KHULNA UNIVERSITY OF ENGINEERING & TECHNOLOGY

Department of Mechatronics Engineering

B.Sc. Engineering 2nd Year 2nd Term Examination, 2021

EEE 2231

(Signals and Linear Systems)

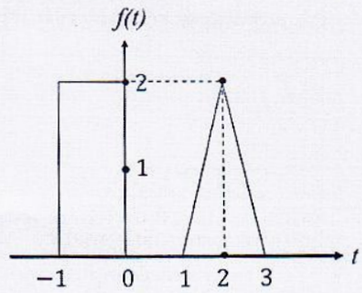
Time: 3.00 Hrs. Total Marks: 210

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

SECTION-A

1(a) Define a signal with examples. Is temperature a signal? Mention the reasons. Explain briefly different types of elementary signal. 15

1(b) Sketch and level the odd and even components of following signal. 10



1(c) Consider the following signals: 10

(i) $x(n) = 5\sin(2n)$

(ii) $x(n) = 5\cos(0.2\pi n)$

Determine whether they are periodic or not. If periodic, determine the fundamental period.

2(a) The moving average system is given by 12

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

Show that, it is (i) causal (ii) has memory (iii) BIBO stable and (iv) is linear.

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

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

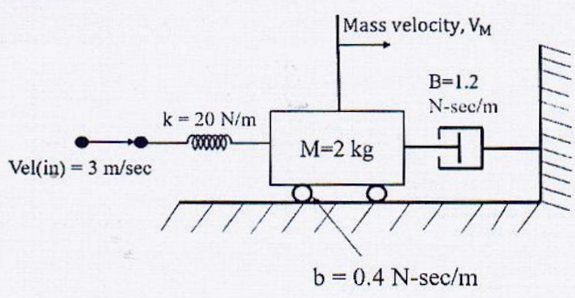
Where, y(t) and x(t) are output and input, respectively. The expression may contain arbitrary constant.

2(c) For the system of equation $y(n) = nx(n)$, determine whether it is time invariant or time varying. 06

2(d) Show that, the square law system described by the input-output relation $y(t) = x^2(t)$ is non-invertible. 05

3(a) Why the study of analogous system is necessary in mechatronic engineering? Mention the translational and rotational mechanical elements with their force and torque expression. 10

3(b) For the mechanical system shown below, determine the transfer function using mechanical and electrical quantities. 15



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

4(a) For the following mechanical coupling devices, draw the analogous electrical circuit with f-v and f-i analogy. 15

(i) A pair of non-slipping friction wheels
(ii) Friction wheel coupling
(iii) A simple lever

Also write down the necessary relationship expressions.

4(b) A system is described by the state equation and output equation. Here, 10

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

Determine the transfer function of the system.

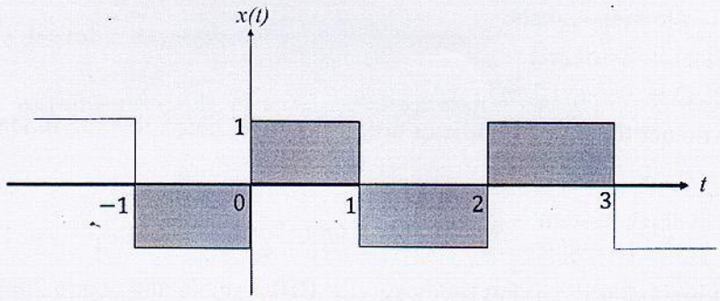
4(c) Find the general solution of the following system (determine $i(t)$). 10

$$L\frac{di(t)}{dt} + Ri(t) = u(t)$$

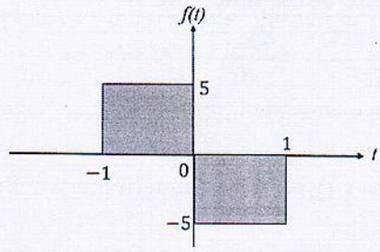
Where, u(t) and i(t) are the input and output respectively.

