## Muzaffarpur Institute of Technology, Muzaffarpur



COURSE FILE OF

Electromagnetic Field Theory
(031606)

Faculty Name:
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## VISION STATEMENT OF ELECTRICAL ENGINEERING DEPARTMENT

To produce cutting edge Electrical Engineers, innovators, researchers, and entrepreneurs with high human values to serve society, industry, nation and the world.

## MISSION STATEMENT OF ELECTRICAL ENGINEERING DEPARTMENT

M1. To create state-of-the-art facilities for under-graduate, post- graduate and R\&D work.
M2. To cater the needs of society with recent technologies, innovative ideas and inculcate ethical responsibilities.

M3. To develop strong collaborative links with premier industries, institutions and the government agencies.

## Program Educational Objectives (PEOs) of Electrical Engineering Department:

PEO 1. Students will be able to engage in life-long learning and research including supportive and responsible roles on multi-disciplinary tasks.
PEO 2. Students will acquire, use and develop skills as required for effective professional and societal practices and leadership quality.
PEO 3. Students will be able to create a new dimension of innovation and entrepreneurship.

Program Outcomes (POs) based on Program Educational Objectives (PEOs) of Electrical Engineering Department:

PO 1. Students will be able to apply knowledge of applied mathematics \& science in electrical engineering problems.
PO 2. Students will be able to identify, formulate and solve society and industries related problems.
PO 3. Students will be able to apply knowledge to design a system, component or process to meet desired needs within realistic constraints.

PO 4. Students will be able to conduct laboratory experiments and to critically analyze and interpret experimental data.
PO 5. Students will be able to use the recent techniques, skills, and modern tools necessary for engineering practices.
PO 6. Students will be able to understand the impact of engineering problems, solutions in a global and societal context.
PO 7. Students will be able to demonstrate professional and ethical responsibilities.

PO 8. Students will be able to apply leadership quality to work with team in the area of electrical engineering towards the solution of multi-disciplinary tasks.

PO 9. Students will be able to communicate effectively through verbally, technical writing, reports and presentation.
PO 10. Students will be able to develop confidence for self-education and ability to engage in life-long learning.

## Course Description

This course is designed to review the fundamentals and application of electromagnetic field theory. This course also enables the students to understand all Maxwell's equation in time varying field. In this course the students will also learn about Transmission line, smith Chart and reflection and refraction on plane as well oblique plane. The students will also be able to understand to solve real life problem related to electromagnetics.

## Course Objectives

To introduce the concepts of different coordinate systems, Maxwell's equations, static electric and magnetic fields and methods of solving for the quantities associated with these fields, time varying fields and displacement current, propagation of electromagnetic waves and their applications in practical problems.

## Course Outcomes

After completing the course, the students should be able:

1. To differentiate different types of coordinate systems and use them for solving the problems of electromagnetic field theory.
2. To describe static electric and magnetic fields, their behavior in different media, associated laws, boundary conditions and electromagnetic potentials.
3. To use integral and point form of Maxwell's equations for solving the problems of electromagnetic field theory.
4. To describe time varying fields, propagation of electromagnetic waves in different media, pyonting theorem, their sources \& effects and to apply the theory of electromagnetic waves in practical problems.
5. To apply concepts of Wave reflection and refraction, Smith Chart in practical Field.

CO-PO MAPPING

| Sr. No. | Course Outcome | PO |
| :---: | :--- | :--- |
| 1. | To differentiate different types of coordinate systems and <br> use them for solving the problems of electromagnetic field <br> theory. | PO1, PO2, PO3 |
| 2. | To describe static electric and magnetic fields, their <br> behavior in different media, associated laws, boundary <br> conditions and electromagnetic potentials. | PO1, PO2, PO6 |
| 3. | To use integral and point form of Maxwells equations for <br> solving the problems of electromagnetic field theory. | PO2, PO3, PO10 |
| 4. | To describe time varying fields, propagation of <br> electromagnetic waves in different media, pyonting <br> theorem, their sources \& effects and to apply the theory of <br> electromagnetic waves in practical problems. | PO2, PO4, PO10 |
| 5. | To apply concepts of Wave reflection and refraction, Smith <br> Chart in practical Field. | PO5, PO7, PO8, PO9, PO10 |


| Course Outcomes | P01 | P02 | P03 | P04 | P05 | P06 | P07 | P08 | P09 | P010 |
| :---: | :---: | :---: | :---: | :---: | :---: | :---: | :---: | :---: | :---: | :---: |
| CO1. To differentiate different types of coordinate systems and use them for solving the problems of electromagnetic field theory. | V | $\checkmark$ | $\checkmark$ |  |  |  |  |  |  |  |
| CO 2 . To describe static electric and magnetic fields, their behavior in different media, associated laws, boundary conditions electromagnetic potentials. | $\checkmark$ |  |  |  |  | v |  |  |  |  |
| CO3. To use integral and point form of Maxwell`s equations for solving the problems of electromagnetic field theory. & & \(\checkmark\) & V & & & & & & & V \\ \hline CO4. To describe time varying fields, propagation of electromagnetic waves in different media, pyonting theorem, their sources \& effects and to apply the theory of electromagnetic waves in practical problems. & & v & & V & & & & & & v \\ \hline CO5. To apply concepts of Wave reflection and refraction, Smith Chart in practical Field. & & & & & v & & V & v & v & v \\ \hline \end{tabular} \begin{tabular}{\|c|c|} \hline Course Title & Electromagnetic Field Theory \\ \hline Course number & 031506 \\ \hline Credit Value & 4 \\ \hline Course Category & Core \\ \hline Contact Hours (L-T-P) & 3-1-0 \\ \hline Type of Course & Theory \\ \hline Course Objectives & To introduce the concepts of different coordinate systems, Maxwell's equations, static electric and magnetic fields and methods of solving for the quantities associated with these fields, time varying fields and displacement current, propagation of electromagnetic waves and their applications in practical problems. \\ \hline \begin{tabular}{l} Course \\ Outcomes \end{tabular} & \begin{tabular}{l} After completing the course, the students should be able: \\ 1. To differentiate different types of coordinate systems and use them for solving the problems of electromagnetic field theory. \\ 2. To describe static electric and magnetic fields, their behavior in different media, associated laws, boundary conditions and electromagnetic potentials. \\ 3. To use integral and point form of Maxwell`s equations for solving the problems of electromagnetic field theory. |  |  |  |  |  |  |  |  |  |  |
| 4. To describe time varying fields, propagation of electromagnetic waves in different media, pyonting theorem, their sources \& effects and to apply the theory of electromagnetic waves in practical problems. |  |  |  |  |  |  |  |  |  |  |
| 5. To apply concepts of Wave reflection and refraction, Smith Chart in practical Field. |  |  |  |  |  |  |  |  |  |  | <br>


\hline Syllabus \& | 1. Introduction of field co-ordinate systems |
| :--- |
| 2. Electrostatics :Coulomb's law, Gauss's law and its applications, the potential functíons, Equipotential surface, Poisson's and Laplace's equation, Applications (solution for some simple cases), Capacitance, Electrostatics energy, Conductor properties and boundary conditions between dielectric and dielectric-conductor, Uniqueness Theorems. |
| 3. Magneto statics :Biot-savart law, Ampere's circuital law, Curl, Stroke's theorem, Magnetic flux and magnetic flux density, Energy stored In magnetic field, Ampere force law, Magnetic vector potential, Analogy between electric and magnetic field. |
| 4. Maxwell's equations: Equation of Continuity for time varying field . Inconsistency of ampere circuital law, Maxwell's equations in differential and integral form. | <br>


\hline \& | 5. Electromagnetic wave: Solution of wave equation in free space, Uniform plane wave propagation, Uniform plane waves, the wave equation for conducting medium, Wave propagation in lossless medium and in conductive medium, Conductors and dielectrics, Polarization. |
| :--- |
| 6. Reflections and refractions: reflection by a perfect conductor with normal as well as oblique incidence. Reflection and refraction by perfect dielectrics with normal and oblique incidence. Surface impedance. |
| 7. Pointing vector :Pointing theorem, instantaneous average and | <br>

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\end{tabular}

|  |  | complex pointing vector, power loss in a plane conductor. <br> 8. Transmission Lines : Transmission lion theory, low loss radiofrequency and UHF transmission line. UHF line as a transformer, voltage step up of the quarter wave transformer.Transmission line chart (Smith Chart) |  |  |
| :---: | :---: | :---: | :---: | :---: |
| Books*/References |  | 1. M. N. O. Sadiku, Elements of Electromagnetics; Oxford University Press 2. W. H. Hayt \& J.A Buck, Engineering Electromagnetics $7^{\text {th }}$ Edition, McGraw Hill. |  |  |
| Course <br> Assessment/ <br> Evaluation/G <br> rading Policy | MidSemesterExamination | Assignments, Quiz |  | 05 Marks |
|  |  | Class Attendance |  | 05 Marks |
|  |  | Mid Term Examination (2 |  | 20 Marks / |
|  |  |  | Total | 30 Marks |
|  | End Semester Examination (3 Hours) |  |  | 70 Marks |
|  |  |  |  | 100 Marks |

## GATE SYLLABUS 2019

## Electromagnetic Fields

Coulomb's Law, Electric Field Intensity, Electric Flux Density, Gauss's Law, Divergence, Electric field and potential due to point, line, plane and spherical charge distributions, Effect of dielectric medium, Capacitance of simple configurations, Biot-Savart's law, Ampere's law, Curl, Faraday's law, Lorentz force, Inductance, Magnetomotive force, Reluctance, Magnetic circuits,Self and Mutual inductance of simple configurations.
(https://drive.google.com/file/d/1tqnglhiggf3d5rPYATs4Mue7Tj13gU N/view)

TIME TABLE $5^{\text {TH }}$ SEMESTER ELECTRICAL ENGINEERING DEPARTMENT 2k16 BATCH (2018-19 SWESSION) ELECTROMAGNETIC FIELD THEORY

ROOM NO. 15

| DAY/TIME | 9:00-10:00 | 10:0-11:00 | 11:00-12:00 | 12:00-13:00 | 13:00-14:00 | 14:00-15:00 | 15:00-16:00 | 16:00-17:00 |
| :---: | :---: | :---: | :---: | :---: | :---: | :---: | :---: | :---: |
| MONDAY |  |  |  | EMFT (T2) <br> (EE) 15 |  | WEEKLY TEST <br> EMFT (15:00-15:30) (EE) |  |  |
| TUESDAY | EMFT (T4) (EE) 15 |  |  |  |  | EMFT (T3) 15 |  |  |
| WEDNESDAY |  |  |  |  |  |  |  |  |
| THURSDAY |  |  |  | EMFT (EE) 15 |  | EMFT (T1) 15 |  |  |
| FRIDAY |  |  | EMFT (EE) 15 |  |  |  |  |  |
| SATURDAY |  | EMFT (EE) 15 |  |  |  |  |  |  |

Student List (5 ${ }^{\text {TH }}$ SEMESTER EE, 2K16 BATCH, MIT MUZAFFARPUR)

| S. No. | Roll No. | Name |
| :---: | :---: | :---: |
| 1 | 16E44 | ANISH BHARTI |
| 2 | 16E25 | AMITESH KUMAR |
| 3 | 16E30 | RAVI KUMAR |
| 4 | 16E34 | MANOJ KUMAR SONI |
| 5 | 16E03 | KAUSTUBHA |
| 6 | 16E55 | GOLDEN KUMAR |
| 7 | 16E63 | SUMAN KUMAR |
| 8 | 16E33 | BAJRANGI KUMAR |
| 9 | 16E56 | MURLIMANOHAR |
| 10 | 16E05 | AMRITA KUMARI |
| 11 | 16E12 | KULDEEP THAKUR |
| 12 | 16E62 | RISHABH KUMAR |
| 13 | 16E23 | DEVENDRA KUMAR |
| 14 | 16E49 | PRASHANT KUMAR |
| 15 | 16E21 | CHANDAN KUMAR THAKUR |
| 16 | 16E24 | ARVIND KUMAR |
| 17 | 16E64 | SUNITA KUMARI |
| 18 | 16E45 | RAHUL KUMAR |
| 19 | 16E15 | PRIYAM KUMARI |
| 20 | 16E36 | NEERAJ KUMAR |
| 21 | 16E27 | VIKASH KUMAR RAY |
|  | 16E11 | PREETI KUMARI |
| 23 | 16E67 | ANKIT RAJ |
| 24 | 16E22 | ALOK KUMAR |
| 25 | 16E69 | PRATAP CHANDRA CHOUDHARY |
| 26 | 16E60 | SUMAN KUMAR BHARTIYA |



| 56 | 16 E 06 | SUMIT KUMAR |
| :---: | :---: | :---: |
| 57 | 16 E 66 | VIPIN SINGH |
| 58 | 16 E 51 | KESHAV CHANDRA |
| 59 | $17(\mathrm{LE}) \mathrm{E} 01$ | VIVEK KUMAR |
| 60 | $17(\mathrm{LE}) \mathrm{E} 02$ | RITIK KUMAR |
| 61 | $17(\mathrm{LE}) \mathrm{E} 10$ | RANISH KUMAR CHOUDHARY |
| 62 | $17(\mathrm{LE}) \mathrm{E} 08$ | ANAND KUMAR |
| 63 | $17(\mathrm{LE}) \mathrm{E} 09$ | ANAND RANJAN |
| 64 | $17(\mathrm{LE}) \mathrm{E} 03$ | SAURAV KUMAR JHA |
| 65 | $17(\mathrm{LE}) \mathrm{E} 06$ | ABHISHEK KUMAR |
| 66 | $17(\mathrm{LE}) \mathrm{E} 04$ | PARMANAND KUMAR |
| 67 | $17(\mathrm{LE}) \mathrm{E} 07$ | POONAM KUMAR |
| 68 | $17(\mathrm{LE}) \mathrm{E} 05$ |  |


| Institute Name : | Muzaffarpur Institute of Technology, Muzaffarpur |  |  |
| :--- | :--- | :--- | :---: |
| Program Name | B. Tech. in Electrical Engineering |  |  |
| Course Code | 031506 |  |  |
| Course Name | Electromagnetic Field Theory |  |  |
| Lecture / Tutorial (per <br> week): | $3 / 4$ | Course Credits |  | 4.4.

