KHULNA UNIVERSITY OF ENGINEERING & TECHNOLOGY

Department of Mechatronics Engineering

B.Sc. Engineering 2nd Year 2nd Term Examination, 2022

EEE 2231

(Signals and Linear Systems)

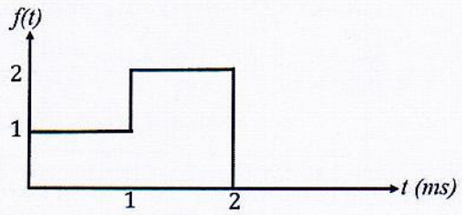
Time: 3.00 Hrs. Total Marks: 210

N.B.: i) Answer any THREE questions from each section in separate scripts.
ii) Figures in the right margin indicate full marks.
iii) Assume necessary data.

SECTION-A

1(a) Define a signal with examples. 06

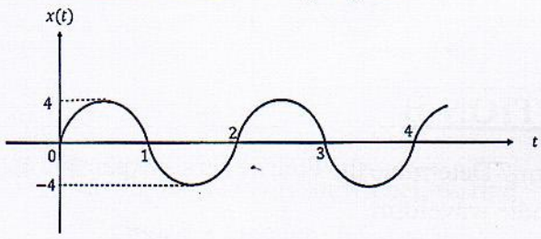
1(b) Find the even and odd components of following wave. 07



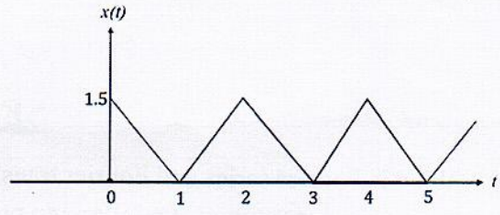
1(c) Evaluate energy and power of the following signal. 08

$$x(t) = 6\sin(2\pi t)\,;\ -\infty < t < \infty$$

1(d) Differentiate the following signals. 08



(i)



(ii)

1(e) Sketch the impulse waveform for the following signal. 06

$$x(n) = 1.5\delta(n+2) - 1.6\delta(n+1) + 1.2\delta(n) - 0.5\delta(n-1) + 0.5\delta(n-2) + 1.6\delta(n-5)$$

2(a) A moving average system is given by 13

$$y(n) = 1/3[x(n) + x(n-1) + x(n-2)]$$

Determine whether the system is (i) causal (ii) has memory (iii) stable or not and (iv) linear.

2(b) Determine zero-input response of the following system: 12

$$\frac{d^2y(t)}{dt^2} + 4\frac{dy(t)}{dt} + 40y(t) = \frac{dx(t)}{dt} + 2$$

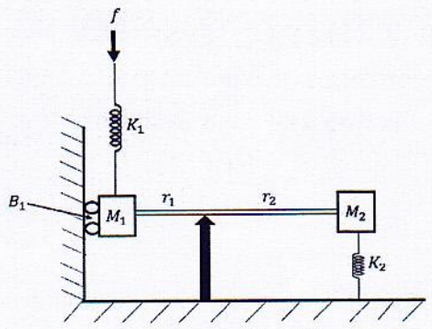
Where, y(t) and x(t) are output and input, respectively. The expression may contain arbitrary constant.

2(c) Determine the periodicity of the following CT signal. 10

$$x(t) = 5cos4\pi t + 3sin8\pi t$$

3(a) Why the study of analogous system is necessary in mechatronics engineering? Mention the translational and rotational mechanical elements with their forces and torques expressions. 10

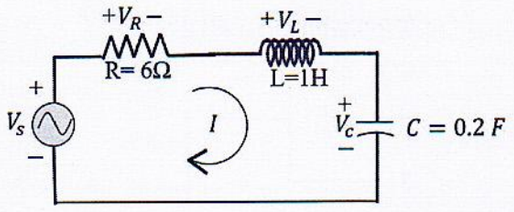
3(b) For the following mechanical system, (i) Draw the mechanical network, (ii) Draw the analogous electrical network and (iii) Write down the equation of performance in terms of electrical and mechanical quantities. 15



3(c) Define the state of a dynamic system with example. Also define state variables, state vector and state-space. 10

4(a) State and explain D'Alembert's principle. State the rules for drawing f-v analogous electrical circuits from mechanical system. 10

4(b) Obtain the state equation for the following circuit. The output is taken across the capacitor. 15



