \geq M$.

**Step 1 – state the requirement:** $M = 10$, so we need $2^n \geq 10$.

**Step 2 – test $n = 3$:** $2^3 = 8 < 10$ (not enough).

**Step 3 – test $n = 4$:** $2^4 = 16 \geq 10$ (sufficient).

**Step 4 – conclude:** The smallest adequate count is $n = 4$ flip-flops.

**Final Answer:** $n = 4 \Rightarrow \boxed{\text{B}}$

**Answer: (B)** Go Back to Q39

## Q40.

**Solution**

**Concept – frequency division by a ripple counter:** Each flip-flop of a binary ripple counter divides the frequency by 2, so an $n$-bit counter divides the clock by $2^n$ at its most-significant output.

**Step 1 – list the data:** $n = 3$ bits, clock $= 8$ kHz.

**Step 2 – form the division factor:** $2^n = 2^3 = 8$

**Step 3 – divide the clock frequency:** $f_{out} = \dfrac{8 \text{ kHz}}{8}$

**Step 4 – evaluate:** $f_{out} = 1$ kHz

**Final Answer:** $f_{out} = 1$ kHz $\Rightarrow \boxed{\text{A}}$

**Answer: (A)** Go Back to Q40

## Q41.

**Solution**

**Concept – hexadecimal to decimal conversion:** Each hex digit carries a weight that is a power of 16; the value is $d_1 \times 16^1 + d_0 \times 16^0$, with $\text{A}_{16} = 10$.

**Step 1 – identify the digits:** $(2\text{A})_{16}$ has $d_1 = 2$ and $d_0 = \text{A} = 10$.

**Step 2 – weight the most-significant digit:** $2 \times 16 = 32$

**Step 3 – weight the least-significant digit:** $10 \times 1 = 10$

**Step 4 – add the two contributions:** $32 + 10 = 42$

**Final Answer:** $(2\text{A})_{16} = 42 \Rightarrow \boxed{\text{D}}$

**Answer: (D)** Go Back to Q41

## Q42.

**Solution**

**Concept – output of a buck converter:** In continuous conduction the average output of a step-down converter is the input scaled by the duty ratio, $V_o = D\,V_s$.

**Step 1 – list the data:** $V_s = 48$ V, $D = 0.25$.

**Step 2 – multiply:** $V_o = 0.25 \times 48$

**Step 3 – evaluate:** $V_o = 12$ V

**Step 4 – sanity check:** A buck output must be below the input, and $12 < 48$, which is consistent.

**Final Answer:** $V_o = 12 \text{ V} \Rightarrow \boxed{\text{B}}$

**Answer: (B)** Go Back to Q42

## Q43.

**Solution**

**Concept – output of a boost converter:** A step-up converter in continuous conduction produces $V_o = \dfrac{V_s}{1-D}$.

**Step 1 – list the data:** $V_s = 20$ V, $D = 0.5$.

**Step 2 – form the factor $1-D$:** $1 - D = 1 - 0.5 = 0.5$

**Step 3 – divide:** $V_o = \dfrac{20}{0.5}$

**Step 4 – evaluate:** $V_o = 40$ V

**Step 5 – sanity check:** A boost output must exceed the input, and $40 > 20$, which is consistent.

**Final Answer:** $V_o = 40 \text{ V} \Rightarrow \boxed{\text{C}}$

**Answer: (C)** Go Back to Q43

## Q44.

**Solution**

**Concept – output of a buck-boost converter:** The magnitude of the average output of a buck-boost converter is $|V_o| = V_s\,\dfrac{D}{1-D}$.

**Step 1 – list the data:** $V_s = 24$ V, $D = 0.6$.

**Step 2 – form the factor $1-D$:** $1 - D = 1 - 0.6 = 0.4$

**Step 3 – form the ratio $D/(1-D)$:** $\dfrac{0.6}{0.4} = 1.5$

**Step 4 – multiply by the input:** $|V_o| = 24 \times 1.5$

**Step 5 – evaluate:** $|V_o| = 36$ V

**Final Answer:** $|V_o| = 36 \text{ V} \Rightarrow \boxed{\text{C}}$

Answer: (C) Go Back to Q44

## Q45.

### Solution

**Concept – duty ratio of a buck converter:** Since $V_o = D\,V_s$, the duty ratio needed for a target output is $D = \dfrac{V_o}{V_s}$.

**Step 1 – list the data:** $V_o = 5$ V, $V_s = 20$ V.

**Step 2 – form the ratio:** $D = \dfrac{5}{20}$

**Step 3 – evaluate:** $D = 0.25$

**Step 4 – validity check:** $0 < 0.25 < 1$, so it is a realisable duty ratio.

**Final Answer:** $D = 0.25 \Rightarrow \boxed{\text{B}}$

Answer: (B) Go Back to Q45

## Q46.

### Solution

**Concept – duty ratio of a boost converter:** From $V_o = \dfrac{V_s}{1-D}$, the required duty ratio is found by rearranging to $1 - D = \dfrac{V_s}{V_o}$.

**Step 1 – list the data:** $V_s = 12$ V, $V_o = 48$ V.

**Step 2 – form the voltage ratio:** $\dfrac{V_s}{V_o} = \dfrac{12}{48} = 0.25$

**Step 3 – set $1 - D$ equal to that ratio:** $1 - D = 0.25$

**Step 4 – solve for $D$:** $D = 1 - 0.25$

**Step 5 – evaluate:** $D = 0.75$

**Step 6 – sanity check:** A large step-up ratio needs a high duty ratio, and $0.75$ is consistent with a fourfold boost.

**Final Answer:** $D = 0.75 \Rightarrow \boxed{\text{B}}$

Answer: (B) Go Back to Q46

## Answer Key

| Q | Ans | Q | Ans | Q | Ans | Q | Ans | Q | Ans |
|---|---|---|---|---|---|---|---|---|---|
| 1 | A | 2 | B | 3 | D | 4 | A | 5 | C |
| 6 | A | 7 | C | 8 | C | 9 | D | 10 | C |
| 11 | D | 12 | A | 13 | A | 14 | C | 15 | B |
| 16 | D | 17 | D | 18 | B | 19 | B | 20 | C |
| 21 | D | 22 | B | 23 | A | 24 | B | 25 | A |
| 26 | A | 27 | C | 28 | D | 29 | A | 30 | C |
| 31 | D | 32 | D | 33 | C | 34 | B | 35 | B |
| 36 | A | 37 | D | 38 | A | 39 | B | 40 | A |
| 41 | D | 42 | B | 43 | C | 44 | C | 45 | B |
| 46 | B | | | | | | | | |