## LECTURE PLAN

| Topics | Lecture <br> Number | Date on which the Lecture was taken |
| :---: | :---: | :---: |
| Introduction |  |  |
| Introduction and Objectives of Learning Electromagnetic Field Theory and General Application | 1. | I |
| Introduction of field co-ordinate systems | 2. |  |
| Transformation of Variables in orthogonal Systems |  |  |
| Electrostatics |  |  |
| Coulomb's law | 4. |  |
| Coulomb's law and its application | 5. |  |
| Gauss's law and its applications | 6. |  |
| Gauss's law and its applications | 7. |  |
| Potential functions | 8. |  |
| Relation between Electric field and potential function | 9. |  |
| Equipotential surface, Poisson's and Laplace's equation | 10. |  |
| Applications of Laplace's Equation for boundary value problems | 11. |  |
| Capacitance, Electrostatics energy, Condúctor propertíes | 12. |  |
| boundary conditions between dielectric and dielectric-conductor | 13. |  |
| Application of boundary conditions | 14. |  |
| Uniqueness Theorems | 15. |  |
| Magneto statics |  |  |
| Biot-savart law y | 16. |  |
| Ampere's circuital law ( ) | 17. |  |
| Application of Ampere's circuital Law | 18. |  |
| Curl, Stroke's theorem, Magnetic flux | 19. |  |
| magnetic flux density, Énergy stored In magnetic field | 20. |  |
| Ampere force law | 21. |  |
| Magnetic vector potential | 22. |  |
| Analogy between electric and magnetic field | 23. |  |
| Maxwell's equations |  |  |
| Equation of Continuity for time varying field | 24. |  |
| Inconsistency of ampere circuital law | 25. |  |
| Maxwell's equations in differential and integral form | 26. |  |
| Maxwell's equations in differential and integral form | 27. |  |
| Electromagnetic wave |  |  |
| Solution of wave equation in free space | 28. |  |
| Solution of wave equation in free space | 29. |  |
| Uniform plane wave propagation | 30. |  |
| Uniform plane waves, the wave equation for conducting medium | 31. |  |


| Wave propagation in lossless medium | $\mathbf{3 2 .}$ |  |
| :--- | ---: | ---: |
| Wave propagation in conductive medium | $\mathbf{3 3 .}$ |  |
| Wave propagation Conductors and dielectrics | $\mathbf{3 4 .}$ |  |
| Polarization | $\mathbf{3 5 .}$ |  |
| Reflections and refractions |  |  |
| reflection by a perfect conductor with normal as well as oblique incidence | $\mathbf{3 6 .}$ |  |
| reflection by a perfect conductor with normal as well as oblique incidence | $\mathbf{3 7 .}$ |  |
| Reflection and refraction by perfect dielectrics with normal and oblique <br> incidence | $\mathbf{3 8 .}$ |  |
| Surface impedance | $\mathbf{3 9 .}$ |  |
| Pointing vector |  |  |
| Pointing theorem, instantaneous average and complex pointing vector | $\mathbf{4 0 .}$ |  |
| power loss in a plane conductor | $\mathbf{4 1 .}$ |  |
| Transmission Lines |  |  |
| UHF line as a transformer, voltage step up of the quarter wave <br> transformer | $\mathbf{4 2 .}$ |  |
| Transmission lion theory, low loss radio-frequency and UHF transmission <br> line | $\mathbf{4 3 .}$ |  |
| Transmission line chart (Smith Chart). | $\mathbf{4 4 .}$ |  |
| Transmission line chart (Smith Chart). | $\mathbf{4 5 .}$ |  |
| Transmission line chart (Smith Chart). | $\mathbf{4 6 .}$ |  |

## TUTORIAL SHEET OF EMFT

| S. No. | QUESTIONS |
| :---: | :---: |
| 1. | Express the vector field $\overline{\boldsymbol{H}}=x y^{2} z \widehat{\boldsymbol{a}_{\boldsymbol{x}}}+x^{2} y z \widehat{\boldsymbol{a}_{\boldsymbol{y}}}+x y z^{2} \widehat{\boldsymbol{a}_{\boldsymbol{z}}}$ <br> in cylindrical and spherical coordinates and also find it at ( $3,-4,5$ ). |
|  | Ans: <br> Cylindrical <br> Spherical $\begin{gathered} \overline{\boldsymbol{H}}=288 \widehat{\boldsymbol{a}_{\boldsymbol{\rho}}}+84 \widehat{\boldsymbol{a}_{\boldsymbol{\phi}}}-300 \widehat{\boldsymbol{a}_{\boldsymbol{z}}} \\ \overline{\boldsymbol{H}}=-8.485 \widehat{\boldsymbol{a}_{r}}+415.8 \widehat{\boldsymbol{a}_{\boldsymbol{\theta}}}+84 \widehat{\boldsymbol{a}_{\boldsymbol{\phi}}} \end{gathered}$ |
| 2. | Given that $\overline{\boldsymbol{G}}=\left(x+y^{2}\right) \widehat{\boldsymbol{a}_{\boldsymbol{x}}}+x z \widehat{\boldsymbol{a}_{\boldsymbol{y}}}+\left(z^{2}+z y\right) \widehat{\boldsymbol{a}_{\boldsymbol{z}}}$, find the vector component of $\overline{\boldsymbol{G}}$ along $\widehat{\boldsymbol{a}_{\boldsymbol{\phi}}}$ at point $P\left(8,30^{\circ}, 60^{\circ}\right)$. Your answer should be left in Cartesian system. Ans: $4.5 \widehat{\boldsymbol{a}_{x}}-2.598 \widehat{\boldsymbol{a}_{y}}$ |
| 3. | Let $\overline{\boldsymbol{H}}=5 \rho \operatorname{Sin} \Phi \widehat{\boldsymbol{a}_{\boldsymbol{\rho}}}-\rho z \operatorname{Cos} \Phi \widehat{\boldsymbol{a}_{\boldsymbol{\phi}}}+2 \rho \widehat{\boldsymbol{a}_{\mathbf{z}}}$. At point $\mathrm{P}\left(2,30^{\circ},-1\right)$, find: <br> (a) a unit vector along $\overline{\boldsymbol{H}}$ <br> (b) the component of $\overline{\boldsymbol{H}}$ parallel to $\widehat{\boldsymbol{a}_{\boldsymbol{x}}}$ <br> (c) the component of $\overline{\boldsymbol{H}}$ normal to $\rho=2$ <br> (d) the component of $\overline{\boldsymbol{H}}$ tangential to $\Phi=30$ <br> Ans <br> a) $0.7538 \widehat{\boldsymbol{a}_{\rho}}+0.2611 \widehat{\boldsymbol{a}_{\boldsymbol{\phi}}}-0.603 \widehat{\boldsymbol{a}_{z}}$ <br> (b) $13 \widehat{a_{x}}$ <br> (c) $0.7538 \widehat{\boldsymbol{a}_{\boldsymbol{\rho}}}$ <br> (d) $0.7538 \widehat{\boldsymbol{a}_{\boldsymbol{\rho}}}-0.603 \widehat{\boldsymbol{a}_{z}}$ |
| 4. | Let $\overline{\boldsymbol{A}}=\rho\left(z^{2}-1\right) \widehat{\boldsymbol{a}_{\boldsymbol{\rho}}}-\rho z \operatorname{Cos} \Phi \widehat{\boldsymbol{a}_{\boldsymbol{\phi}}}+\rho^{2} z^{2} \widehat{\boldsymbol{a}_{z}}$ <br> and $\overline{\boldsymbol{B}}=r^{2} \operatorname{Cos} \Phi \widehat{\boldsymbol{a}_{\boldsymbol{r}}}+2 r \operatorname{Sin} \theta \widehat{\boldsymbol{a}_{\boldsymbol{\phi}}}$ <br> At T(-3, 4, 1), calculate: <br> (a) $\bar{A}$ and $\bar{B}$ <br> (b) The vector component in cylindrical coordinates of $\bar{A}$ along $\bar{B}$ <br> (c) The unit vector in spherical coordinates perpendicular to both $\bar{A}$ and $\bar{B}$ <br> Ans <br> (a) $3 \widehat{a_{\phi}}+2.5 \widehat{a_{z}}, \quad-15.6 \widehat{a_{r}}+10 \widehat{a_{\phi}}$ <br> (b) $2.071 \widehat{a_{\rho}}-1.354 \widehat{a_{\phi}}+0.4141 \widehat{a_{z}}$ <br> (c) $\pm\left(0.528 \widehat{a_{r}}-0.2064 \widehat{a_{\theta}}+0.8238 \widehat{a_{\phi}}\right)$ |
|  | Find the volume cut from the sphere radius $r=a$ by the cone $\theta=\alpha$. calculate the volume when $\alpha=\pi / 3$ and $\alpha=\pi / 2$. <br> Ans $\begin{aligned} & \pi a^{3} / 3 \text { when } \alpha=\pi / 3 \\ & 2 \pi a^{3} / 3 \text { when } \alpha=\pi / 2 . \end{aligned}$ |


| 6. | Using the differential length dl, find the length of each of the following curves: <br> (a) $\rho=3, \pi / 4<\Phi<\pi / 2, z=$ constant <br> (b) $r=1, \theta=30^{0}, 0<\Phi<60^{\circ}$ <br> (c) $r=4,30^{\circ}<\theta<90^{\circ}$, $\Phi=$ constant <br> Ans <br> (a) 2.356 <br> (b) 0.5236 <br> (c) 4.189 |
| :---: | :---: |
| 7. | Calculate the areas of the following surfaces using the differential surface area dS: <br> (a) $\rho=2,0<z<5, \pi / 3<\Phi<\pi / 2$ <br> (b) $z=1,1<\rho<3,0<\Phi<\pi / 4$ <br> (c) $r=10, \pi / 4<\theta<2 \pi / 3,0<\Phi<2 \pi$ <br> (d) $0<r<4,60^{\circ}<\theta<90^{\circ}$, $\Phi=$ constant <br> Ans <br> (a) 5.236 <br> (b) 3.142 <br> (c) 7.584 <br> (d) 4.189 |
| 8. | Use the differential volume dv to determine the volumes of the following regions: <br> (a) $0<x<1,1<y<2,-3<z<3$ <br> (b) $2<\rho<5, \pi / 3<\Phi<\pi,-1<z<4$ <br> (c) $1<r<3, \pi / 2<\theta<2 \pi / 3, \pi / 6<\Phi<\pi / 2$ <br> Ans <br> (a) 6 <br> (b) 10 <br> (c) 4.538 |
| 9. | If $\overrightarrow{\boldsymbol{H}}=(x-y) \widehat{\boldsymbol{a}_{\boldsymbol{x}}}+\left(x^{2}+y z\right) \widehat{\boldsymbol{a}_{\boldsymbol{y}}}+5 y z \widehat{\boldsymbol{a}_{\boldsymbol{z}}}$ <br> Evaluate $\int \overline{\boldsymbol{H}} \cdot \overline{\boldsymbol{d l}}$ along the contour of Figure 1. <br> Figure 1. <br> Ans: 1.5 |

## TUTORIAL SHEET OF EMFT



| 12. | Determine the total charge: <br> (a) On line $0<x<5 \mathrm{~m}$ if $\rho_{L}=12 x^{2} \mathrm{mC} / \mathrm{m}$ <br> (b) On the cylinder $\rho=3,0<z<4 m$ if $\rho_{s}=\rho z^{2} n C / m^{2}$ <br> (c) Within the sphere $r=4 \mathrm{~m}$ if $\rho_{v}=\frac{10}{r \sin \theta} C / \mathrm{m}^{3}$ |
| :---: | :---: |
|  | Ans <br> (a) 0.5 C <br> (b) $1.206 \mu \mathrm{C}$ <br> (c) 157.91 C |
| 13. | A circular disk of radius $a$ carries charge $\rho_{s}=\frac{1}{\rho} C / m^{2}$. Calculate the potential at $(0,0, h)$. <br> Ans $V=\frac{1}{2 \varepsilon_{0}} \ln \left\{\frac{a+\sqrt{\rho^{2}+h^{2}}}{h}\right\}$ |
| 14. | Plane $x+2 y=5$ carries charge $\rho_{s}=6 n C / m^{2}$. Determine $\overline{\boldsymbol{E}}$ at $(-1,0,1)$. <br> Ans $-151.7 \widehat{a_{x}}-303.5 \widehat{a_{y}} \mathrm{~V} / \mathrm{m}$ |
| 15. | Given that $\rho_{v}=\left\{\begin{array}{lc} 12 \rho n C / m^{3}, & 1<\rho<2 \\ 0, & \text { otherwise } \end{array}\right.$ <br> Determine $\overline{\boldsymbol{D}}$ everywhere. <br> Ans $\overline{\boldsymbol{D}}=\left\{\begin{array}{lr} 0, & \rho<1 \\ \frac{8\left(\rho^{3}-1\right)}{2 \rho}, & 1<\rho<2 \\ \frac{28}{\rho}, & \rho>2 \end{array}\right.$ |
| 16. | Let $\rho_{v}=\left\{\begin{array}{lr} \frac{10}{r^{2}} m C / m^{3}, & 1<r<4 \\ 0, & r>4 \end{array}\right.$ <br> (a) Find the net flux crossing surface $r=2 m$ and $r=6 \mathrm{~m}$. <br> (b) Determine $\overline{\mathbf{D}}$ at $r=1 \mathrm{~m}$ and $r=5 \mathrm{~m}$. |
|  | Ans <br> (a) $\psi=502.6 \mathrm{mC}$ <br> (b) $10 \widehat{\boldsymbol{a}_{\boldsymbol{r}}} n C / m^{2}$ at $r=1 \mathrm{~m}, \quad 1.60 \widehat{\boldsymbol{a}_{\boldsymbol{r}}} n C / m^{2}$ at $r=5 \mathrm{~m}$ |

## TUTORIAL SHEET OF EMFT




## TUTORIAL SHEET OF EMFT

| 26. | Two homogeneous dielectric regions $1(\rho \leq 4 \mathrm{~cm})$ and 2 ( $\rho \geq 4 \mathrm{~cm}$ ) have dielectric constants 3.5 and 1.5 , respectively. If $\overline{\boldsymbol{D}_{2}}=12 \widehat{\boldsymbol{a}_{\rho}}-6 \widehat{\boldsymbol{a}_{\boldsymbol{\phi}}}+9 \widehat{\boldsymbol{a}_{z}} n C / m^{2}$ <br> Calculate: <br> (a) $\overline{\boldsymbol{E}_{\mathbf{1}}}$ and $\overline{\boldsymbol{D}_{\mathbf{1}}}$ <br> (b) the energy density for each region <br> Ans <br> (a) $\overline{\boldsymbol{E}_{\mathbf{1}}}=387.8 \widehat{\boldsymbol{a}_{\boldsymbol{\rho}}}-452.4 \widehat{\boldsymbol{a}_{\boldsymbol{\phi}}}+678.6 \widehat{\boldsymbol{a}_{\mathbf{z}}} \mathrm{V} / \mathrm{m}$, <br> (b) $9.839 \mathrm{~mJ} / \mathrm{m}^{3}$ |
| :---: | :---: |
| 27. | A silver coated sphere of radius 5 cm carries a total charge of 12 nC uniformly distributed on its surface in free space. Calculate: <br> (a) $\|\overline{\boldsymbol{D}}\|$ on the surface of the sphere <br> (b) $\overline{\boldsymbol{D}}$ external to the sphere <br> (c) the total energy stored in the field <br> Ans <br> (a) $381.97 \mathrm{nC} / \mathrm{m}^{2}$ <br> (b) $\frac{0.955}{r^{2}} \widehat{a_{r}}$ <br> (c) 12.96 |
| 28. | In free space $V=6 x y^{2} z+8$. At point $P(1,2,-5)$, calculate $\overline{\boldsymbol{E}}$ and $\rho_{v}$ Ans <br> (a) $120 \widehat{\boldsymbol{a}_{\boldsymbol{x}}}+120 \widehat{\boldsymbol{a}_{\boldsymbol{y}}}-12 \widehat{\boldsymbol{a}_{\boldsymbol{z}}}, \quad 530.5 \mathrm{pC} / \mathrm{m}^{3}$ |
| 29. | The potential field $V=2 x^{2} y z-y^{3} z$ exists in a dielectric medium having $\varepsilon=2 \varepsilon_{0}$. <br> (a) Does V satisfy Laplace's equation? <br> (b) calculate the total charge within the unit cube $0<x, y, z<1 m$. |
| 30. | The region between concentric spherical conducting shells $r=0.5 \mathrm{~m}$ and $r=1 \mathrm{~m}$ is charge free. If $V(r=0.5)=-50 V$ and $V(r=1)=50 V$, determine the potential distribution and dielectric field strength in the region between the shells. <br> Ans $V=-\frac{100}{r}+150 \mathrm{~V}, \quad \overline{\boldsymbol{E}}=-\frac{100}{r^{2}} \widehat{a_{r}}$ |
| 31. | Concentric cylinders $\rho=2 \mathrm{~cm}$ and $\rho=6 \mathrm{~cm}$ are maintained at $V=60 \mathrm{~V}$ and $V=-20 \mathrm{~V}$ respectively. Calculate $V, \overline{\boldsymbol{E}}$ and $\overline{\boldsymbol{D}}$ at $\rho=4 \mathrm{~cm}$. <br> Ans |
|  | $V=9.52 \mathrm{~V}, \overline{\boldsymbol{E}}=18.21 \widehat{\boldsymbol{a}_{\boldsymbol{\rho}}} \mathrm{V} / \mathrm{m}, \overline{\mathrm{D}}=0.161 \widehat{\boldsymbol{a}_{\boldsymbol{\rho}}} \mathrm{nC} / \mathrm{m}^{2}$ |