SECTION-B

5(a) Define Fourier series and Fourier transform mathematically. Determine the Fourier series expansion and frequency spectrum of the following periodic waveform. 15



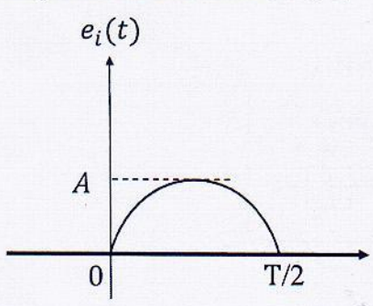
5(b) Determine the Fourier transform and frequency spectrum of the signal shown below. 10

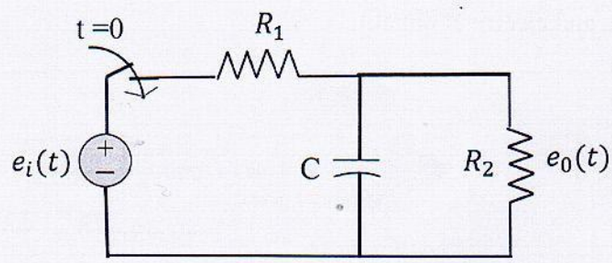


5(c) Show that the linear system creates no new frequency component. 05

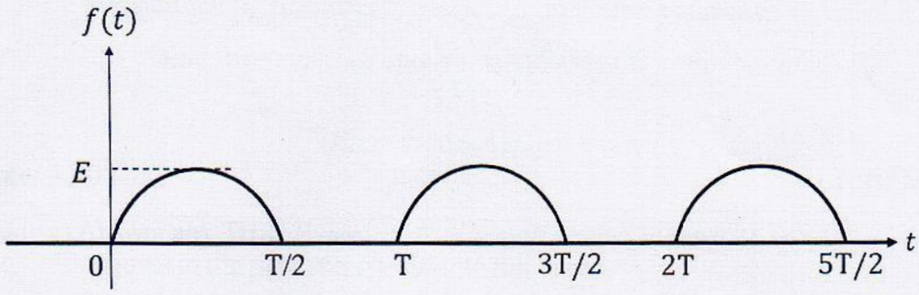
5(d) Write down the Dirichlet conditions. 05

6(a) Determine the response of the circuit below to an applied single half-sine voltage of amplitude A and duration T/2. 20





6(b) Find the Laplace transform of the periodic, rectified half-sine wave shown below. 15



7(a) Write down the differential and integral theorems of Laplace transform. 10

7(b) Find the Laplace transform of the following signals: 12

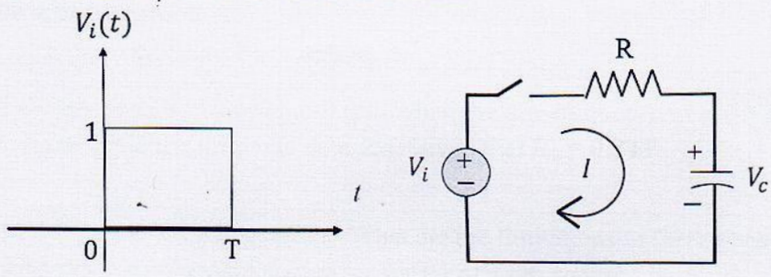
(i) t^n

(ii) $Ae^{-\alpha t}\sin(\beta t + \theta)$

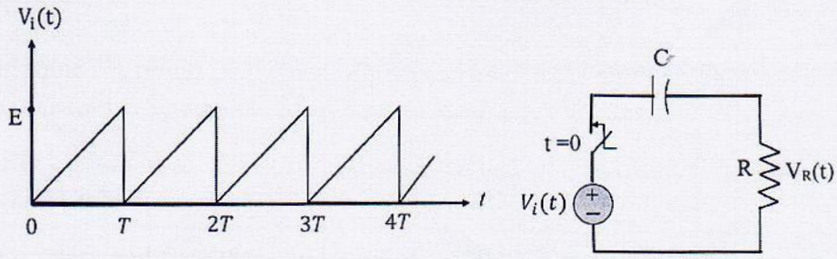
7(c) Find the inverse Laplace transform of the following expression: 13