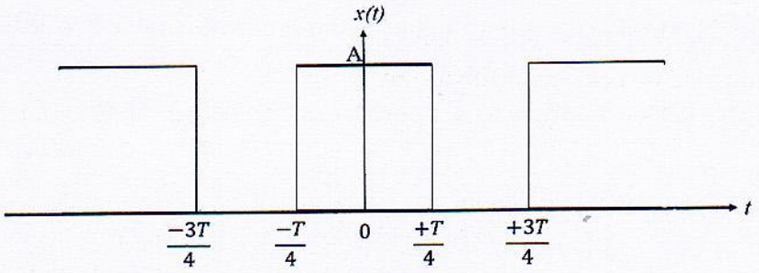
4(c) A system is described by the state equation $\dot{x} = Ax + Bu$ and output equation $y = Cx$. Here, 10

$A = \begin{bmatrix} -4 & -1 \\ 3 & -1 \end{bmatrix}$, $B = \begin{bmatrix} 1 \\ 1 \end{bmatrix}$ and $C = [1 \quad 0]$

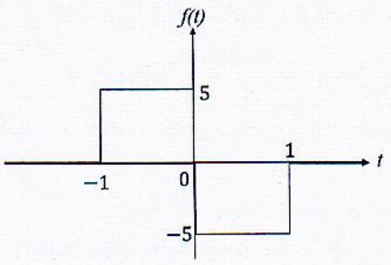
Determine the transfer function of the system.

SECTION-B

5(a) What is Fourier series and Fourier transform? Determine the Fourier series expansion and frequency spectrum of the following periodic waveform. 15



5(b) Obtain the Fourier transform of the function shown below. 10



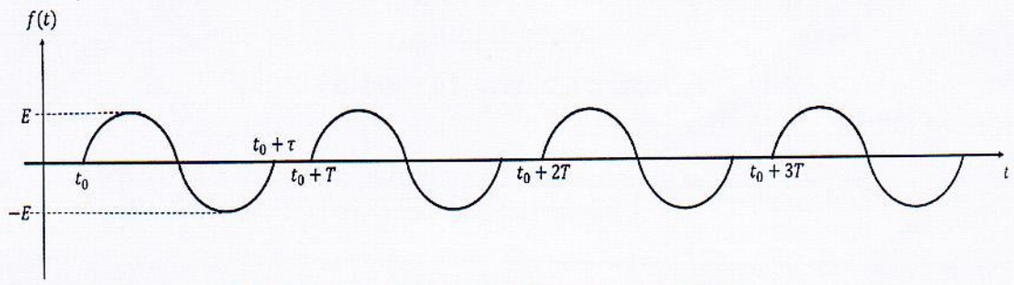
5(c) Derive the exponential form of Fourier series. 10

6(a) Find the Laplace transform of the following signals: 10

(i) $t^3 - 2t + 1$

(ii) $\frac{\sin\omega t}{t}$

6(b) Find the Laplace transform of the periodic train of one-cycle sinusoidal pulses shown below. 15



6(c) Find the inverse Laplace transform of the following expression: 10

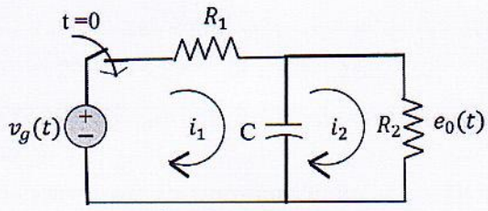
$$F(s) = \frac{se^{-2s}}{s^2 + 2s + 5}$$

7(a) State and prove convolution theorem. Find the inverse Laplace transform of following expression by using convolution theorem. 12

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

7(b) State and prove superposition integral theorem. 08

7(c) The switch in the circuit shown below is closed at $t = 0$. Find the current i_2 in R_2 for $V_g(t) = V_g e^{-\alpha t}$ by using the superposition integral. 15



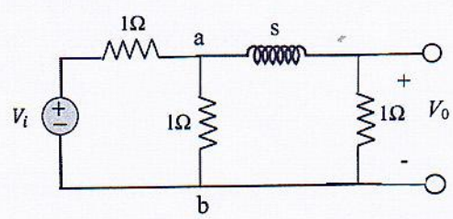
8(a) For the s-domain circuit shown below, find 25

(i) The transfer function, $H(s) = \frac{V_0}{V_i}$

(ii) The impulse response

(iii) The response when $v_i(t) = u(t)$ volt

(iv) The response when $v_i(t) = 8cos2t$ volt



8(b) A Laplace transform of a function is given below: 10

$$F(s) = A\frac{(s+\alpha)sin\theta + \beta cos\theta}{(s+\alpha)^2 + \beta^2}$$

Find the values of $f(t)$ and its slope at $t = 0+$.