## TUTORIAL SHEET OF EMFT

| 32. | The space between spherical conducting shells $r=5 \mathrm{~cm}$ and $\mathrm{r}=10 \mathrm{~cm}$ is filled with a dielectric material for which $\varepsilon=2.25 \varepsilon_{0}$. The two shells are maintained at a potential difference of 80 V . <br> (a) Find the capacitance of the system <br> (b) Calculate the charge density on shell $\mathrm{r}=5 \mathrm{~cm}$. <br> Ans <br> (a) $25 p F$ <br> (b) $63.66 \mathrm{nC} / \mathrm{m}^{2}$ |
| :---: | :---: |
| 33. | A spherical capacitor has inner radius a and outer radius b and filled with an inhomogeneous dielectric with $\varepsilon=\varepsilon_{0} \frac{K}{r^{2}}$. Show that the capacitance of the capacitor is $C=\frac{4 \pi \epsilon_{0} K}{b-a}$ |
| 34. | A cylindrical capacitor with inner radius a and outer radius b is filled with an inhomogeneous dielectric having $\varepsilon=\varepsilon_{0} \frac{K}{\rho}$. where K is a constant. Calculate the capacitance per unit length of the capacitor. <br> Ans |
| 35. | In free space, infinite planes $\mathrm{y}=4$ and $\mathrm{y}=8$ carry charges $20 \mathrm{nC} / \mathrm{m}^{2}$ and $30 \mathrm{nC} / \mathrm{m}^{2}$, respectively. If plane $\mathrm{y}=2$ is grounded, calculate E at $\mathrm{P}(0,0,0)$ and $\mathrm{Q}(-4,6,2)$. <br> Ans <br> $0, \quad 2.262 \widehat{\boldsymbol{a}_{\boldsymbol{y}}} \mathrm{kV} / \mathrm{m}$ |

## Q. 1 - Q. 5 carry one mark each.

Q. 1 The man who is now Municipal Commissioner worked as $\qquad$ .
(A) the security guard at a university
(B) a security guard at the university
(C) a security guard at university
(D) the security guard at the university
Q. 2 Nobody knows how the Indian cricket team is going to cope with the difficult and seamer-friendly wickets in Australia.

Choose the option which is closest in meaning to the underlined phrase in the above sentence.
(A) put up with
(B) put in with
(C) put down to
(D) put up against
Q. 3 Find the odd one in the following group of words. mock, deride, praise, jeer
(A) mock
(B) deride
(C) praise
(D) jeer
Q. 4 Pick the odd one from the following options.
(A) CADBE
(B) JHKIL
(C) XVYWZ
(D) ONPMQ
Q. 5 In a quadratic function, the value of the product of the roots $(\alpha, \beta)$ is 4. Find the value of

$$
\frac{\alpha^{n}+\beta^{n}}{\alpha^{-n}+\beta^{-n}}
$$

(A) $n^{4}$
(B) $4^{n}$
(C) $2^{2 n-1}$
(D) $4^{n-1}$

## Q. 6 - Q. 10 carry two marks each.

Q. 6 Among 150 faculty members in an institute, 55 are connected with each other through Facebook ${ }^{\circledR}$ and 85 are connected through WhatsApp ${ }^{\circledR}$. 30 faculty members do not have Facebook ${ }^{\circledR}$ or WhatsApp ${ }^{\circledR}$ accounts. The number of faculty members connected only through Facebook ${ }^{\circledR}$ accounts is $\qquad$ .
(A) 35
(B) 45
(C) 65
(D) 90
Q. 7 Computers were invented for performing only high-end useful computations. However, it is no understatement that they have taken over our world today. The internet, for example, is ubiquitous. Many believe that the internet itself is an unintended consequence of the original invention. With the advent of mobile computing on our phones, a whole new dimension is now enabled. One is left wondering if all these developments are good or, more importantly, required.

Which of the statement(s) below is/are logically valid and can be inferred from the above paragraph?
(i) The author believes that computers are not good for us.
(ii) Mobile computers and the internet are both intended inventions
(A) (i) only
(B) (ii) only
(C) both (i) and (ii)
(D) neither (i) nor (ii)
Q. 8 All hill-stations have a lake. Ooty has two lakes.

Which of the statement(s) below is/are logically valid and can be inferred from the above sentences?
(i) Ooty is not a hill-station.
(ii) No hill-station can have more than one lake.
(A) (i) only
(B) (ii) only
(C) both (i) and (ii)
(D) neither (i) nor (ii)
Q. 9 In a $2 \times 4$ rectangle grid shown below, each cell is a rectangle. How many rectangles can be observed in the grid?

(A) 21
(B) 27
(C) 30
(D) 36
Q. 10


Choose the correct expression for $f(x)$ given in the graph.
(A) $f(x)=1-|x-1|$
(B) $f(x)=1+|x-1|$
(C) $f(x)=2-|x-1|$
(D) $f(x)=2+|x-1|$

## END OF THE QUESTION PAPER

## Q. 1 - Q. 25 carry one mark each.

Q. 1 The maximum value attained by the function $f(x)=x(x-1)(x-2)$ in the interval [1, 2] is
$\qquad$ -.
Q. 2 Consider a $3 \times 3$ matrix with every element being equal to 1 . Its only non-zero eigenvalue is $\qquad$ .
Q. 3 The Laplace Transform of $f(t)=e^{2 t} \sin (5 t) u(t)$ is
(A) $\frac{5}{s^{2}-4 s+29}$
(B) $\frac{5}{s^{2}+5}$
(C) $\frac{s-2}{s^{2}-4 s+29}$
(D) $\frac{5}{s+5}$
Q. 4 A function $y(t)$, such that $y(0)=1$ and $y(1)=3 e^{-1}$, is a solution of the differential equation $\frac{d^{2} y}{d t^{2}}+2 \frac{d y}{d t}+y=0$. Then $y(2)$ is
(A) $5 e^{-1}$
(B) $5 e^{-2}$
(C) $7 e^{-1}$
(D) $7 e^{-2}$
Q. 5 The value of the integral

$$
\oint_{C} \frac{2 z+5}{\left(z-\frac{1}{2}\right)\left(z^{2}-4 z+5\right)} d z
$$

over the contour $|z|=1$, taken in the anti-clockwise direction, would be
(A) $\frac{24 \pi i}{13}$
(B) $\frac{48 \pi i}{13}$
(C) $\frac{24}{13}$
(D) $\frac{12}{13}$
Q. 6

The transfer function of a system is $\frac{Y(s)}{R(s)}=\frac{s}{s+2}$. The steady state output $y(t)$ is $A \cos (2 t+\varphi)$ for the input $\cos (2 t)$. The values of $A$ and $\varphi$, respectively are
(A) $\frac{1}{\sqrt{2}},-45^{\circ}$
(B) $\frac{1}{\sqrt{2}},+45^{\circ}$
(C) $\sqrt{2},-45^{\circ}$
(D) $\sqrt{2},+45^{\circ}$
Q. 7 The phase cross-over frequency of the transfer function $G(s)=\frac{100}{(s+1)^{3}}$ in rad/s is
(A) $\sqrt{3}$
(B) $\frac{1}{\sqrt{3}}$
(C) 3
(D) $3 \sqrt{3}$
Q. 8 Consider a continuous-time system with input $x(t)$ and output $y(t)$ given by

$$
y(t)=x(t) \cos (t)
$$

This system is
(A) linear and time-invariant
(B) non-linear and time-invariant
(C) linear and time-varying
(D) non-linear and time-varying
Q. 9 The value of $\int_{-\infty}^{+\infty} e^{-t} \delta(2 t-2) \mathrm{d} t$, where $\delta(t)$ is the Dirac delta function, is
(A) $\frac{1}{2 e}$
(B) $\frac{2}{e}$
(C) $\frac{1}{e^{2}}$
(D) $\frac{1}{2 e^{2}}$
Q. 10 A temperature in the range of $-40^{\circ} \mathrm{C}$ to $55^{\circ} \mathrm{C}$ is to be measured with a resolution of $0.1^{\circ} \mathrm{C}$. The minimum number of ADC bits required to get a matching dynamic range of the temperature sensor is
(A) 8
(B) 10
(C) 12
(D) 14
Q. 11 Consider the following circuit which uses a 2-to-1 multiplexer as shown in the figure below. The Boolean expression for output F in terms of A and B is

(A) $A \oplus B$
(B) $\overline{A+B}$
(C) $A+B$
(D) $\overline{A \oplus B}$
Q. 12 A transistor circuit is given below. The Zener diode breakdown voltage is 5.3 V as shown. Take base to emitter voltage drop to be 0.6 V . The value of the current gain $\beta$ is $\qquad$ _.

Q. 13 In cylindrical coordinate system, the potential produced by a uniform ring charge is given by $\varphi=f(r, z)$, where $f$ is a continuous function of $r$ and $z$. Let $\vec{E}$ be the resulting electric field. Then the magnitude of $\nabla \times \vec{E}$
(A) increases with $r$.
(B) is 0 .
(C) is 3 .
(D) decreases with $z$.
Q. 14 A soft-iron toroid is concentric with a long straight conductor carrying a direct current $I$. If the relative permeability $\mu_{r}$ of soft-iron is 100 , the ratio of the magnetic flux densities at two adjacent points located just inside and just outside the toroid, is $\qquad$ -.
Q. $15 \quad R_{A}$ and $R_{B}$ are the input resistances of circuits as shown below. The circuits extend infinitely in the direction shown. Which one of the following statements is TRUE?

(A) $\mathrm{R}_{\mathrm{A}}=\mathrm{R}_{\mathrm{B}}$
(B) $\mathrm{R}_{\mathrm{A}}=\mathrm{R}_{\mathrm{B}}=0$
(C) $\mathrm{R}_{\mathrm{A}}<\mathrm{R}_{\mathrm{B}}$
(D) $\mathrm{R}_{\mathrm{B}}=\mathrm{R}_{\mathrm{A}} /\left(1+\mathrm{R}_{\mathrm{A}}\right)$
Q. 16 In a constant V/f induction motor drive, the slip at the maximum torque
(A) is directly proportional to the synchronous speed.
(B) remains constant with respect to the synchronous speed.
(C) has an inverse relation with the synchronous speed.
(D) has no relation with the synchronous speed.
Q. 17 In the portion of a circuit shown, if the heat generated in $5 \Omega$ resistance is 10 calories per second, then heat generated by the $4 \Omega$ resistance, in calories per second, is $\qquad$ .

Q. 18 In the given circuit, the current supplied by the battery, in ampere, is $\qquad$ .

Q. 19 In a 100 bus power system, there are 10 generators. In a particular iteration of Newton Raphson load flow technique (in polar coordinates), two of the PV buses are converted to PQ type. In this iteration,
(A) the number of unknown voltage angles increases by two and the number of unknown voltage magnitudes increases by two.
(B) the number of unknown voltage angles remains unchanged and the number of unknown voltage magnitudes increases by two.
(C) the number of unknown voltage angles increases by two and the number of unknown voltage magnitudes decreases by two.
(D) the number of unknown voltage angles remains unchanged and the number of unknown voltage magnitudes decreases by two.
Q. 20 The magnitude of three-phase fault currents at buses A and B of a power system are 10 pu and 8 pu, respectively. Neglect all resistances in the system and consider the pre-fault system to be unloaded. The pre-fault voltage at all buses in the system is 1.0 pu . The voltage magnitude at bus B during a three-phase fault at bus A is 0.8 pu . The voltage magnitude at bus A during a three-phase fault at bus $B$, in pu, is $\qquad$ .
Q. 21 Consider a system consisting of a synchronous generator working at a lagging power factor, a synchronous motor working at an overexcited condition and a directly grid-connected induction generator. Consider capacitive VAr to be a source and inductive VAr to be a sink of reactive power. Which one of the following statements is TRUE?
(A) Synchronous motor and synchronous generator are sources and induction generator is a sink of reactive power.
(B) Synchronous motor and induction generator are sources and synchronous generator is a sink of reactive power.
(C) Synchronous motor is a source and induction generator and synchronous generator are sinks of reactive power.
(D) All are sources of reactive power.
Q. 22 A buck converter, as shown in Figure (a) below, is working in steady state. The output voltage and the inductor current can be assumed to be ripple free. Figure (b) shows the inductor voltage $\mathrm{v}_{\mathrm{L}}$ during a complete switching interval. Assuming all devices are ideal, the duty cycle of the buck converter is $\qquad$ .

Q. 23 A steady dc current of 100 A is flowing through a power module (S, D) as shown in Figure (a). The V-I characteristics of the IGBT (S) and the diode (D) are shown in Figures (b) and (c), respectively. The conduction power loss in the power module (S, D), in watts, is $\qquad$ -.