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

8(a) A rectangular voltage pulse of unit height and duration T is applied to a series R-C combination at t=0. Determine the voltage across the capacitor C as a function of time. The R-C circuit and voltage pulse are shown below. 12



8(b) Find the voltage $V_R(t)$ across the resistor, R in the following circuit when the input voltage, $V_i(t)$ is a periodic sawtooth wave as shown below, and the initial voltage across the capacitor, $V_c(0)=0$. 16



8(c) Find the initial value and final values of the function whose Laplace transform is: 07

$$H(s) = \frac{20}{(s+3)(s^2 + 8s + 25))}$$

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KHULNA UNIVERSITY OF ENGINEERING & TECHNOLOGY

Department of Mechatronics Engineering

B.Sc. Engineering 2nd Year 2nd Term Examination, 2021

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) Find each of the indicated roots and locate them graphically for $(2-2\sqrt{3})^{1/4}$ 08

1(b) Represent graphically the set of values of z for which $\left|\frac{z-5}{z+9}\right| = 7$. 06

1(c) State Taylor's theorem. Expand $f(z) = z^3-7z^3+9z-10$ in a Taylor series about $z = -1$. 12

1(d) Define the following singularities with example: (i) pole, (ii) Essential singularity and (iii) Isolated singularity. 09

2(a) State Cauchy-Riemann equation. Let $u = e^{-x}(xsiny - ycosy)$, show that u satisfies the Cauchy-Riemann equation. Also find v such that $f(z) = u+iv$ is analytic. 15

2(b) Using Cauchy's integral formula, evaluate $\oint_c \frac{zdz}{(9-z)^2(z+1)}$, where c is the circle $|z| = 4$. 12

2(c) Prove that an analytic function with constant modulus is constant. 08

3(a) Evaluate $\int_{(0,3)}^{(2,4)}(2y + x^2)dx + (3x - y)dy$ along the parabola $x = 2t, y = t^2 + 3$. 10

3(b) Show that (i) $\oint_c dz = 0$ and (ii) $\oint_c zdz = 0$. 10

3(c) Evaluate $\oint_c \frac{dz}{z-a}$; where c is any simple closed curve and $z = a$ is (i) outside c and (ii) inside c. 15

4(a) State Laurent's theorem. Expand $f(z) = \frac{1}{(z+1)(z+3)}$ in a Laurent series valid for (i) $1 < |z| < 3$, (ii) $|z| > 3$ and (iii) $0 < |z + 1| < 2$. 15

4(b) By the help of contour integration, find the value of $\int_0^\infty \frac{sinx}{x}dx$ and $\int_0^\infty cosx^2 dx$. 20

SECTION-B

5(a) Write down the Legendre differential equation. From the Rodrigues's formula $P_n(x) = \frac{1}{2^n n!}\frac{d^n}{dx^n}(x^2-1)^n$, find the value of $P_0(x)$, $P_1(x)$, $P_2(x)$ and $P_3(x)$ and roughly sketch their graphs. 15

5(b) Express $f(x) = 4x^3 + 6x^2 + 7x + 2$ in terms of Legendre polynomials. 10

5(c) Let $P_n(x)$ and $P_m(x)$ are two solutions of Legendre equation. Check whether they are orthogonal or not. 10

6(a) Prove that, $J_{\frac{1}{2}}(x) = \sqrt{\frac{2}{\pi x}}sinx$ 09

6(b) Prove that $\int_0^1 xJ_n(\alpha x)J_n(\beta x)\,dx = 0$, where α and β are the roots of $J_n(x) = 0$. 12