— × —

KHULNA UNIVERSITY OF ENGINEERING & TECHNOLOGY

Department of Mechatronics Engineering

B.Sc. Engineering 2nd Year 2nd Term Examination, 2022

Math 2231

(Complex Variables and Harmonic Analysis)

Time: 3.00 Hrs. Total Marks: 210

N.B.: i) Answer any THREE questions from each section in separate scripts.
ii) Figures in the right margin indicate full marks.

SECTION-A

1(a) Explain what is principal argument? Find all the roots of $z^4 - 2 + i2\sqrt{3} = 0$ and locate them in the argand plane. 08

1(b) Compute the limit: $\lim_{z\to i} \frac{iz^3-1}{z-i}$ and determine the function $f(z) = \frac{iz^3-1}{z-i}$ at $z = i$ such that $f(z)$ is continuous at $z = i$. 08

1(c) Is the function $\psi(x,y) = \ln(x^2+y^2) + x + y, z \neq 0$ harmonic? If so, find the corresponding conjugate harmonic function $\phi(x,y)$ and construct the analytic function $W(z) = \phi + i\psi$. 15

1(d) Explain non-isolated singular point with an example. 04

2(a) Evaluate $\int_c \bar{z}dz$ from $z = 0$ to $z = 4 + 2i$ along the curve c given by (i) $z = t^2 + it$ (ii) the line from $z = 0$ to $z = 2i$ and then the line from $z = 2i$ to $z = 4 + 2i$. 10

2(b) Find all possible series expansion of the function $f(z) = \frac{z+7}{(z-3)(z+2)}$ about $z = -2$ by specifying the regions of convergence where such expressions are valid. 11

2(c) Evaluate $\int_{-\infty}^{\infty} \frac{cos\pi x}{(1+x^2)^2} dx$ using the method of contour integration. 14

3(a) Evaluate $\oint_c \frac{e^{\pi z}}{z^2-2z+5} dz$; where c is the circle and (i) $|z| = 1$, (ii) $|z + 1 - i| = 3$, (iii) $|z + 1 + i| = 3$ using suitable theorem(s) and state those theorems you have used. (all circles are in the positive sense) 15

3(b) Evaluate $\int_0^{2\pi} \frac{d\theta}{1+3sin^2\theta}$ by the method of contour integration. 15

3(c) Locate and name all the singularities of $f(z) = \frac{z^8+z^4+2}{(z^2+1)(3z+2)^2}$ 05

4(a) Show that under the transformation $w = z^2$, the domain in the z-plane between the lines $x = 0$ and $x = a$ corresponds to the interior of the parabola $v^2 = -4a^2(u - a^2)$ enclosed by v-axis in the w-plane. 12

4(b) What is bilinear transformation and why does it called so? What are the interior points of this transformation? 08

4(c) Show that the relation $w = \frac{5-4z}{4z-2}$ transforms the circle $|z| = 2$ into a circle with center $(-\frac{9}{10}, 0)$ and radius $\frac{2}{5}$ in the w-plane. 15

SECTION-B

5(a) Write down the Bessel's ordinary differential equation and its solution. Find $J_0(x)$ and $J_1(x)$ from its solution. 05

5(b) Verify that the Bessel's function $J_{\frac{1}{2}}(x) = \sqrt{\frac{2}{\pi x}}\sin x$ satisfies the Bessel's differential equation of order ½. Also, prove that $J_{-\frac{1}{2}}(x) = \sqrt{\frac{2}{\pi x}}\cos x$ 15

5(c) Prove the following recurrence formulas: 15
(i) $xJ_n' = nJ_n - xJ_{n+1}$ (ii) $xJ_n' = -nJ_n + xJ_{n-1}$

6(a) Write down the Legendre ordinary differential equation. Prove that the Legendre function $P_n(x)$ can be written as $P_n(x) = \frac{1}{2^n n!}\frac{d^n}{dx^n}(x^2-1)^n$. Also, find the values of P_0, P_1, P_2 and P_3. 18