Q. 24 A 4-pole, lap-connected, separately excited dc motor is drawing a steady current of 40 A while running at 600 rpm . A good approximation for the waveshape of the current in an armature conductor of the motor is given by
(A)

(B)


(D)
(C)

Q. 25 If an ideal transformer has an inductive load element at port 2 as shown in the figure below, the equivalent inductance at port 1 is

(A) $n L$
(B) $n^{2} L$
(C) $\frac{n}{L}$
(D) $\frac{n^{2}}{L}$

## Q. 26 - Q. 55 carry two marks each.

Q. 26 Candidates were asked to come to an interview with 3 pens each. Black, blue, green and red were the permitted pen colours that the candidate could bring. The probability that a candidate comes with all 3 pens having the same colour is $\qquad$ .
Q. 27

Let $S=\sum_{n=0}^{\infty} n \alpha^{n}$ where $|\alpha|<1$. The value of $\alpha$ in the range $0<\alpha<1$, such that $S=2 \alpha$ is $\qquad$ .
Q. 28 Let the eigenvalues of a $2 \times 2$ matrix $A$ be $1,-2$ with eigenvectors $x_{1}$ and $x_{2}$ respectively. Then the eigenvalues and eigenvectors of the matrix $A^{2}-3 A+4 I$ would, respectively, be
(A) 2,$14 ; x_{1}, x_{2}$
(B) 2,$14 ; x_{1}+x_{2}, x_{1}-x_{2}$
(C) 2,$0 ; x_{1}, x_{2}$
(D) 2,$0 ; x_{1}+x_{2}, x_{1}-x_{2}$
Q. 29 Let $A$ be a $4 \times 3$ real matrix with rank 2 . Which one of the following statement is TRUE?
(A) Rank of $A^{T} A$ is less than 2.
(B) Rank of $A^{T} A$ is equal to 2 .
(C) Rank of $A^{T} A$ is greater than 2 .
(D) Rank of $A^{T} A$ can be any number between 1 and 3 .
Q. 30 Consider the following asymptotic Bode magnitude plot ( $\omega$ is in $\mathrm{rad} / \mathrm{s}$ ).


Which one of the following transfer functions is best represented by the above Bode magnitude plot?
(A) $\frac{2 s}{(1+0.5 s)(1+0.25 s)^{2}}$
(B) $\frac{4(1+0.5 s)}{s(1+0.25 s)}$
(C) $\frac{2 s}{(1+2 s)(1+4 s)}$
(D) $\frac{4 s}{(1+2 s)(1+4 s)^{2}}$
Q. 31 Consider the following state-space representation of a linear time-invariant system.

$$
\dot{\boldsymbol{x}}(t)=\left[\begin{array}{ll}
1 & 0 \\
0 & 2
\end{array}\right] \boldsymbol{x}(t), \quad y(t)=\boldsymbol{c}^{\mathrm{T}} \boldsymbol{x}(t), \quad \boldsymbol{c}=\left[\begin{array}{l}
1 \\
1
\end{array}\right] \text { and } \boldsymbol{x}(0)=\left[\begin{array}{l}
1 \\
1
\end{array}\right]
$$

The value of $y(t)$ for $t=\log _{\mathrm{e}} 2$ is $\qquad$ .
Q. 32

Loop transfer function of a feedback system is $G(s) H(s)=\frac{s+3}{s^{2}(s-3)}$. Take the Nyquist contour in the clockwise direction. Then, the Nyquist plot of $G(s) H(s)$ encircles $-1+j 0$
(A) once in clockwise direction
(B) twice in clockwise direction
(C) once in anticlockwise direction
(D) twice in anticlockwise direction
Q. 33 Given the following polynomial equation

$$
s^{3}+5.5 s^{2}+8.5 s+3=0
$$

the number of roots of the polynomial, which have real parts strictly less than -1 , is $\qquad$ .
Q. 34 Suppose $x_{1}(t)$ and $x_{2}(t)$ have the Fourier transforms as shown below.



Which one of the following statements is TRUE?
(A) $x_{1}(t)$ and $x_{2}(t)$ are complex and $x_{1}(t) x_{2}(t)$ is also complex with nonzero imaginary part
(B) $x_{1}(t)$ and $x_{2}(t)$ are real and $x_{1}(t) x_{2}(t)$ is also real
(C) $x_{1}(t)$ and $x_{2}(t)$ are complex but $x_{1}(t) x_{2}(t)$ is real
(D) $x_{1}(t)$ and $x_{2}(t)$ are imaginary but $x_{1}(t) x_{2}(t)$ is real
Q. 35 The output of a continuous-time, linear time-invariant system is denoted by $\boldsymbol{T}\{x(t)\}$ where $x(t)$ is the input signal. A signal $z(t)$ is called eigen-signal of the system $\boldsymbol{T}$, when $\boldsymbol{T}\{z(t)\}=\gamma z(t)$, where $\gamma$ is a complex number, in general, and is called an eigenvalue of $\boldsymbol{T}$. Suppose the impulse response of the system $\boldsymbol{T}$ is real and even. Which of the following statements is TRUE?
(A) $\cos (t)$ is an eigen-signal but $\sin (t)$ is not
(B) $\cos (t)$ and $\sin (t)$ are both eigen-signals but with different eigenvalues
(C) $\sin (t)$ is an eigen-signal but $\cos (t)$ is not
(D) $\cos (t)$ and $\sin (t)$ are both eigen-signals with identical eigenvalues
Q. 36 The current state $\mathrm{Q}_{\mathrm{A}} \mathrm{Q}_{\mathrm{B}}$ of a two JK flip-flop system is 00 . Assume that the clock rise-time is much smaller than the delay of the JK flip-flop. The next state of the system is

(A) 00
(B) 01
(C) 11
(D) 10
Q. 37 A 2-bit flash Analog to Digital Converter (ADC) is given below. The input is $0 \leq \mathrm{V}_{\text {IN }} \leq 3$ Volts. The expression for the LSB of the output $\mathrm{B}_{0}$ as a Boolean function of $\mathrm{X}_{2}, \mathrm{X}_{1}$, and $\mathrm{X}_{0}$ is

(A) $X_{0}\left[\overline{X_{2} \oplus X_{1}}\right]$
(B) $\bar{X}_{0}\left[\overline{X_{2} \oplus X_{1}}\right]$
(C) $X_{0}\left[X_{2} \oplus X_{1}\right]$
(D) $\bar{X}_{0}\left[X_{2} \oplus X_{1}\right]$
Q. 38 Two electric charges $q$ and $-2 q$ are placed at $(0,0)$ and $(6,0)$ on the $x-y$ plane. The equation of the zero equipotential curve in the $x-y$ plane is
(A) $x=-2$
(B) $y=2$
(C) $x^{2}+y^{2}=2$
(D) $(x+2)^{2}+y^{2}=16$
Q. 39 In the circuit shown, switch $\mathrm{S}_{2}$ has been closed for a long time. At time $t=0$ switch $\mathrm{S}_{1}$ is closed. At $t=0^{+}$, the rate of change of current through the inductor, in amperes per second, is $\qquad$ .

Q. 40 A three-phase cable is supplying 800 kW and 600 kVAr to an inductive load. It is intended to supply an additional resistive load of 100 kW through the same cable without increasing the heat dissipation in the cable, by providing a three-phase bank of capacitors connected in star across the load. Given the line voltage is $3.3 \mathrm{kV}, 50 \mathrm{~Hz}$, the capacitance per phase of the bank, expressed in microfarads, is $\qquad$ .
Q. 41 A 30 MVA, 3-phase, $50 \mathrm{~Hz}, 13.8 \mathrm{kV}$, star-connected synchronous generator has positive, negative and zero sequence reactances, $15 \%, 15 \%$ and $5 \%$ respectively. A reactance $\left(X_{n}\right)$ is connected between the neutral of the generator and ground. A double line to ground fault takes place involving phases ' $b$ ' and ' $c$ ', with a fault impedance of $j 0.1$ p.u. The value of $X_{n}$ (in p.u.) that will limit the positive sequence generator current to 4270 A is $\qquad$ -.
Q. 42 If the star side of the star-delta transformer shown in the figure is excited by a negative sequence voltage, then

(A) $\mathrm{V}_{\mathrm{AB}}$ leads $\mathrm{V}_{\mathrm{ab}}$ by $60^{\circ}$
(B) $\mathrm{V}_{\mathrm{AB}}$ lags $\mathrm{V}_{\mathrm{ab}}$ by $60^{\circ}$
(C) $\mathrm{V}_{\mathrm{AB}}$ leads $\mathrm{V}_{\mathrm{ab}}$ by $30^{\circ}$
(D) $\mathrm{V}_{\mathrm{AB}}$ lags $\mathrm{V}_{\mathrm{ab}}$ by $30^{\circ}$
Q. 43 A single-phase thyristor-bridge rectifier is fed from a $230 \mathrm{~V}, 50 \mathrm{~Hz}$, single-phase AC mains. If it is delivering a constant DC current of 10 A , at firing angle of $30^{\circ}$, then value of the power factor at AC mains is
(A) 0.87
(B) 0.9
(C) 0.78
(D) 0.45
Q. 44 The switches T1 and T2 in Figure (a) are switched in a complementary fashion with sinusoidal pulse width modulation technique. The modulating voltage $v_{m}(t)=0.8 \sin (200 \pi t) \mathrm{V}$ and the triangular carrier voltage $\left(v_{c}\right)$ are as shown in Figure (b). The carrier frequency is 5 kHz . The peak value of the 100 Hz component of the load current ( $\mathrm{i}_{\mathrm{L}}$ ), in ampere, is $\qquad$ .

(a)
Q. 45 The voltage $\left(v_{s}\right)$ across and the current $\left(i_{s}\right)$ through a semiconductor switch during a turn-ON transition are shown in figure. The energy dissipated during the turn-ON transition, in mJ , is
$\qquad$ .

Q. 46 A single-phase $400 \mathrm{~V}, 50 \mathrm{~Hz}$ transformer has an iron loss of 5000 W at the rated condition. When operated at $200 \mathrm{~V}, 25 \mathrm{~Hz}$, the iron loss is 2000 W . When operated at $416 \mathrm{~V}, 52 \mathrm{~Hz}$, the value of the hysteresis loss divided by the eddy current loss is $\qquad$ .
Q. 47 A DC shunt generator delivers 45 A at a terminal voltage of 220 V . The armature and the shunt field resistances are $0.01 \Omega$ and $44 \Omega$ respectively. The stray losses are 375 W . The percentage efficiency of the DC generator is $\qquad$ .
Q. 48 A three-phase, 50 Hz salient-pole synchronous motor has a per-phase direct-axis reactance $\left(X_{d}\right)$ of 0.8 pu and a per-phase quadrature-axis reactance $\left(X_{q}\right)$ of 0.6 pu . Resistance of the machine is negligible. It is drawing full-load current at 0.8 pf (leading). When the terminal voltage is 1 pu , per-phase induced voltage, in pu, is $\qquad$ .
Q. 49 A single-phase, $22 \mathrm{kVA}, 2200 \mathrm{~V} / 220 \mathrm{~V}, 50 \mathrm{~Hz}$, distribution transformer is to be connected as an auto-transformer to get an output voltage of 2420 V . Its maximum kVA rating as an autotransformer is
(A) 22
(B) 24.2
(C) 242
(D) 2420
Q. 50 A single-phase full-bridge voltage source inverter (VSI) is fed from a 300 V battery. A pulse of $120^{\circ}$ duration is used to trigger the appropriate devices in each half-cycle. The rms value of the fundamental component of the output voltage, in volts, is
(A) 234
(B) 245
(C) 300
(D) 331
Q. 51 A single-phase transmission line has two conductors each of 10 mm radius. These are fixed at a center-to-center distance of 1 m in a horizontal plane. This is now converted to a three-phase transmission line by introducing a third conductor of the same radius. This conductor is fixed at an equal distance D from the two single-phase conductors. The three-phase line is fully transposed. The positive sequence inductance per phase of the three-phase system is to be $5 \%$ more than that of the inductance per conductor of the single-phase system. The distance D, in meters, is $\qquad$ -.
Q. 52 In the circuit shown below, the supply voltage is $10 \sin (1000 t)$ volts. The peak value of the steady state current through the $1 \Omega$ resistor, in amperes, is $\qquad$ -.

Q. 53 A dc voltage with ripple is given by $v(t)=[100+10 \sin (\omega t)-5 \sin (3 \omega t)]$ volts. Measurements of this voltage $v(t)$, made by moving-coil and moving-iron voltmeters, show readings of $V_{l}$ and $V_{2}$ respectively. The value of $V_{2}-V_{1}$, in volts, is $\qquad$ .
Q. 54 The circuit below is excited by a sinusoidal source. The value of $R$, in $\Omega$, for which the admittance of the circuit becomes a pure conductance at all frequencies is $\qquad$ .

Q. 55 In the circuit shown below, the node voltage $\mathrm{V}_{\mathrm{A}}$ is $\qquad$ V.


## END OF THE QUESTION PAPER

## Q. 1 - Q. 5 carry one mark each.

Q. 1 The chairman requested the aggrieved shareholders to $\qquad$ him.
(A) bare with
(B) bore with
(C) bear with
(D) bare
Q. 2 Identify the correct spelling out of the given options:
(A) Managable
(B) Manageable
(C) Mangaeble
(D) Managible
Q. 3 Pick the odd one out in the following:
$13,23,33,43,53$
(A) 23
(B) 33
(C) 43
(D) 53
Q. $4 \quad$ R2D2 is a robot. R2D2 can repair aeroplanes. No other robot can repair aeroplanes.

Which of the following can be logically inferred from the above statements?
(A) R2D2 is a robot which can only repair aeroplanes.
(B) R2D2 is the only robot which can repair aeroplanes.
(C) R2D2 is a robot which can repair only aeroplanes.
(D) Only R2D2 is a robot.
Q. 5 If $|9 y-6|=3$, then $y^{2}-4 y / 3$ is $\qquad$ .
(A) 0
(B) $+1 / 3$
(C) $-1 / 3$
(D) undefined

## Q. 6 - Q. 10 carry two marks each.

Q. 6 The following graph represents the installed capacity for cement production (in tonnes) and the actual production (in tonnes) of nine cement plants of a cement company. Capacity utilization of a plant is defined as ratio of actual production of cement to installed capacity. A plant with installed capacity of at least 200 tonnes is called a large plant and a plant with lesser capacity is called a small plant. The difference between total production of large plants and small plants, in tonnes is
$\qquad$ -.

Q. 7 A poll of students appearing for masters in engineering indicated that $60 \%$ of the students believed that mechanical engineering is a profession unsuitable for women. A research study on women with masters or higher degrees in mechanical engineering found that $99 \%$ of such women were successful in their professions.

Which of the following can be logically inferred from the above paragraph?
(A) Many students have misconceptions regarding various engineering disciplines.
(B) Men with advanced degrees in mechanical engineering believe women are well suited to be mechanical engineers.
(C) Mechanical engineering is a profession well suited for women with masters or higher degrees in mechanical engineering.
(D) The number of women pursuing higher degrees in mechanical engineering is small.
Q. 8 Sourya committee had proposed the establishment of Sourya Institutes of Technology (SITs) in line with Indian Institutes of Technology (IITs) to cater to the technological and industrial needs of a developing country.

Which of the following can be logically inferred from the above sentence?
Based on the proposal,
(i) In the initial years, SIT students will get degrees from IIT.
(ii) SITs will have a distinct national objective.
(iii) SIT like institutions can only be established in consultation with IIT.
(iv) SITs will serve technological needs of a developing country.
(A) (iii) and (iv) only.
(B) (i) and (iv) only.
(C) (ii) and (iv) only.
(D) (ii) and (iii) only.
Q. 9 Shaquille O' Neal is a $60 \%$ career free throw shooter, meaning that he successfully makes 60 free throws out of 100 attempts on average. What is the probability that he will successfully make exactly 6 free throws in 10 attempts?
(A) 0.2508
(B) 0.2816
(C) 0.2934
(D) 0.6000
Q. 10 The numeral in the units position of $211^{870}+146^{127} \times 3^{424}$ is $\qquad$ .