6(c) Prove that $J_n(x) = \frac{1}{\pi}\int_0^{\pi} \cos(n\theta - x\sin\theta)\, d\theta$ 14

7(a) What is Laplace equation? Is the function $u(x,y) = 2x - x^3 + 3xy^2$ harmonic? Justify your answer. 10

7(b) Find the temperature of a thin metal bar of length L at different points from the heat equation $\frac{\partial u}{\partial t} = c^2 \frac{\partial^2 u}{\partial t^2}$ with the conditions $u(0,t) = u(L,t) = 0$ and $u(x,0) = f(x)$. 25

8(a) Explain spherical harmonic by solving the Laplace equation in spherical form 25

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

8(b) What is surface zonal harmonic? Draw the graph of surface zonal harmonic functions. 10

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KHULNA UNIVERSITY OF ENGINEERING & TECHNOLOGY
Department of Mechatronics Engineering
B. Sc. Engineering 2nd Year 2nd Term Examination, 2021

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.
iv) Table 12.1 is available upon reasonable request.

SECTION-A

1(a)	Define system and surroundings. Clarify different types of systems with examples.	10
1(b)	Differentiate intensive and extensive properties with examples.	05
1(c)	"Thermodynamic properties are point functions but heat and work are path functions"- how?	10
1(d)	A gas undergoes a thermodynamic cycle consisting of three processes beginning at an initial state where p_1=1.2 bar, v_1=1.6 m^3, and U_1=520 KJ. The processes are as follows: i) Process 1-2: compression with PV=constant to p_2=2 bar and U_2=690 KJ, ii) Process 2-3: W_{23}=0 KJ and Q_{23}=-150 KJ, and iii) Process 3-1: W_{31}=50 KJ. Neglecting KE and PE changes, determine the heat interactions Q_{12} and Q_{31}.	10
2(a)	What is the first law of thermodynamics? Explain it with mathematical expression.	09
2(b)	A person from Rupsha, Khulna claimed that he invented an engine which can produce work without any energy consumption. Is it possible? Justify your viewpoint with respect to thermodynamics.	10
2(c)	The combustion engine vehicles are being replaced by the electric vehicles". How and why?	10
2(d)	Define entropy and enthalpy of a system.	06
3(a)	"The Clausius and the Kelvin-Planck statements are two equivalent expressions of the second law of thermodynamics". Justify this statement.	10
3(b)	Write the essentials of a good boiler.	07
3(c)	Compare between the fire tube boiler and water tube boiler.	08
3(d)	What are meant by boiler mountings and accessories? Briefly describe one mounting and one accessories of a boiler.	10
4(a)	Why the Carnot cycle is not used in practice?	06
4(b)	Draw the P-V and T-S diagrams of the Otto cycle, Diesel cycle, and Brayton cycle and compare their thermodynamic processes.	17
4(c)	In an Otto cycle, air at 1 bar and 290K is compressed isentropically until the pressure reaches 15 bar. The heat is added at constant volume until the pressure rises to 40 bar. Calculate the air standard cycle efficiency. Take c_v = 0.717 KJ/kgK and R_{univ} = 8.314 KJ/kgK.	12