6(b) Solve the equation $\frac{\partial^2 u}{\partial t^2} = c^2\left(\frac{\partial^2 u}{\partial r^2} + \frac{1}{r}\frac{\partial u}{\partial r}\right)$ where the initial and boundary conditions are $U(R,t) = 0$ for all $t \geq 0$, $u(r,0) = f(r)$ and $u_t(r,0) = g(r)$. 17

7(a) Prove that $\int_{-1}^{1} P_m(x)P_n(x)dx = 0$ for $m \neq n$. 10

7(b) Solve the Laplace equation in spherical coordinate. 25

$$\nabla^2 u = \frac{\partial^2 u}{\partial r^2} + \frac{2}{r}\frac{\partial u}{\partial r} + \frac{1}{r^2}\left(\frac{\partial^2 u}{\partial \theta^2} + \cot\theta\frac{\partial u}{\partial \theta} + \operatorname{cosec}^2\theta\frac{\partial^2 u}{\partial \phi^2}\right) = 0$$

8(a) Define zonal harmonic, tesseral harmonic and sectorial harmonic functions. 05

8(b) From $Y_{n,m}(\theta,\phi) = \sqrt{\frac{(2n+1)(n-m)!}{4\pi(n+m)!}}P_n^m(\cos\theta)e^{im\phi}$, derive the spherical harmonics for $n = 0,1,2,3$ and $m = -n, \ldots, n$ 15

8(c) Determine the steady-state temperature in a semi-circular metal plate of radius 'a' whose circumference is maintained at temperature $T = 100°C$ while the base is kept at zero temperature if the faces are insulated. 15

— × —

KHULNA UNIVERSITY OF ENGINEERING & TECHNOLOGY

Department of Mechatronics Engineering

B. Sc. Engineering 2nd Year 2nd Term Examination, 2022

ME 2231

(Thermodynamics and Heat Transfer)

Time: 3 Hours | Total Marks: 210

N.B.: i) Answer any THREE questions from each section in separate scripts.
ii) Figures in the right margin indicate full marks.
iii) Assume reasonable data if any missing.

SECTION-A

1(a)	What are meant by thermodynamic equilibrium and quasi-static process?	06
1(b)	Write short notes on: Enthalpy and Entropy.	06
1(c)	Derive the steady flow energy equation mentioning the assumptions upon which it is based. Reduce the expression applicable to a turbine.	12
1(d)	The internal energy of a gas is given by the equation: $u = 3.65PV + 8u$, where u is given in kJ/kg, P is in kPa, and V is in m^3/kg. A system composed of 8kg of this substance expands from an initial pressure of 7 bar and a volume of 0.25 m^3 to a final pressure of 1.0 bar in a process in which pressure and volume are related by $PV^{1.55}$ = constant. Find Q, ΔU and W for the process, if the expression is quasi-static.	11
2(a)	Discuss the differences among heat engine, refrigerator and heat pump.	09
2(b)	Prove that Kelvin-Planck's statement and Clausius statement for 2nd law of thermodynamics are equivalent.	08
2(c)	Why PMM2 is impossible?	05
2(d)	In an air standard diesel cycle, the compression ratio is 16 and at the beginning of isentropic compression the temperature is 15°C and the pressure is 0.1 MPa. Heat is added until the temperature at the end of the constant pressure process is 1480°C. Calculate i) the cut-off ratio, ii) heat supplied per kg of air, iii) the cycle efficiency and iv) the mean effective pressure.	13
3(a)	What is the difference between boiler mountings and accessories? Describe the function of safety valve, blow-off cock, economizer and air preheater.	12
3(b)	Differentiate between fire tube and water tube boiler.	05
3(c)	Why superheated steam is used in vapour power cycle? What are the characteristics of a vapour power cycle?	08
3(d)	Discuss the salient features of binary cycle and combined gas-vapor power cycle.	10
4(a)	What are the main components of an IC engine?	06
4(b)	Write short notes on the followings: i) Detonation ii) Scavenging iii) Supercharging and iv) Octane number.	12
4(c)	Discuss the methods of improving thermal efficiency of gas turbines.	08
4(d)	In a gas turbine plant working on Brayton cycle, air enters to the compression at 0.1 MPa and 30°C. The pressure ratio is 6 and the maximum cycle temperature is 900°C. If the turbine and compressor have each an efficiency of 80%, find the cycle efficiency.	09