## END OF THE QUESTION PAPER

## Q. 1 - Q. 25 carry one mark each.

Q. 1 The output expression for the Karnaugh map shown below is

(A) $A+\bar{B}$
(B) $A+\bar{C}$
(C) $\bar{A}+\bar{C}$
(D) $\bar{A}+C$
Q. 2 The circuit shown below is an example of a

(A) low pass filter.
(B) band pass filter.
(C) high pass filter.
(D) notch filter.
Q. 3 The following figure shows the connection of an ideal transformer with primary to secondary turns ratio of $1: 100$. The applied primary voltage is $100 \mathrm{~V}(\mathrm{rms}), 50 \mathrm{~Hz}, \mathrm{AC}$. The rms value of the current $I$, in ampere, is $\qquad$ .

Q. 4 Consider a causal LTI system characterized by differential equation $\frac{d y(t)}{d t}+\frac{1}{6} y(t)=3 x(t)$. The response of the system to the input $x(t)=3 e^{-\frac{t}{3}} u(t)$, where $u(t)$ denotes the unit step function, is
(A) $9 e^{-\frac{t}{3}} u(t)$.
(B) $9 e^{-\frac{t}{6}} u(t)$.
(C) $9 e^{-\frac{t}{3}} u(t)-6 e^{-\frac{t}{6}} u(t)$.
(D) $54 e^{-\frac{t}{6}} u(t)-54 e^{-\frac{t}{3}} u(t)$.
Q. 5 Suppose the maximum frequency in a band-limited signal $x(t)$ is 5 kHz . Then, the maximum frequency in $x(t) \cos (2000 \pi t)$, in kHz , is $\qquad$ .
Q. 6 Consider the function $f(z)=z+z^{*}$ where $z$ is a complex variable and $z^{*}$ denotes its complex conjugate. Which one of the following is TRUE?
(A) $f(z)$ is both continuous and analytic
(B) $f(z)$ is continuous but not analytic
(C) $f(z)$ is not continuous but is analytic
(D) $f(z)$ is neither continuous nor analytic
Q. $7 \quad$ A $3 \times 3$ matrix $P$ is such that, $P^{3}=P$. Then the eigenvalues of $P$ are
(A) $1,1,-1$
(B) $1,0.5+j 0.866,0.5-j 0.866$
(C) $1,-0.5+j 0.866,-0.5-j 0.866$
(D) $0,1,-1$
Q. 8 The solution of the differential equation, for $t>0, y^{\prime \prime}(t)+2 y^{\prime}(t)+y(t)=0$ with initial conditions $y(0)=0$ and $y^{\prime}(0)=1$, is $(u(t)$ denotes the unit step function),
(A) $t e^{-t} u(t)$
(B) $\left(e^{-t}-t e^{-t}\right) u(t)$
(C) $\left(-e^{-t}+t e^{-t}\right) u(t)$
(D) $e^{-t} u(t)$
Q. 9 The value of the line integral

$$
\int_{C}\left(2 x y^{2} d x+2 x^{2} y d y+d z\right)
$$

along a path joining the origin $(0,0,0)$ and the point $(1,1,1)$ is
(A) 0
(B) 2
(C) 4
(D) 6
Q. 10 Let $f(x)$ be a real, periodic function satisfying $f(-x)=-f(x)$. The general form of its Fourier series representation would be
(A) $f(x)=a_{0}+\sum_{k=1}^{\infty} a_{k} \cos (k x)$
(B) $f(x)=\sum_{k=1}^{\infty} b_{k} \sin (k x)$
(C) $f(x)=a_{0}+\sum_{k=1}^{\infty} a_{2 k} \cos (k x)$
(D) $f(x)=\sum_{k=0}^{\infty} a_{2 k+1} \sin (2 k+1) x$
Q. 11 A resistance and a coil are connected in series and supplied from a single phase, $100 \mathrm{~V}, 50 \mathrm{~Hz}$ ac source as shown in the figure below. The rms values of plausible voltages across the resistance $\left(\mathrm{V}_{\mathrm{R}}\right)$ and coil $\left(\mathrm{V}_{\mathrm{C}}\right)$ respectively, in volts, are

(A) 65,35
(B) 50,50
(C) 60,90
(D) 60,80
Q. 12 The voltage (V) and current (A) across a load are as follows.
$v(t)=100 \sin (\omega t)$,
$i(t)=10 \sin \left(\omega t-60^{\circ}\right)+2 \sin (3 \omega t)+5 \sin (5 \omega t)$.
The average power consumed by the load, in W , is $\qquad$ .
Q. 13 A power system with two generators is shown in the figure below. The system (generators, buses and transmission lines) is protected by six overcurrent relays $R_{1}$ to $R_{6}$. Assuming a mix of directional and nondirectional relays at appropriate locations, the remote backup relays for $R_{4}$ are

(A) $\mathrm{R}_{1}, \mathrm{R}_{2}$
(B) $\mathrm{R}_{2}, \mathrm{R}_{6}$
(C) $\mathrm{R}_{2}, \mathrm{R}_{5}$
(D) $\mathrm{R}_{1}, \mathrm{R}_{6}$
Q. 14 A power system has 100 buses including 10 generator buses. For the load flow analysis using Newton-Raphson method in polar coordinates, the size of the Jacobian is
(A) $189 \times 189$
(B) $100 \times 100$
(C) $90 \times 90$
(D) $180 \times 180$
Q. 15 The inductance and capacitance of a 400 kV , three-phase, 50 Hz lossless transmission line are 1.6 $\mathrm{mH} / \mathrm{km} /$ phase and $10 \mathrm{nF} / \mathrm{km} /$ phase respectively. The sending end voltage is maintained at 400 kV . To maintain a voltage of 400 kV at the receiving end, when the line is delivering 300 MW load, the shunt compensation required is
(A) capacitive
(B) inductive
(C) resistive
(D) zero
Q. 16 A parallel plate capacitor filled with two dielectrics is shown in the figure below. If the electric field in the region A is $4 \mathrm{kV} / \mathrm{cm}$, the electric field in the region B , in $\mathrm{kV} / \mathrm{cm}$, is

(A) 1
(B) 2
(C) 4
(D) 16
Q. 17 A $50 \mathrm{MVA}, 10 \mathrm{kV}, 50 \mathrm{~Hz}$, star-connected, unloaded three-phase alternator has a synchronous reactance of 1 p.u. and a sub-transient reactance of 0.2 p.u. If a 3 -phase short circuit occurs close to the generator terminals, the ratio of initial and final values of the sinusoidal component of the short circuit current is $\qquad$ .
Q. 18 Consider a linear time-invariant system with transfer function

$$
H(s)=\frac{1}{(s+1)}
$$

If the input is $\cos (t)$ and the steady state output is $A \cos (t+\alpha)$, then the value of $A$ is $\qquad$ .
Q. 19 A three-phase diode bridge rectifier is feeding a constant DC current of 100 A to a highly inductive load. If three-phase, $415 \mathrm{~V}, 50 \mathrm{~Hz} \mathrm{AC}$ source is supplying to this bridge rectifier then the rms value of the current in each diode, in ampere, is $\qquad$ .
Q. 20 A buck-boost DC-DC converter, shown in the figure below, is used to convert 24 V battery voltage to 36 V DC voltage to feed a load of 72 W . It is operated at 20 kHz with an inductor of 2 mH and output capacitor of $1000 \mu \mathrm{~F}$. All devices are considered to be ideal. The peak voltage across the solid-state switch (S), in volt, is $\qquad$ .

Q. 21 For the network shown in the figure below, the frequency (in $\mathrm{rad} / \mathrm{s}$ ) at which the maximum phase lag occurs is, $\qquad$ .

Q. 22 The direction of rotation of a single-phase capacitor run induction motor is reversed by
(A) interchanging the terminals of the AC supply.
(B) interchanging the terminals of the capacitor.
(C) interchanging the terminals of the auxiliary winding.
(D) interchanging the terminals of both the windings.
Q. 23 In the circuit shown below, the voltage and current sources are ideal. The voltage $\left(\mathrm{V}_{\text {out }}\right)$ across the current source, in volts, is

(A) 0
(B) 5
(C) 10
(D) 20
Q. 24 The graph associated with an electrical network has 7 branches and 5 nodes. The number of independent KCL equations and the number of independent KVL equations, respectively, are
(A) 2 and 5
(B) 5 and 2
(C) 3 and 4
(D) 4 and 3
Q. 25 Two electrodes, whose cross-sectional view is shown in the figure below, are at the same potential. The maximum electric field will be at the point

(A) A
(B) B
(C) C
(D) D

## Q. 26 - Q. 55 carry two marks each.

Q. 26 The Boolean expression $\overline{(a+\bar{b}+c+\bar{d})+(b+\bar{c})}$ simplifies to
(A) 1
(B) $\overline{a . b}$
(C) $a . b$
(D) 0
Q. 27 For the circuit shown below, taking the opamp as ideal, the output voltage $\mathrm{V}_{\text {out }}$ in terms of the input voltages $V_{1}, V_{2}$ and $V_{3}$ is

(A) $1.8 \mathrm{~V}_{1}+7.2 \mathrm{~V}_{2}-\mathrm{V}_{3}$
(B) $2 \mathrm{~V}_{1}+8 \mathrm{~V}_{2}-9 \mathrm{~V}_{3}$
(C) $7.2 \mathrm{~V}_{1}+1.8 \mathrm{~V}_{2}-\mathrm{V}_{3}$
(D) $8 \mathrm{~V}_{1}+2 \mathrm{~V}_{2}-9 \mathrm{~V}_{3}$
Q. 28 Let $x_{1}(t) \leftrightarrow X_{1}(\omega)$ and $x_{2}(t) \leftrightarrow X_{2}(\omega)$ be two signals whose Fourier Transforms are as shown in the figure below. In the figure, $h(t)=e^{-2|t|}$ denotes the impulse response.


For the system shown above, the minimum sampling rate required to sample $y(t)$, so that $y(t)$ can be uniquely reconstructed from its samples, is
(A) $2 \mathrm{~B}_{1}$
(B) $2\left(\mathrm{~B}_{1}+\mathrm{B}_{2}\right)$
(C) $4\left(\mathrm{~B}_{1}+\mathrm{B}_{2}\right)$
(D) $\infty$
Q. 29 The value of the integral $2 \int_{-\infty}^{\infty}\left(\frac{\sin 2 \pi t}{\pi t}\right) d t$ is equal to
(A) 0
(B) 0.5
(C) 1
(D) 2
Q. 30

Let $y(x)$ be the solution of the differential equation $\frac{d^{2} y}{d x^{2}}-4 \frac{d y}{d x}+4 y=0$ with initial conditions $y(0)=0$ and $\left.\frac{d y}{d x}\right|_{x=0}=1$. Then the value of $y(1)$ is $\qquad$ .
Q. 31 The line integral of the vector field $F=5 x z \hat{\imath}+\left(3 x^{2}+2 y\right) \hat{\jmath}+x^{2} z \hat{k}$ along a path from $(0,0,0)$ to $(1,1,1)$ parametrized by $\left(t, t^{2}, t\right)$ is $\qquad$ -
Q. 32 Let $P=\left[\begin{array}{ll}3 & 1 \\ 1 & 3\end{array}\right]$. Consider the set $S$ of all vectors $\binom{x}{y}$ such that $a^{2}+b^{2}=1$ where $\binom{a}{b}=P\binom{x}{y}$. Then $S$ is
(A) a circle of radius $\sqrt{10}$
(B) a circle of radius $\frac{1}{\sqrt{10}}$
(C) an ellipse with major axis along $\binom{1}{1}$
(D) an ellipse with minor axis along $\binom{1}{1}$
Q. 33 Let the probability density function of a random variable, $X$, be given as:

$$
f_{X}(x)=\frac{3}{2} e^{-3 x} u(x)+a e^{4 x} u(-x)
$$

where $u(x)$ is the unit step function.
Then the value of ' $a$ ' and $\operatorname{Prob}\{X \leq 0\}$, respectively, are
(A) $2, \frac{1}{2}$
(B) $4, \frac{1}{2}$
(C) $2, \frac{1}{4}$
(D) $4, \frac{1}{4}$
Q. 34 The driving point input impedance seen from the source $V_{S}$ of the circuit shown below, in $\Omega$, is
$\qquad$ -.

Q. 35 The $z$-parameters of the two port network shown in the figure are $z_{11}=40 \Omega, z_{12}=60 \Omega$, $z_{21}=80 \Omega$ and $z_{22}=100 \Omega$. The average power delivered to $R_{L}=20 \Omega$, in watts, is $\qquad$ .

Q. 36 In the balanced 3-phase, 50 Hz , circuit shown below, the value of inductance ( L ) is 10 mH . The value of the capacitance (C) for which all the line currents are zero, in millifarads, is $\qquad$ .

Q. 37 In the circuit shown below, the initial capacitor voltage is 4 V . Switch $\mathrm{S}_{1}$ is closed at $t=0$. The charge (in $\mu \mathrm{C}$ ) lost by the capacitor from $t=25 \mu \mathrm{~s}$ to $t=100 \mu \mathrm{~s}$ is $\qquad$ .

Q. 38 The single line diagram of a balanced power system is shown in the figure. The voltage magnitude at the generator internal bus is constant and 1.0 p.u. The p.u. reactances of different components in the system are also shown in the figure. The infinite bus voltage magnitude is 1.0 p.u. A three phase fault occurs at the middle of line 2 .

The ratio of the maximum real power that can be transferred during the pre-fault condition to the maximum real power that can be transferred under the faulted condition is $\qquad$ -.

Q. 39 The open loop transfer function of a unity feedback control system is given by

$$
G(s)=\frac{K(s+1)}{s(1+T s)(1+2 s)}, \quad K>0, T>0 .
$$

The closed loop system will be stable if,
(A) $0<T<\frac{4(K+1)}{K-1}$
(B) $0<K<\frac{4(T+2)}{T-2}$
(C) $0<K<\frac{T+2}{T-2}$
(D) $0<T<\frac{8(K+1)}{K-1}$
Q. 40 At no load condition, a 3-phase, 50 Hz , lossless power transmission line has sending-end and receiving-end voltages of 400 kV and 420 kV respectively. Assuming the velocity of traveling wave to be the velocity of light, the length of the line, in km , is $\qquad$ .
Q. 41 The power consumption of an industry is 500 kVA , at 0.8 p.f. lagging. A synchronous motor is added to raise the power factor of the industry to unity. If the power intake of the motor is 100 kW , the p.f. of the motor is $\qquad$
Q. 42 The flux linkage $(\lambda)$ and current $(i)$ relation for an electromagnetic system is $\lambda=(\sqrt{i}) / g$. When $i=$ 2 A and $g$ (air-gap length) $=10 \mathrm{~cm}$, the magnitude of mechanical force on the moving part, in N , is
$\qquad$ .
Q. 43 The starting line current of a 415 V , 3-phase, delta connected induction motor is 120 A , when the rated voltage is applied to its stator winding. The starting line current at a reduced voltage of 110 V , in ampere, is $\qquad$ .
Q. 44 A single-phase, $2 \mathrm{kVA}, 100 / 200 \mathrm{~V}$ transformer is reconnected as an auto-transformer such that its kVA rating is maximum. The new rating, in kVA , is $\qquad$ .
Q. 45 A full-bridge converter supplying an RLE load is shown in figure. The firing angle of the bridge converter is $120^{\circ}$. The supply voltage $v_{m}(t)=200 \pi \sin (100 \pi t) \mathrm{V}, \mathrm{R}=20 \Omega, \mathrm{E}=800 \mathrm{~V}$. The inductor L is large enough to make the output current $\mathrm{I}_{\mathrm{L}}$ a smooth dc current. Switches are lossless. The real power fed back to the source, in kW , is $\qquad$ .