SECTION-B

5(a)	What are the modes of heat transfer?	06
5(b)	How does the term "Thermal conductivity" vary from "Thermal diffusivity"?	06
5(c)	What is the significance of "critical thickness of insulation"? Why it is required?	08
5(d)	Determine the temperature distribution for an infinitely long fin.	15
6(a)	What is the physical mechanism of convection?	05
6(b)	What is thermal boundary layer? How does it develop?	08
6(c)	How the intensity of radiation is related to the emissive power? Develop the relationship between these two.	10
6(d)	The filament of a light bulb is assumed to emit radiation as a blackbody at T=2400K. If the bulb glass has a transmissivity of $\tau = 0.90$ for the radiation emitted by the filament in the visible range, calculate the percentage of the total energy emitted by the filament that reaches the ambient as visible light.	12
7(a)	Discuss different types of heat exchanger.	06
7(b)	What is refrigeration and tonne of refrigeration?	05
7(c)	What are the desirable properties of a good refrigerant?	09
7(d)	Discuss the working principle of a Vapor-compression refrigeration system with neat sketch.	15
8(a)	What are the factors that affect comfort air conditioning?	06
8(b)	Define Relative humidity, dew point temperature, and dry bulb temperature.	06
8(c)	Explain the working principles of the summer and winter air conditioning system with neat sketches.	18
8(d)	Differentiate between central and unitary air-conditioning system.	05

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KHULNA UNIVERSITY OF ENGINEERING & TECHNOLOGY

Department of Mechatronics Engineering

B.Sc. Engineering 2nd Year 2nd Term Examination, 2021

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) For each of the following systems, argue in your opinion if it is open-loop or closed-loop. In the arguments, include definitions of the systems inputs and outputs. Describe how feedback is affected in the systems which is to be decided as closed-loop. 10

(i) Air conditioner
(ii) Washing machine
(iii) Audio speaker

1(b) Describe the three major design criteria for control systems. 10

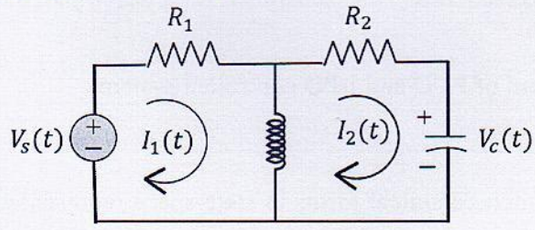
1(c) Describe a typical control system design task. 10

1(d) Name three approaches to the mathematical modeling of control system. 05

2(a) Given the following differential equation, solve for $y(t)$ if all initial conditions are zero. Use the Laplace transform. 10

$$\frac{d^2y}{dt^2} + 12\frac{dy}{dt} + 32y = 32u(t)$$

2(b) Derive the transfer function of the electrical network shown below with the source voltage $V_s(t)$ as input and the capacitor current $I_2(t)$. 12



2(c) A unity feedback system is characterized by an open loop transfer function 13

$$G(s) = \frac{K}{s(s+20)}$$

Determine the gain K so that the system will have a damping ratio of 0.6. For this value of K, calculate settling time and percentage of overshoot for a unit step input.

3(a) Define phase margin and gain margin. Write down the advantages and disadvantages of frequency domain analysis. 10

3(b) Sketch the Bode plot for the following transfer function: 15

$$G(s) = \frac{1000}{s(1+0.1s)(1+0.001s)}$$

Determine:

(i) Gain crossover frequency
(ii) Phase crossover frequency
(iii) Gain margin and phase margin
(iv) Stability of the system

3(c) Using the Routh table, mention how many roots are in LHP and RHP. 10

$$P(s) = 3s^7 + 9s^6 + 6s^5 + 4s^4 + 7s^3 + 8s^2 + 2s + 6$$

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

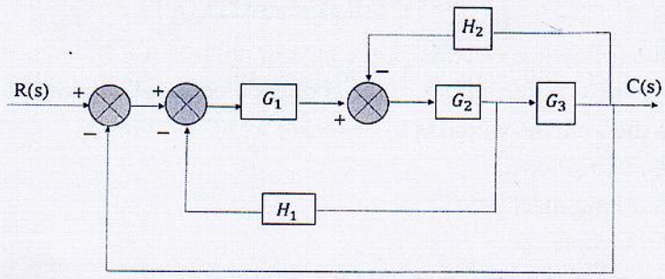
$$G = \frac{K}{s(s+2)(s^2+6s+25)}$$

(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.