SECTION-B

5(a)	Discuss the mechanism of conduction heat transfer.	05
5(b)	Derive the general heat conduction equation in the rectangular coordinate. Also simplify it for one-dimensional and no heat generation condition.	13
5(c)	Derive an expression of temperature distribution for an infinitely long fin.	12
5(d)	What is critical thickness of insulation?	05
6(a)	Discuss the physical significance of the following dimensionless parameters: i) Nusselt number, ii) Rayleigh number, iii) Prandtl number and iv) Grashof number.	08
6(b)	Define the following terms: (i) Gray body (ii) Emissivity (iii) Absorptivity	09
6(c)	Derive the Wien's displacement law from the Planck's law.	06
6(d)	Air at 27°C and 1 atm flows over a flat plate with a free stream velocity of 4 m/s. Assume the plate is heated over its entire length to a temperature of 65°C. Calculate the heat transferred in the first 25 cm of the plate.	12
7(a)	Compare between parallel flow and counter flow heat exchanger with respective temperature profiles.	06
7(b)	What is LMTD? Derive an expression of LMTD for parallel flow heat exchangers.	14
7(c)	Differentiate between refrigerator and heat pump.	06
7(d)	Discuss the working principle of a Vapor-absorption refrigeration system.	09
8(a)	Discuss about the selection criteria of a good refrigerant.	07
8(b)	Discuss coefficient of performance of a refrigerator. Show that, $(C.O.P)_{Heat\ Pump} = 1 + (C.O.P)_{Refrigerator}$.	10
8(c)	Write down the difference between vapour compression and absorption refrigeration system.	08
8(d)	Draw the layout of a vapour absorption refrigeration system. State the function of each component.	10

— × —

KHULNA UNIVERSITY OF ENGINEERING & TECHNOLOGY

Department of Mechatronics Engineering

B.Sc. Engineering 2nd Year 2nd Term Examination, 2022

MTE 2201

(Control Systems)

Time: 3.00 Hrs. Total Marks: 210

N.B.: i) Answer any THREE questions from each section in separate scripts.
ii) Figures in the right margin indicate full marks.

SECTION-A

1(a) What is the closed loop transfer function of a system with negative feedback? Explain what the effect of negative feedback on stability is. 10

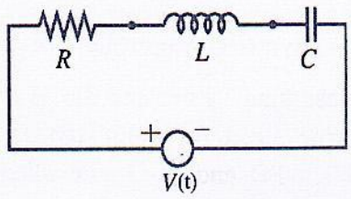
1(b) Find ξ, ω_n, T_s, T_p and $\%OS$ for the following second-order system. 12

$$\frac{d^2y}{dt^2} + 2\frac{dy}{dt} + 2y = 2X$$

1(c) Describe the three major design criteria for an elevator control system. 10

1(d) Functionally, how do closed-loop systems differ from open-loop systems? 03

2(a) Find the state-space representation of the following RLC network. The output is the voltage across the inductor. 13



2(b) Convert the following state-space representation to transfer function. 12

$$\dot{X} = \begin{bmatrix} 0 & 1 & 0 \\ 0 & 0 & 1 \\ -2 & -3 & -4 \end{bmatrix} X + \begin{bmatrix} 2 \\ 0 \\ 1 \end{bmatrix} u$$

$$y = [1 \quad 0 \quad 0]X$$

2(c) For the following system representation in state-space, find out how many poles are in the left-half plane, in the right half plane and on the $j\omega$ axis. 10

$$\dot{X} = \begin{bmatrix} 0 & 3 & 1 \\ 2 & 8 & 1 \\ -10 & -5 & -2 \end{bmatrix} X + \begin{bmatrix} 10 \\ 0 \\ 0 \end{bmatrix} u$$

$$y = [1 \quad 0 \quad 0]X$$

3(a) For the unity feedback system, the open-loop transfer function is given by: 15

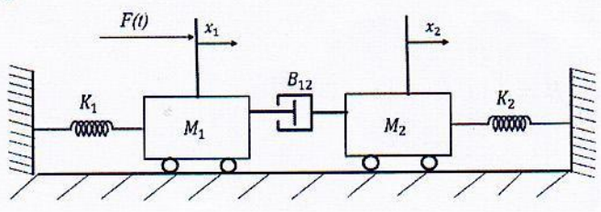
$$G(s) = \frac{K}{s(s+4)(s+5)}$$

(i) Sketch the root locus for $0 \leq K \leq \propto$

(ii) At what values of 'K', the system becomes unstable?

(iii) At this point of instability, determine the frequency of oscillation of the system.