Q. 46 A three-phase Voltage Source Inverter (VSI) as shown in the figure is feeding a delta connected resistive load of $30 \Omega$ /phase. If it is fed from a 600 V battery, with $180^{\circ}$ conduction of solid-state devices, the power consumed by the load, in kW , is $\qquad$ .

Q. 47 A DC-DC boost converter, as shown in the figure below, is used to boost 360 V to 400 V , at a power of 4 kW . All devices are ideal. Considering continuous inductor current, the rms current in the solid state switch (S), in ampere, is $\qquad$ .

Q. 48 A single-phase bi-directional voltage source converter (VSC) is shown in the figure below. All devices are ideal. It is used to charge a battery at 400 V with power of 5 kW from a source $\mathrm{V}_{\mathrm{s}}=220$ V (rms), 50 Hz sinusoidal AC mains at unity p.f. If its AC side interfacing inductor is 5 mH and the switches are operated at 20 kHz , then the phase shift ( $\delta$ ) between AC mains voltage $\left(\mathrm{V}_{\mathrm{s}}\right)$ and fundamental AC rms VSC voltage ( $\mathrm{V}_{\mathrm{C} 1}$ ), in degree, is $\qquad$ .

Q. 49 Consider a linear time invariant system $\dot{x}=A x$, with initial condition $x(0)$ at $t=0$. Suppose $\alpha$ and $\beta$ are eigenvectors of $(2 \times 2)$ matrix $A$ corresponding to distinct eigenvalues $\lambda_{1}$ and $\lambda_{2}$ respectively. Then the response $x(t)$ of the system due to initial condition $x(0)=\alpha$ is
(A) $e^{\lambda_{1} t} \alpha$
(B) $e^{\lambda_{2} t} \beta$
(C) $e^{\lambda_{2} t} \alpha$
(D) $e^{\lambda_{1} t} \alpha+e^{\lambda_{2} t} \beta$
Q. 50 A second-order real system has the following properties:
a) the damping ratio $\zeta=0.5$ and undamped natural frequency $\omega_{n}=10 \mathrm{rad} / \mathrm{s}$,
b) the steady state value of the output, to a unit step input, is 1.02 .

The transfer function of the system is
(A) $\frac{1.02}{s^{2}+5 s+100}$
(B) $\frac{102}{s^{2}+10 s+100}$
(C) $\frac{100}{s^{2}+10 s+100}$
(D) $\frac{102}{s^{2}+5 s+100}$
Q. 51 Three single-phase transformers are connected to form a delta-star three-phase transformer of $110 \mathrm{kV} / 11 \mathrm{kV}$. The transformer supplies at 11 kV a load of 8 MW at 0.8 p.f. lagging to a nearby plant. Neglect the transformer losses. The ratio of phase currents in delta side to star side is
(A) $1: 10 \sqrt{3}$
(B) $10 \sqrt{3}: 1$
(C) $1: 10$
(D) $\sqrt{3}: 10$
Q. 52 The gain at the breakaway point of the root locus of a unity feedback system with open loop transfer function $G(s)=\frac{K s}{(s-1)(s-4)}$ is
(A) 1
(B) 2
(C) 5
(D) 9
Q. 53 Two identical unloaded generators are connected in parallel as shown in the figure. Both the generators are having positive, negative and zero sequence impedances of j0.4 p.u., j0.3 p.u. and j0.15 p.u., respectively. If the pre-fault voltage is 1 p.u., for a line-to-ground (L-G) fault at the terminals of the generators, the fault current, in p.u., is $\qquad$ .

Q. 54 An energy meter, having meter constant of 1200 revolutions $/ \mathrm{kWh}$, makes 20 revolutions in 30 seconds for a constant load. The load, in kW , is $\qquad$ .
Q. 55 A rotating conductor of 1 m length is placed in a radially outward (about the $z$-axis) magnetic flux density (B) of 1 Tesla as shown in figure below. Conductor is parallel to and at 1 m distance from the z -axis. The speed of the conductor in r.p.m. required to induce a voltage of 1 V across it, should be $\qquad$ .


## END OF THE QUESTION PAPER

Question Paper Name:
Subject Name:

## Duration:

Total Marks:

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Electrical Engineering
180
100


## Organizing Institute:

## Indian Institute of Technology Roorkee



The matrix $\mathbf{A}=\left[\begin{array}{ccc}\frac{3}{2} & 0 & \frac{1}{2} \\ 0 & -1 & 0 \\ \frac{1}{2} & 0 & \frac{3}{2}\end{array}\right]$ has three distinct eigenvalues and one of its eigenvectors is $\left[\begin{array}{l}1 \\ 0 \\ 1\end{array}\right]$.
Which one of the following can be another eigenvector of $\mathbf{A}$ ?
(A) $\left[\begin{array}{c}0 \\ 0 \\ -1\end{array}\right]$
(B) $\left[\begin{array}{c}-1 \\ 0 \\ 0\end{array}\right]$
(C) $\left[\begin{array}{c}1 \\ 0 \\ -1\end{array}\right]$
(D) $\left[\begin{array}{c}1 \\ -1 \\ 1\end{array}\right]$

## Question Number : 2

Correct: $\mathbf{1}$ Wrong : -0.33
For a complex number $z, \lim _{z \rightarrow i} \frac{z^{2}+1}{z^{3}+2 z-i\left(z^{2}+2\right)}$ is
(A) $-2 i$
(B) $-i$
(C) $i$
(D) $2 i$

Question Number : 3
Correct : 1 Wrong : -0.33
Let $z(t)=x(t) * y(t)$, where "*" denotes convolution. Let $c$ be a positive real-valued constant. Choose the correct expression for $z(c t)$.
(A) $c \cdot x(c t) * y(c t)$
(B) $x(c t) * y(c t)$
(C) $c \cdot x(t) * y(c t)$
(D) $c \cdot x(c t) * y(t)$

## Question Number : 4

Correct : 1 Wrong : -0.33
A solid iron cylinder is placed in a region containing a uniform magnetic field such that the cylinder axis is parallel to the magnetic field direction. The magnetic field lines inside the cylinder will
(A) bend closer to the cylinder axis
(B) bend farther away from the axis
(C) remain uniform as before
(D) cease to exist inside the cylinder

## Question Number : 5

Consider an electron, a neutron and a proton initially at rest and placed along a straight line such that the neutron is exactly at the center of the line joining the electron and proton. At $t=0$, the particles are released but are constrained to move along the same straight line. Which of these will collide first?
(A) the particles will never collide
(B) all will collide together
(C) proton and neutron
(D) electron and neutron

Question Number : 6
Correct: $\mathbf{1}$ Wrong : -0.33

The transfer function of a system is given by,

$$
\frac{V_{o}(s)}{V_{i}(s)}=\frac{1-s}{1+s}
$$

Let the output of the system be $v_{o}(t)=V_{m} \sin (\omega t+\varphi)$ for the input, $v_{i}(t)=V_{m} \sin (\omega t)$. Then the minimum and maximum values of $\varphi$ (in radians) are respectively
(A) $\frac{-\pi}{2}$ and $\frac{\pi}{2}$
(B) $\frac{-\pi}{2}$ and 0
(C) 0 and $\frac{\pi}{2}$
(D) $-\pi$ and 0

## Question Number : 7

Correct : 1 Wrong : -0.33

Consider the system with following input-output relation

$$
y[n]=\left(1+(-1)^{n}\right) x[n]
$$

where, $x[n]$ is the input and $y[n]$ is the output. The system is
(A) invertible and time invariant
(B) invertible and time varying
(C) non-invertible and time invariant
(D) non-invertible and time varying

Question Number : 8
Correct : $\mathbf{1}$ Wrong : -0.33

A 4 pole induction machine is working as an induction generator. The generator supply frequency is 60 Hz . The rotor current frequency is 5 Hz . The mechanical speed of the rotor in RPM is
(A) 1350
(B) 1650
(C) 1950
(D) 2250

A source is supplying a load through a 2 -phase, 3 -wire transmission system as shown in figure below. The instantaneous voltage and current in phase-a are $v_{a n}=220 \sin (100 \pi t) \mathrm{V}$ and $i_{a}=10 \sin (100 \pi t)$ A, respectively. Similarly for phase-b, the instantaneous voltage and current are $v_{b n}=220 \cos (100 \pi t) \mathrm{V}$ and $i_{b}=10 \cos (100 \pi t) \mathrm{A}$, respectively.


The total instantaneous power flowing from the source to the load is
(A) 2200 W
(B) $2200 \sin ^{2}(100 \pi t) \mathrm{W}$
(C) 4400 W
(D) $2200 \sin (100 \pi t) \cos (100 \pi t) \mathrm{W}$

A 3-bus power system is shown in the figure below, where the diagonal elements of $Y$-bus matrix are: $Y_{11}=-j 12 \mathrm{pu}, Y_{22}=-j 15 \mathrm{pu}$ and $Y_{33}=-j 7 \mathrm{pu}$.


The per unit values of the line reactances $p, q$ and $r$ shown in the figure are
(A) $p=-0.2, q=-0.1, r=-0.5$
(B) $p=0.2, q=0.1, r=0.5$
(C) $p=-5, q=-10, r=-2$
(D) $p=5, q=10, r=2$

A closed loop system has the characteristic equation given by $s^{3}+K s^{2}+(K+2) s+3=0$. For this system to be stable, which one of the following conditions should be satisfied?
(A) $0<K<0.5$
(B) $0.5<K<1$
(C) $0<K<1$
(D) $K>1$

Question Number : 12
Correct : 1 Wrong : -0.33
The slope and level detector circuit in a CRO has a delay of 100 ns . The start-stop sweep generator has a response time of 50 ns . In order to display correctly, a delay line of
(A) 150 ns has to be inserted into the $y$-channel
(B) 150 ns has to be inserted into the x -channel
(C) 150 ns has to be inserted into both x and y channels
(D) 100 ns has to be inserted into both x and y channels

Question Number : 13
Correct : 1 Wrong : -0.33
The Boolean expression $A B+A \bar{C}+B C$ simplifies to
(A) $B C+A \bar{C}$
(B) $A B+A \bar{C}+B$
(C) $A B+A \bar{C}$
(D) $A B+B C$

Question Number : 14
Correct : $\mathbf{1}$ Wrong : -0.33
For the circuit shown in the figure below, assume that diodes $D_{1}, D_{2}$ and $D_{3}$ are ideal.


The DC components of voltages $v_{1}$ and $v_{2}$, respectively are
(A) 0 V and 1 V
(B) -0.5 V and 0.5 V
(C) 1 V and 0.5 V
(D) 1 V and 1 V

For the power semiconductor devices IGBT, MOSFET, Diode and Thyristor, which one of the following statements is TRUE?
(A) All the four are majority carrier devices.
(B) All the four are minority carrier devices.
(C) IGBT and MOSFET are majority carrier devices, whereas Diode and Thyristor are minority carrier devices.
(D) MOSFET is majority carrier device, whereas IGBT, Diode, Thyristor are minority carrier devices.

## Question Number : 16

Correct: 1 Wrong: 0

Consider $g(t)=\left\{\begin{array}{l}t-\lfloor t\rfloor, \quad t \geq 0 \\ t-\lceil t\rceil, \text { otherwise }\end{array}\right.$, where $t \in \mathbb{R}$.
Here, $\lfloor t\rfloor$ represents the largest integer less than or equal to $t$ and $\lceil t\rceil$ denotes the smallest integer greater than or equal to $t$. The coefficient of the second harmonic component of the Fourier series representing $g(t)$ is $\qquad$

Let $I=c \iint_{R} x y^{2} d x d y$, where $R$ is the region shown in the figure and $c=6 \times 10^{-4}$. The value of $I$ equals $\qquad$ . (Give the answer up to two decimal places.)


The power supplied by the 25 V source in the figure shown below is $\qquad$ W.


The equivalent resistance between the terminals $A$ and $B$ is $\qquad$ $\Omega$.


A three-phase, 50 Hz , star-connected cylindrical-rotor synchronous machine is running as a motor. The machine is operated from a 6.6 kV grid and draws current at unity power factor (UPF). The synchronous reactance of the motor is $30 \Omega$ per phase. The load angle is $30^{\circ}$. The power delivered to the motor in kW is $\qquad$ . (Give the answer up to one decimal place).

Question Number : 21
Correct : 1 Wrong: 0

A 10-bus power system consists of four generator buses indexed as G1, G2, G3, G4 and six load buses indexed as L1, L2, L3, L4, L5, L6. The generator-bus G1 is considered as slack bus, and the load buses L3 and L4 are voltage controlled buses. The generator at bus G2 cannot supply the required reactive power demand, and hence it is operating at its maximum reactive power limit. The number of non-linear equations required for solving the load flow problem using Newton-Raphson method in polar form is $\qquad$ .

Question Number : 22
Correct : 1 Wrong: 0

Consider the unity feedback control system shown. The value of $K$ that results in a phase margin of the system to be $30^{\circ}$ is $\qquad$ . (Give the answer up to two decimal places.)


Question Number : 23
Correct: 1 Wrong: 0

The following measurements are obtained on a single phase load: $\mathrm{V}=220 \mathrm{~V} \pm 1 \%, \mathrm{I}=5.0 \mathrm{~A} \pm 1 \%$ and $\mathrm{W}=555 \mathrm{~W} \pm 2 \%$. If the power factor is calculated using these measurements, the worst case error in the calculated power factor in percent is $\qquad$ . (Give answer up to one decimal place.)

In the converter circuit shown below, the switches are controlled such that the load voltage $v_{o}(t)$ is a 400 Hz square wave.


The RMS value of the fundamental component of $v_{o}(t)$ in volts is $\qquad$ .

A 3-phase voltage source inverter is supplied from a 600 V DC source as shown in the figure below. For a star connected resistive load of $20 \Omega$ per phase, the load power for $120^{\circ}$ device conduction, in kW , is $\qquad$ .


A function $f(x)$ is defined as $f(x)=\left\{\begin{array}{ll}e^{x}, & x<1 \\ \ln x+a x^{2}+b x, & x \geq 1\end{array}\right.$, where $x \in \mathbb{R}$. Which one of the following statements is TRUE?
(A) $f(x)$ is NOT differentiable at $x=1$ for any values of $a$ and $b$.
(B) $f(x)$ is differentiable at $x=1$ for the unique values of $a$ and $b$.
(C) $f(x)$ is differentiable at $x=1$ for all values of $a$ and $b$ such that $a+b=e$.
(D) $f(x)$ is differentiable at $x=1$ for all values of $a$ and $b$.