4(b) Determine the ratio $\frac{C(s)}{R(s)}$ for the system shown below. 12



4(c) Draw a typical transient response output for an underdamped second order system and show the locations of all the transient response specifications. 08

SECTION-B

5(a) Classify modes of controller with example. What are the effects of proportional, integral and derivative action on rise time, % overshoot, settling time, and steady state error? 10

5(b) Design a PI controller for the system such that the % overshoot is less than 10% and the settling time is less than 5sec. Also show that, for a step input, the steady state error is zero. 15

5(c) Show block diagram of PI-D and I-PD controlled system. 10

6(a) What are the common canonical forms in state-space representation? Give examples of each one. 09

6(b) Find out the state transition matrix of the following system. 15

$$\dot{X} = \begin{bmatrix} -1 & -0.5 \\ 1 & 0 \end{bmatrix} X$$

6(c) For the system represented in state-space as follows: 11

$$\dot{X} = \begin{bmatrix} 1 & 3 \\ -4 & -6 \end{bmatrix} X + \begin{bmatrix} 1 \\ 3 \end{bmatrix} u$$

$$y = [1 \quad 4]X$$

Convert the system to one where the new state vector Z is: $Z = \begin{bmatrix} 3 & -2 \\ 1 & -4 \end{bmatrix} X$

7(a) A regulator system has a plant $\frac{Y(s)}{U(s)} = \frac{10}{(s+1)(s+2)(s+3)}$ 15

By the use of state-feedback control $u = -\boldsymbol{K}\underline{X}$, it is desired to place the closed-loop poles at $s = -2 \pm 2\sqrt{3}i, s = -1$. Determine the state-feedback gain matrix $\boldsymbol{K}$.

7(b) Why optimal control is used? 05

7(c) Consider the system $\begin{bmatrix}\dot{X}_1\\ \dot{X}_2\end{bmatrix} = \begin{bmatrix}0 & 1\\ 0 & 0\end{bmatrix}\begin{bmatrix}X_1\\ X_2\end{bmatrix} + \begin{bmatrix}0\\ 1\end{bmatrix}u$ 15

It is desired to find the optimal control signal u such that the performance index J is minimized. Determine the optimal signal $u(t)$.

Here, $J = \int_0^\infty (X^T QX + u^2)dt$, $Q = \begin{bmatrix}1 & 0\\ 0 & u\end{bmatrix}$

8(a) Define observer in control system. Why we use it? Classify observer with definition of each. 10

8(b) Consider the plant $\dot{\underline{X}} = \mathbf{A}\underline{X} + \mathbf{B}u$; $y = \boldsymbol{C}\underline{X}$ where, 17

$$\boldsymbol{A} = \begin{bmatrix}0 & 1\\ 20 & 60\end{bmatrix}; \boldsymbol{B} = \begin{bmatrix}0\\ 1\end{bmatrix}; \boldsymbol{C} = [1 \quad 0]$$

Design a regulator system for this plant by using the pole-placement with observer approach. Assume the desired closed-loop poles for pole placement are located at

$$s = -1 \pm i$$

The observer poles are based on rule of thumbs. Find the system after applying this observer based control.