3(b) Derive the system equations and find the value of $X_2(s)/F(s)$ for the system shown below. 15

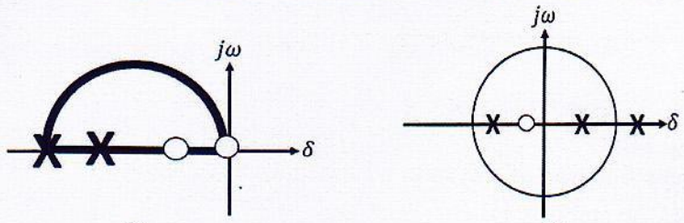


3(c) Define phase margin and gain margin.

4(a) What will be the responses if 12

i. A pole is moved with a constant imaginary part
ii. A pole is moved with a constant real part
iii. A pole is moved along a radial line extending from the origin

4(b) For each of the root loci shown in following figure, tell whether or not the sketch can be a root locus. If the sketch can't be a root locus, explain why. Give all reasons. 10



(i) (ii)

4(c) Physically what happens to a system that is unstable? 05

4(d) What are the effect of adding a pole and a zero in the forward path for a second order system? 08

SECTION-B

5(a) Define controller. Why do we need it in a control system? 05

5(b) Design a Proportional-Derivative (PD) controller for the system $G_p(s) = \frac{1}{s(s^2+2s+1)}$ so that the settling time, t_s is less than 10 sec and the % overshoot is less than 10%. Also show that the steady state error is zero for a unit step input. 18

5(c) Draw block diagram of PID, I-PD and PI-D controlled system. Why do we use I-PD controller over a PID controller? 12

6(a) Suppose, a plant is given to you to design a PID controller. The mathematical model of the plant is unknown. Briefly describe how will you tune the PID controller. Draw figure if necessary. 15

6(b) What is the problem associated with integral action? How can we solve it? Briefly describe one with proper figure. 15

6(c) Why two position controller is better with differential gap? 05

7(a) Diagonalize the following state-space representation: 15

$$\dot{X} = \begin{bmatrix} -3 & 1 \\ 1 & -3 \end{bmatrix} X + \begin{bmatrix} 1 \\ 2 \end{bmatrix} u$$
$$y = [2 \quad 3]X$$

7(b) "The state-space representation of a system is not unique", justify this statement with the following system where mass of the block (m) is 3 kg, stiffness of the spring (k) is 3 N/m, and the damping coefficient (b) due to friction is 1 Ns/m. 14

7(c) Define controllability and observability. 06

8(a) Determine whether the system is controllable and observable? Why do we need observer in control system? 13

$$A = \begin{bmatrix} -1 & 1 & 2 \\ 0 & -1 & 5 \\ 0 & 3 & -4 \end{bmatrix}, B = \begin{bmatrix} 2 \\ 1 \\ 1 \end{bmatrix}, C = [1 \quad 0 \quad 0]$$

8(b) Consider the following transfer function: 14

$$G(s) = \frac{10}{(s+1)(s+2)(s+3)}$$

What should you do before designing a controller in state-space? Find state feedback gain matrix, K for the desired poles at $s = -10, -2 \pm 2\sqrt{3}i$.

8(c) Write short notes on (i) LQR and (ii) LQG 08

—— × ——

KHULNA UNIVERSITY OF ENGINEERING & TECHNOLOGY

Department of Mechatronics Engineering

B.Sc. Engineering 2nd Year 2nd Term Examination, 2022

MTE 2207

(Electro-Mechanical Systems)

Time: 3.00 Hrs. Total Marks: 210

N.B.: i) Answer any THREE questions from each section in separate scripts.
ii) Figures in the right margin indicate full marks.

SECTION-A

1(a) Explain Faraday's law of electromagnetic induction and Lenz's law. 10

1(b) Deduce the condition of a DC generator at which it's efficiency reaches peak. 10

1(c) The armature of a 4-pole DC shunt generator is lap-wound and generates 216 V when running at 600 rpm. Its armature has 144 slots, with 6 conductors per slot. If this armature is rewound and wave connected, find the emf generated with the same flux per pole but running at 500 rpm. 15

2(a) Write short notes on (i) commutator (ii) pole pitch and (iii) coil pitch. 06

2(b) Define armature reaction of a DC generator. Also describe its effects. Draw the OCC curve, internal and external characteristics curves of a DC generator. 12