Consider the differential equation $\left(t^{2}-81\right) \frac{d y}{d t}+5 t y=\sin (t)$ with $y(1)=2 \pi$. There exists a unique solution for this differential equation when $t$ belongs to the interval
(A) $(-2,2)$
(B) $(-10,10)$
(C) $(-10,2)$
(D) $(0,10)$

Consider the line integral $I=\int_{C}\left(x^{2}+i y^{2}\right) d z$, where $z=x+i y$. The line $c$ is shown in the figure below.


The value of $I$ is
(A) $\frac{1}{2} i$
(B) $\frac{2}{3} i$
(C) $\frac{3}{4} i$
(D) $\frac{4}{5} i$

Two passive two-port networks are connected in cascade as shown in figure. A voltage source is connected at port 1 .


Given

$$
\begin{aligned}
& V_{1}=A_{1} V_{2}+B_{1} I_{2} \\
& I_{1}=C_{1} V_{2}+D_{1} I_{2} \\
& V_{2}=A_{2} V_{3}+B_{2} I_{3} \\
& I_{2}=C_{2} V_{3}+D_{2} I_{3}
\end{aligned}
$$

$A_{1}, B_{1}, C_{1}, D_{1}, A_{2}, B_{2}, C_{2}$, and $D_{2}$ are the generalized circuit constants. If the Thevenin equivalent circuit at port 3 consists of a voltage source $V_{T}$ and an impedance $Z_{T}$, connected in series, then
(A) $V_{T}=\frac{V_{1}}{A_{1} A_{2}}, Z_{T}=\frac{A_{1} B_{2}+B_{1} D_{2}}{A_{1} A_{2}+B_{1} C_{2}}$
(B) $V_{T}=\frac{V_{1}}{A_{1} A_{2}+B_{1} C_{2}}, Z_{T}=\frac{A_{1} B_{2}+B_{1} D_{2}}{A_{1} A_{2}}$
(C) $V_{T}=\frac{V_{1}}{A_{1}+A_{2}}, Z_{T}=\frac{A_{1} B_{2}+B_{1} D_{2}}{A_{1}+A_{2}}$
(D) $V_{T}=\frac{V_{1}}{A_{1} A_{2}+B_{1} C_{2}}, Z_{T}=\frac{A_{1} B_{2}+B_{1} D_{2}}{A_{1} A_{2}+B_{1} C_{2}}$

## Question Number : 30

Let a causal LTI system be characterized by the following differential equation, with initial rest condition

$$
\frac{d^{2} y}{d t^{2}}+7 \frac{d y}{d t}+10 y(t)=4 x(t)+5 \frac{d x(t)}{d t}
$$

where, $x(t)$ and $y(t)$ are the input and output respectively. The impulse response of the system is ( $u(t)$ is the unit step function)
(A) $2 e^{-2 t} u(t)-7 e^{-5 t} u(t)$
(B) $-2 e^{-2 t} u(t)+7 e^{-5 t} u(t)$
(C) $7 e^{-2 t} u(t)-2 e^{-5 t} u(t)$
(D) $-7 e^{-2 t} u(t)+2 e^{-5 t} u(t)$

Let the signal

$$
x(t)=\sum_{k=-\infty}^{+\infty}(-1)^{k} \delta\left(t-\frac{k}{2000}\right)
$$

be passed through an LTI system with frequency response $\mathrm{H}(\omega)$, as given in the figure below


The Fourier series representation of the output is given as
(A) $4000+4000 \cos (2000 \pi t)+4000 \cos (4000 \pi t)$
(B) $2000+2000 \cos (2000 \pi t)+2000 \cos (4000 \pi t)$
(C) $4000 \cos (2000 \pi t)$
(D) $2000 \cos (2000 \pi t)$

In the system whose signal flow graph is shown in the figure, $U_{1}(s)$ and $U_{2}(s)$ are inputs. The transfer function $\frac{Y(s)}{U_{1}(s)}$ is

(A) $\frac{k_{1}}{J L s^{2}+J R s+k_{1} k_{2}}$
(B) $\frac{k_{1}}{J L s^{2}-J R s-k_{1} k_{2}}$
(C) $\frac{k_{1}-U_{2}(R+s L)}{J L s^{2}+\left(J R-U_{2} L\right) s+k_{1} k_{2}-U_{2} R}$
(D) $\frac{k_{1}-U_{2}(s L-R)}{J L s^{2}-\left(J R+U_{2} L\right) s-k_{1} k_{2}+U_{2} R}$

## Question Number : 33

The transfer function of the system $\mathrm{Y}(\mathrm{s}) / \mathrm{U}(\mathrm{s})$ whose state-space equations are given below is:

$$
\begin{gathered}
{\left[\begin{array}{l}
\dot{x}_{1}(t) \\
\dot{x}_{2}(t)
\end{array}\right]=\left[\begin{array}{ll}
1 & 2 \\
2 & 0
\end{array}\right]\left[\begin{array}{l}
x_{1}(t) \\
x_{2}(t)
\end{array}\right]+\left[\begin{array}{l}
1 \\
2
\end{array}\right] u(t)} \\
y(\mathrm{t})=\left[\begin{array}{ll}
1 & 0
\end{array}\right]\left[\begin{array}{l}
x_{1}(t) \\
x_{2}(t)
\end{array}\right] .
\end{gathered}
$$

(A) $\frac{(s+2)}{\left(s^{2}-2 s-2\right)}$
(B) $\frac{(s-2)}{\left(s^{2}+s-4\right)}$
(C) $\frac{(s-4)}{\left(s^{2}+s-4\right)}$
(D) $\frac{(s+4)}{\left(s^{2}-s-4\right)}$

The load shown in the figure is supplied by a 400 V (line-to-line), 3-phase source (RYB sequence). The load is balanced and inductive, drawing 3464 VA. When the switch S is in position N, the three watt-meters $\mathrm{W}_{1}, \mathrm{~W}_{2}$ and $\mathrm{W}_{3}$ read 577.35 W each. If the switch is moved to position Y , the readings of the watt-meters in watts will be:

(A) $\mathrm{W}_{1}=1732$ and $\mathrm{W}_{2}=\mathrm{W}_{3}=0$
(B) $\mathrm{W}_{1}=0, \mathrm{~W}_{2}=1732$ and $\mathrm{W}_{3}=0$

The approximate transfer characteristic for the circuit shown below with an ideal operational amplifier and diode will be


(B)

(D)

The output expression for the Karnaugh map shown below is

(A) $B \bar{D}+B C D$
(B) $B \bar{D}+A B$
(C) $\bar{B} D+A B C$
(D) $B \bar{D}+A B C$

## Question Number : 37

The logical gate implemented using the circuit shown below where, $\mathrm{V}_{1}$ and $\mathrm{V}_{2}$ are inputs (with 0 V as digital 0 and 5 V as digital 1 ) and $\mathrm{V}_{\text {out }}$ is the output, is

(A) NOT
(B) NOR
(C) NAND
(D) XOR

The input voltage $\mathrm{V}_{\mathrm{DC}}$ of the buck-boost converter shown below varies from 32 V to 72 V . Assume that all components are ideal, inductor current is continuous, and output voltage is ripple free. The range of duty ratio $D$ of the converter for which the magnitude of the steady-state output voltage remains constant at 48 V is

(A) $\frac{2}{5} \leq D \leq \frac{3}{5}$
(B) $\frac{2}{3} \leq D \leq \frac{3}{4}$
(C) $0 \leq D \leq 1$
(D) $\frac{1}{3} \leq D \leq \frac{2}{3}$

A load is supplied by a $230 \mathrm{~V}, 50 \mathrm{~Hz}$ source. The active power $P$ and the reactive power $Q$ consumed by the load are such that $1 \mathrm{~kW} \leq P \leq 2 \mathrm{~kW}$ and $1 \mathrm{kVAR} \leq Q \leq 2 \mathrm{kVAR}$ A capacitor connected across the load for power factor correction generates 1 kVAR reactive power. The worst case power factor after power factor correction is
(A) 0.447 lag
(B) 0.707 lag
(C) 0.894 lag
(D) 1

The bus admittance matrix for a power system network is

$$
\left[\begin{array}{ccc}
-j 39.9 & j 20 & j 20 \\
j 20 & -j 39.9 & j 20 \\
j 20 & j 20 & -j 39.9
\end{array}\right] \text { pu. }
$$

There is a transmission line, connected between buses 1 and 3 , which is represented by the circuit shown in figure.


If this transmission line is removed from service, what is the modified bus admittance matrix?
(A) $\left[\begin{array}{ccc}-j 19.9 & j 20 & 0 \\ j 20 & -j 39.9 & j 20 \\ 0 & j 20 & -j 19.9\end{array}\right]$ pu
(B) $\left[\begin{array}{ccc}-j 39.95 & j 20 & 0 \\ j 20 & -j 39.9 & j 20 \\ 0 & j 20 & -j 39.95\end{array}\right] \mathrm{pu}$
(C) $\left[\begin{array}{ccc}-j 19.95 & j 20 & 0 \\ j 20 & -j 39.9 & j 20 \\ 0 & j 20 & -j 19.95\end{array}\right] \mathrm{pu}$
(D) $\left[\begin{array}{ccc}-j 19.95 & j 20 & j 20 \\ j 20 & -j 39.9 & j 20 \\ j 20 & j 20 & -j 19.95\end{array}\right] \mathrm{pu}$

## Question Number : 41

Correct : 2 Wrong: -0.66
The switch in the figure below was closed for a long time. It is opened at $t=0$. The current in the inductor of 2 H for $t \geq 0$, is

(A) $2.5 e^{-4 t}$
(B) $5 e^{-4 t}$
(C) $2.5 e^{-0.25 t}$
(D) $5 e^{-0.25 t}$

Only one of the real roots of $f(x)=x^{6}-x-1$ lies in the interval $1 \leq x \leq 2$ and bisection method is used to find its value. For achieving an accuracy of 0.001 , the required minimum number of iterations is $\qquad$ .

Question Number : 43

In the circuit shown below, the maximum power transferred to the resistor $R$ is $\qquad$ W.


The magnitude of magnetic flux density (B) in micro Teslas ( $\mu T$ ), at the center of a loop of wire wound as a regular hexagon of side length 1 m carrying a current $(I=1 \mathrm{~A})$, and placed in vacuum as shown in the figure is $\qquad$ . (Give the answer up to two decimal places.)


A $375 \mathrm{~W}, 230 \mathrm{~V}, 50 \mathrm{~Hz}$, capacitor start single-phase induction motor has the following constants for the main and auxiliary windings (at starting): $Z_{m}=(12.50+j 15.75) \Omega$ (main winding), $Z_{a}=(24.50+j 12.75) \Omega$ (auxiliary winding). Neglecting the magnetizing branch, the value of the capacitance (in $\mu \mathrm{F}$ ) to be added in series with the auxiliary winding to obtain maximum torque at starting is $\qquad$ .

Question Number : 46
Correct : 2 Wrong: 0

Two parallel connected, three-phase, $50 \mathrm{~Hz}, 11 \mathrm{kV}$, star-connected synchronous machines A and B, are operating as synchronous condensers. They together supply 50 MVAR to a 11 kV grid. Current supplied by both the machines are equal. Synchronous reactances of machine A and machine B are $1 \Omega$ and $3 \Omega$, respectively. Assuming the magnetic circuit to be linear, the ratio of excitation current of machine $A$ to that of machine $B$ is $\qquad$ (Give the answer up to two decimal places.)

Question Number : 47
Correct: 2 Wrong: 0

A 220 V DC series motor runs drawing a current of 30 A from the supply. Armature and field circuit resistances are $0.4 \Omega$ and $0.1 \Omega$, respectively. The load torque varies as the square of the speed. The flux in the motor may be taken as being proportional to the armature current. To reduce the speed of the motor by $50 \%$, the resistance in ohms that should be added in series with the armature is $\qquad$ (Give the answer up to two decimal places.)

Question Number : 48
Correct : 2 Wrong: 0

A three-phase, three winding $\Delta / \Delta / \mathrm{Y}(1.1 \mathrm{kV} / 6.6 \mathrm{kV} / 400 \mathrm{~V})$ transformer is energized from AC mains at the 1.1 kV side. It supplies 900 kVA load at 0.8 power factor lag from the 6.6 kV winding and 300 kVA load at 0.6 power factor lag from the 400 V winding. The RMS line current in ampere drawn by the 1.1 kV winding from the mains is $\qquad$ . (Give the answer up to one decimal place.)

A separately excited DC generator supplies 150 A to a 145 V DC grid. The generator is running at 800 RPM . The armature resistance of the generator is $0.1 \Omega$. If the speed of the generator is increased to 1000 RPM, the current in amperes supplied by the generator to the DC grid is
$\qquad$ . (Give the answer up to one decimal place.)

Question Number : 50 Correct:2 Wrong: 0

For a system having transfer function $G(s)=\frac{-s+1}{s+1}$, a unit step input is applied at time $t=0$. The value of the response of the system at $t=1.5 \mathrm{sec}$ (rounded off to three decimal places) is

Consider a causal and stable LTI system with rational transfer function $H(z)$, whose corresponding impulse response begins at $n=0$. Furthermore, $H(1)=\frac{5}{4}$. The poles of $H(z)$ are $p_{k}=\frac{1}{\sqrt{2}} \exp \left(j \frac{(2 k-1) \pi}{4}\right)$ for $k=1,2,3,4$. The zeros of $H(z)$ are all at $z=0$. Let $g[n]=j^{n} h[n]$. The value of $g[8]$ equals $\qquad$ . (Give the answer up to three decimal places.)

The circuit shown in the figure uses matched transistors with a thermal voltage $\mathrm{V}_{\mathrm{T}}=25 \mathrm{mV}$. The base currents of the transistors are negligible. The value of the resistance R in $k \Omega$ that is required to provide $1 \mu \mathrm{~A}$ bias current for the differential amplifier block shown is $\qquad$ . (Give the answer up to one decimal place.)


Question Number : 53
Correct : 2 Wrong: 0
The figure below shows an uncontrolled diode bridge rectifier supplied from a $220 \mathrm{~V}, 50 \mathrm{~Hz}, 1-$ phase ac source. The load draws a constant current $I_{o}=14 \mathrm{~A}$. The conduction angle of the diode $D_{1}$ in degrees (rounded off to two decimal places) is $\qquad$ .


The positive, negative, and zero sequence reactances of a wye-comected synchronous generator are $0.2 \mathrm{pu}, 0.2 \mathrm{pu}$, and 0.1 pu , respectively. The generator is on open circuit with a terminal voltage of 1 pu . The minimum value of the inductive reactance, in pu , required to be connected between neutral and ground so that the fault current does not exceed 3.75 pu if a single line to ground fault occurs at the terminals is $\qquad$ (assume fault impedance to be zero). (Give the answer up to one decimal place.)

Question Number : 55
Correct: 2 Wrong: 0

The figure shows the single line diagram of a power system with a double circuit transmission line. The expression for electrical power is $1.5 \sin \delta$, where $\delta$ is the rotor angle. The system is operating at the stable equilibrium point with mechanical power equal to 1 pu. If one of the transmission line circuits is removed, the maximum value of $\delta$, as the rotor swings, is 1.221 radian. If the expression for electrical power with one transmission line circuit removed is $P_{\max } \sin \delta$, the value of $P_{\max }$, in pu is $\qquad$ . (Give the answer up to three decimal places.)