8(c) Linearize the following differential equation at $\theta = 0°$ 08

$$J\frac{d^2\theta}{dt^2} + \frac{MgL}{2}sin\theta = T$$

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KHULNA UNIVERSITY OF ENGINEERING & TECHNOLOGY

Department of Mechatronics Engineering

B.Sc. Engineering 2nd Year 2nd Term Examination, 2021

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)	What factors determine the voltage induced in a conductor? Why is it necessary to have many turns of wire in a coil?	10
1(b)	Deduce the emf equation for series DC generator. Explain why the armature winding is made distributed on the whole armature surface and not kept concentrated in only two sides?	15
1(c)	A shunt generator delivers 450 A at 230 V and the resistance of the shunt field and armature are 50 Ω and 0.03 Ω respectively. Calculate the generated emf.	10
2(a)	"The efficiency of DC generator is maximum when armature copper losses equals constant losses", justify the statement.	08
2(b)	Explain armature reaction in a DC generator. What are its effects? Describe two methods to neutralize armature reaction.	12
2(c)	What is back emf? Describe its significance in a DC motor.	05
2(d)	A 220 V DC shunt motor runs at 500 rpm when the armature current is 50 A. Calculate the speed of the motor if the torque is doubled. Given that $R_a = 0.2\ \Omega$.	10
3(a)	Why does a DC motor needs a starter? What are the limitations of three point starter of a DC motor? Also draw and explain four point starter of a DC motor.	15
3(b)	Explain the torque-speed characteristics of a DC shunt and series motor.	10
3(c)	Explain the factors on which the speed of a DC motor depends.	05
3(d)	Explain why transformers are rated in KVA.	05
4(a)	State some key points on the working procedure of a transformer. Sketch the phasor diagram of a transformer operating at lagging and leading power factor.	13
4(b)	Briefly explain open-circuit and short-circuit test of a transformer in order to measure core loss and Cu loss.	12
4(c)	The primary and secondary windings of a 500 kVA transformer have resistances of 0.4 Ω and 0.001 Ω respectively. The primary and secondary voltages are 6000 V and 400 V respectively. The iron loss is 3 KW. Calculate the efficiency on full load at 0.8 power factor lagging.	10

SECTION-B

5(a) What are the reasons a single-phase motor is not self-starting? Explain using double field revolving theory. 10

5(b) Describe the construction of operation of overhead ceiling fan motor. 10

5(c) Draw the equivalent circuit of synchronous motor and hence derive, Gross mechanical power $P_m = (3E_b * V/X_s)sin\alpha$, where the symbols have their usual meanings. 10

5(d) What is the frequency of the voltage generated by an alternator having 10 poles and rotating at 3000 r/min? At what speed the alternator rotate in order to generate a voltage at 60Hz? 05

6(a) Derive the relationship between torque and power factor for a 3-phase induction motor when (i) Rotor assumed non-inductive and (ii) Rotor assumed inductive. 10

6(b) 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. 12

6(c) Why the starting torque of a squirrel-cage motor is poor? A 3-phase, slip-ring induction motor with star-connected rotor has an induced emf of 120 volts between slip rings at standstill with normal voltage applied to the stator. The rotor winding has a resistance per phase of 0.3Ω and standstill leakage reactance per phase of 1.5Ω. Calculate: 13

(i) Rotor current/phase when running short-circuited with 4% slip and

(ii) The slip and rotor current/phase when rotor is developing maximum torque.

7(a) Draw the power stages in an induction motor and hence prove that rotor Cu loss= slip × rotor input. 10

7(b) Draw the equivalent circuit of an induction motor. What are the significances of no-load test and blocked-rotor test for an induction motor? 08

7(c) How is a synchronous motor different from an induction motor? Explain the effect of increased load on the synchronous motor under normal excitation where applied voltage and back emf are both equal to each other. 11

7(d) Write down some key points on how DC servo mechanism acts to control the position of a motor shaft precisely. 06

8(a) A 3-phase, permanent magnet stepper motor required for one particular application must be capable of controlling the position of a shaft in steps of 3° and it must be capable of running at speeds up to 300 r/min. 10

(i) How many poles must this motor have?

(ii) At what rate must control pulses be received in the motor's control unit if it is to be driven at 300 r/min?

8(b) Explain the operation of a two-pole, 3-phase permanent magnet stepper motor with neat sketch of relevant waveforms. 10

8(c) Define hysteresis loss. Show that, a hysteresis motor produces constant torque irrespective of speed of rotation. 10

8(d) Mention some crucial points on the construction of brushless DC motor. 05

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