2(c) Describe the significance of back emf in a DC motor. Also, develop the condition for generating maximum power. 10

2(d) In a long shunt compound generator, the terminal voltage is 230 V when generator delivers 150 A. Determine (i) induced emf (ii) total power generated and (iii) distribution of this power. Given that, shunt field, series field, diverter and armature resistance are 92 Ω, 0.015 Ω, 0.03 Ω and 0.032 Ω, respectively. 07

3(a) Explain the factors on which the speed of a DC motor depends. Describe the ward-leonard system used to control the motor speed. 12

3(b) Why does a DC motor need a starter? How does a four-point starter overcome the limitations of a three-point starter? Explain in detail. 13

3(c) Describe the working principle of a transformer. Also, explain why transformers are rated in volt-amperes (i.e. VA, kVA, MVA). 10

4(a) Write short notes on auto transformer and power transformer. 05

4(b) Draw the equivalent circuit of a transformer. Also, sketch the phasor diagram of a transformer operating at lagging power factor. 08

4(c) What are the different ways to measure core loss and Cu loss of a transformer? Describe them in detail. 12

4(d) A 50 kVA, 4400/220 V transformer has R_1= 3.45 Ω and R_2= 0.009 Ω. The values of reactances are X_1= 5.20 Ω and X_2= 0.015 Ω. Calculate for the transformer 10
(i) equivalent resistance as referred to primary
(ii) equivalent resistance as referred to secondary
(iii) equivalent reactance as referred to both primary and secondary
(iv) equivalent impedance as referred to both primary and secondary
(v) total Cu loss using individual resistances of the two windings.

SECTION-B

5(a) What is an induction motor? Explain how a revolving field is produced in an induction motor if a three phase balanced supply is connected to its three-phase windings. 10

5(b) Prove that, starting torque of an induction motor $T_{st} = \frac{3}{2\pi N_s} \frac{E_2^2 R_2}{R_2^2 + X_2^2}$; where the symbols have their usual meanings. Hence, show that starting torque is maximum when rotor resistance equals rotor reactance. 12

5(c) The star-connected rotor of an induction motor has a standstill impedance of (0.4+j4) Ω per phase and the rheostat impedance per phase is (6+j2) Ω. The motor has an induced emf of 80 V between slip rings at standstill when connected to its normal supply voltage. Find (i) rotor current at standstill with the rheostat is in the circuit and (ii) when the slip-rings are short-circuited and motor is running at 3% slip. 13

6(a) Draw the torque vs. speed curve of a 3-phase induction motor and hence, explain the effect of change in (i) slip, (ii) External resistance and (iii) supply voltage on motor torque and speed. 10

6(b) Why single-phase induction motor is not self-starting? Write down the techniques to make single-phase induction motor as self-starting. 10

6(c) The power input to a 500 V, 50 Hz, 6 pole, 3-phase induction motor running at 975 rpm is 40 KW. The stator losses are 1 KW and the friction and windage losses are total 2 KW. Calculate (i) slip (ii) rotor Cu loss (iii) shaft power and (iv) efficiency. 10

6(d) Write down the key differences between split-phase induction motor and permanent split capacitor motor. 05

7(a) What will happen if a DC series motor is connected to AC supply? What are the modifications required for such DC motor to operate satisfactorily on AC supply? 08

7(b) A universal series motor has resistance of 30 Ω and inductance of 0.5 H. When connected to a 250 V DC supply and loaded to take 0.8 A, it runs at 2000 rpm. Estimate its speed and power factor, when connected to a 250 V, 50 Hz AC supply and loaded to take the same current. 11

7(c) Explain how DC servo mechanism acts to control the position of a motor shaft precisely. Also, draw the torque vs. speed graph of DC servo motor. 08

7(d) Describe the operation of variable reluctance stepper motor. Draw the static and dynamic characteristics graph of such stepper motor. 08

8(a) Why synchronous motor is not self-starting? Describe the functions of damper windings used in synchronous motor. 10

8(b) Mention the effect of increase in load angle on V-curve of synchronous motor under normal excitation. 10

8(c) What is a synchronous condenser? Why is unity power factor point seen for synchronous motor? 05

8(d) The input to an 11 KV, 3-phase, star connected synchronous motor is 60 A. The effective resistance and synchronous reactance per phase are 1 Ω and 30 Ω, respectively. Find (i) power supplied to the motor (ii) mechanical power developed and (iii) induced emf for a PF of 0.8 leading. 10

— × —