After Rajendra Chola returned from his voyage to Indonesia, he $\qquad$ to visit the temple in Thanjavur.
(A) was wishing
(B) is wishing
(C) wished
(D) had wished

## Question Number : 57

Correct : 1 Wrong : -0.33

Research in the workplace reveals that people work for many reasons $\qquad$ .
(A) money beside
(B) beside money
(C) money besides
(D) besides money

Question Number : 58
Correct : 1 Wrong : -0.33

Rahul, Murali, Srinivas and Arul are seated around a square table. Rahul is sitting to the left of Murali. Srinivas is sitting to the right of Arul. Which of the following pairs are seated opposite each other?
(A) Rahul and Murali
(B) Srinivas and Arul
(C) Srinivas and Murali
(D) Srinivas and Rahul

Question Number : 59
Correct : $\mathbf{1}$ Wrong : -0.33

Find the smallest number $y$ such that $y \times 162$ is a perfect cube.
(A) 24
(B) 27
(C) 32
(D) 36

Question Number : 60
Correct : 1 Wrong : -0.33

The probability that a $k$-digit number does NOT contain the digits 0,5 , or 9 is
(A) $0.3^{k}$
(B) $0.6^{k}$
(C) $0.7^{k}$
(D) $0.9^{k}$

## Question Number : 61

"The hold of the nationalist imagination on our colonial past is such that anything inadequately or improperly nationalist is just not history."

Which of the following statements best reflects the author's opinion?
(A) Nationalists are highly imaginative.
(B) History is viewed through the filter of nationalism.
(C) Our colonial past never happened.
(D) Nationalism has to be both adequately and properly imagined.

Question Number : 62
Correct : 2 Wrong : -0.66

Six people are seated around a circular table. There are at least two men and two women. There are at least three right-handed persons. Every woman has a left-handed person to her immediate right. None of the women are right-handed. The number of women at the table is
(A) 2
(B) 3
(C) 4
(D) Cannot be determined

Question Number : 63
Correct : 2 Wrong : -0.66
The expression $\frac{(x+y)-|x-y|}{2}$ is equal to
(A) the maximum of $x$ and $y$
(B) the minimum of $x$ and $y$
(C) 1
(D) none of the above

## Question Number : 64

Correct : 2 Wrong : -0.66

Arun, Gulab, Neel and Shweta must choose one shirt each from a pile of four shirts coloured red, pink, blue and white respectively. Arun dislikes the colour red and Shweta dislikes the colour white. Gulab and Neel like all the colours. In how many different ways can they choose the shirts so that no one has a shirt with a colour he or she dislikes?
(A) 21
(B) 18
(C) 16
(D) 14

A contour line joins locations having the same height above the mean sea level. The following is a contour plot of a geographical region. Contour lines are shown at 25 m intervals in this plot. If in a flood, the water level rises to 525 m , which of the villages $\mathrm{P}, \mathrm{Q}, \mathrm{R}, \mathrm{S}, \mathrm{T}$ get submerged?

(A) P, Q
(B) P, Q, T
(C) R, S, T
(D) $\mathrm{Q}, \mathrm{R}, \mathrm{S}$

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Total Marks:

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100


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An urn contains 5 red balls and 5 black balls. In the first draw, one ball is picked at random and discarded without noticing its colour. The probability to get a red ball in the second draw is
(A) $\frac{1}{2}$
(B) $\frac{4}{9}$
(C) $\frac{5}{9}$
(D) $\frac{6}{9}$

## Question Number : 2

Correct : 1 Wrong: -0.33
Consider a solid sphere of radius 5 cm made of a perfect electric conductor. If one million electrons are added to this sphere, these electrons will be distributed
(A) uniformly over the entire volume of the sphere
(B) uniformly over the outer surface of the sphere
(C) concentrated around the centre of the sphere
(D) along a straight line passing through the centre of the sphere

## Question Number : 3

Correct : 1 Wrong: -0.33

The figures show diagramatic representations of vector fields $\vec{X}, \vec{Y}$, and $\vec{Z}$, respectively. Which one of the following choices is true?

(A) $\nabla \cdot \vec{X}=0, \nabla \times \vec{Y} \neq 0, \nabla \times \vec{Z}=0$
(B) $\nabla \cdot \vec{X} \neq 0, \nabla \times \vec{Y}=0, \nabla \times \vec{Z} \neq 0$
(C) $\nabla \cdot \vec{X} \neq 0, \nabla \times \vec{Y} \neq 0, \nabla \times \vec{Z} \neq 0$
(D) $\nabla \cdot \vec{X}=0, \nabla \times \vec{Y}=0, \nabla \times \vec{Z}=0$

The pole-zero plots of three discrete-time systems $\mathbf{P}, \mathbf{Q}$ and $\mathbf{R}$ on the $z$-plane are shown below.


Which one of the following is TRUE about the frequency selectivity of these systems?
(A) All three are high-pass filters.
(B) All three are band-pass filters.
(C) All three are low-pass filters.
(D) $\mathbf{P}$ is a low-pass filter, $\mathbf{Q}$ is a band-pass filter and $\mathbf{R}$ is a high-pass filter.

## Question Number : 5

Correct : $\mathbf{1}$ Wrong : -0.33

If a synchronous motor is running at a leading power factor, its excitation induced voltage $\left(\mathrm{E}_{f}\right)$ is
(A) equal to terminal voltage $\mathrm{V}_{\mathrm{t}}$
(B) higher than the terminal voltage $\mathrm{V}_{\mathrm{t}}$
(C) less than terminal voltage $\mathrm{V}_{\mathrm{t}}$
(D) dependent upon supply voltage $\mathrm{V}_{\mathrm{t}}$

Question Number : 6
Correct : $\mathbf{1}$ Wrong : -0.33

When a unit ramp input is applied to the unity feedback system having closed loop transfer function $\frac{C(s)}{R(s)}=\frac{K s+b}{s^{2}+a s+b},(a>0, b>0, K>0)$, the steady state error will be
(A) 0
(B) $\frac{a}{b}$
(C) $\frac{a+K}{b}$
(D) $\frac{a-K}{b}$

The transfer function $C(s)$ of a compensator is given below.

$$
C(s)=\frac{\left(1+\frac{s}{0.1}\right)\left(1+\frac{s}{100}\right)}{(1+s)\left(1+\frac{s}{10}\right)}
$$

The frequency range in which the phase (lead) introduced by the compensator reaches the maximum is
(A) $0.1<\omega<1$
(B) $1<\omega<10$
(C) $10<\omega<100$
(D) $\omega>100$

## Question Number : 8

Two resistors with nominal resistance values $R_{1}$ and $R_{2}$ have additive uncertainties $\Delta R_{1}$ and $\Delta R_{2}$, respectively. When these resistances are connected in parallel, the standard deviation of the error in the equivalent resistance $R$ is
(A) $\pm \sqrt{\left\{\frac{\partial R}{\partial R_{1}} \Delta R_{1}\right\}^{2}+\left\{\frac{\partial R}{\partial R_{2}} \Delta R_{2}\right\}^{2}}$
(B) $\pm \sqrt{\left\{\frac{\partial R}{\partial R_{2}} \Delta R_{1}\right\}^{2}+\left\{\frac{\partial R}{\partial R_{1}} \Delta R_{2}\right\}^{2}}$
(C) $\pm \sqrt{\left\{\frac{\partial R}{\partial R_{1}}\right\}^{2} \Delta R_{2}+\left\{\frac{\partial R}{\partial R_{2}}\right\}^{2} \Delta R_{1}}$
(D) $\pm \sqrt{\left\{\frac{\partial R}{\partial R_{1}}\right\}^{2} \Delta R_{1}+\left\{\frac{\partial R}{\partial R_{2}}\right\}^{2} \Delta R_{2}}$

## Question Number : 9

A stationary closed Lissajous pattern on an oscilloscope has 3 horizontal tangencies and 2 vertical tangencies for a horizontal input with frequency 3 kHz . The frequency of the vertical input is
(A) 1.5 kHz
(B) 2 kHz
(C) 3 kHz
(D) 4.5 kHz

For a 3-input logic circuit shown below, the output $Z$ can be expressed as

(A) $Q+\bar{R}$
(B) $P \bar{Q}+R$
(C) $\bar{Q}+R$
(D) $P+\bar{Q}+R$

## Question Number : 11

Correct : 1 Wrong : -0.33
A phase-controlled, single-phase, full-bridge conyerter is supplying a highly inductive DC load. The converter is fed from a $230 \mathrm{~V}, 50 \mathrm{~Hz}, \mathrm{AC}$ source. The fundamental frequency in Hz of the voltage ripple on the $D C$ side is
(A) 25
(B) 50
(C) 100
(D) 300

## Question Number : 12

Correct : 1 Wrong : -0.33
In the circuit shown, the diodes are ideal, the inductance is small, and $I_{0} \neq 0$. Which one of the following statements is true?

(A) $\mathrm{D}_{1}$ conducts for greater than $180^{\circ}$ and $\mathrm{D}_{2}$ conducts for greater than $180^{\circ}$.
(B) $\mathrm{D}_{2}$ conducts for more than $180^{\circ}$ and $\mathrm{D}_{1}$ conducts for $180^{\circ}$.
(C) $D_{1}$ conducts for $180^{\circ}$ and $D_{2}$ conducts for $180^{\circ}$.
(D) $\mathrm{D}_{1}$ conducts for more than $180^{\circ}$ and $\mathrm{D}_{2}$ conducts for $180^{\circ}$.

A three-phase voltage source inverter with ideal devices operating in $180^{\circ}$ conduction mode is feeding a balanced star-connected resistive load. The DC voltage input is $V_{d c}$. The peak of the fundamental component of the phase voltage is
(A) $\frac{V_{d c}}{\pi}$
(B) $\frac{2 V_{d c}}{\pi}$
(C) $\frac{3 V_{d c}}{\pi}$
(D) $\frac{4 V_{d c}}{\pi}$

## Question Number : 14

Correct : 1 Wrong : -0.33

A 3-phase, 4-pole, $400 \mathrm{~V}, 50 \mathrm{~Hz}$ squirrel-cage induction motor is operating at a slip of 0.02 . The speed of the rotor flux in mechanical rad/sec, sensed by a stationary observer, is closest to
(A) 1500
(B) 1470
(C) 157
(D) 154

Question Number : 15
Correct : 1 Wrong : -0.33

The figure shows the per-phase representation of a phase-shifting transformer connected between buses 1 and 2 , where $\alpha$ is a complex number with non-zero real and imaginary parts.


For the given circuit, $Y_{b u s}$ and $Z_{b u s}$ are bus admittance matrix and bus impedance matrix, respectively, each of size $2 \times 2$. Which one of the following statements is true?
(A) Both $Y_{\text {bus }}$ and $Z_{\text {bus }}$ are symmetric
(B) $Y_{b u s}$ is symmetric and $Z_{b u s}$ is unsymmetric
(C) $Y_{b u s}$ is unsymmetric and $Z_{b u s}$ is
(D) Both $Y_{b u s}$ and $Z_{b u s}$ are unsymmetric symmetric

The figure below shows the circuit diagram of a controlled rectifier supplied from a $230 \mathrm{~V}, 50 \mathrm{~Hz}$, 1 -phase voltage source and a 10:1 ideal transformer. Assume that all devices are ideal. The firing angles of the thyristors $T_{1}$ and $T_{2}$ are $90^{\circ}$ and $270^{\circ}$, respectively.


The RMS value of the current through diode $D_{3}$ in amperes is $\qquad$

Question Number : 17
Correct : 1 Wrong : 0

Assume that in a traffic junction, the cycle of the traffic signal lights is 2 minutes of green (vehicle does not stop) and 3 minutes of red (vehicle stops). Consider that the arrival time of vehicles at the junction is uniformly distributed over 5 minute cycle. The expected waiting time (in minutes) for the vehicle at the junction is $\qquad$

Question Number : 18
Correct : 1 Wrong: 0

Consider a function $f(x, y, z)$ given by

$$
f(x, y, z)=\left(x^{2}+y^{2}-2 z^{2}\right)\left(y^{2}+z^{2}\right)
$$

The partial derivative of this function with respect to $x$ at the point, $x=2, y=1$ and $z=3$ is
$\qquad$ .

Let $x$ and $y$ be integers satisfying the following equations

$$
\begin{gathered}
2 x^{2}+y^{2}=34 \\
x+2 y=11
\end{gathered}
$$

The value of $(x+y)$ is $\qquad$ .

Question Number : 20
Let $y^{2}-2 y+1=x$ and $\sqrt{x}+y=5$. The value of $x+\sqrt{y}$ equals $\qquad$ . (Give the answer up to three decimal places)

For the given 2-port network, the value of transfer impedance $z_{21}$ in ohms is $\qquad$


The initial charge in the 1 F capacitor present in the circuit shown is zero. The energy in joules transferred from the DC source until steady state condition is reached equals $\qquad$ (Give the answer up to one decimal place.)


The mean square value of the given periodic waveform $f(t)$ is $\qquad$


The nominal $-\pi$ circuit of a transmission line is shown in the figure.


Impedance $Z=100 \angle 80^{\circ} \Omega$ and reactance $X=3300 \Omega$. The magnitude of the characteristic impedance of the transmission line, in $\Omega$, is $\qquad$ . (Give the answer up to one decimal place.)

## Question Number : 25

Correct: 1 Wrong: 0

In a load flow problem solved by Newton-Raphson method with polar coordinates, the size of the Jacobian is $100 \times 100$. If there are 20 PV buses in addition to PQ buses and a slack bus, the total number of buses in the system is $\qquad$ .

Question Number : 26
Correct : $\mathbf{2}$ Wrong: -0.66
Let $g(x)=\left\{\begin{array}{ll}-x, & x \leq 1 \\ x+1, & x \geq 1\end{array}\right.$ and $f(x)=\left\{\begin{array}{ll}1-x, & x \leq 0 \\ x^{2}, & x>0\end{array}\right.$.
Consider the composition of $f$ and $g$, i.e., $(f \circ g)(x)=f(g(x))$. The number of discontinuities in $(f \circ g)(x)$ present in the interval $(-\infty, 0)$ is:
(A) 0
(B) 1
(C) 2
(D) 4

Question Number : 27
Correct : 2 Wrong : -0.66
The value of the contour integral in the complex-plane

$$
\oint \frac{z^{3}-2 z+3}{z-2} d z
$$

along the contour $|z|=3$, taken counter-clockwise is
(A) $-18 \pi i$
(B) 0
(C) $14 \pi i$
(D) $48 \pi i$

The eigenvalues of the matrix given below are

$$
\left[\begin{array}{ccc}
0 & 1 & 0 \\
0 & 0 & 1 \\
0 & -3 & -4
\end{array}\right]
$$

(A) $(0,-1,-3)$
(B) $(0,-2,-3)$
(C) $(0,2,3)$
(D) $(0,1,3)$

Question Number : 29
Correct: $\mathbf{2}$ Wrong: - $\mathbf{0 . 6 6}$

For the balanced Y-Y connected 3-phase circuit shown in the figure below, the line-line voltage is 208 V rms and the total power absorbed by the load is 432 W at a power factor of 0.6 leading.


The approximate value of the impedance $Z$ is
(A) $33 \angle-53.1^{\circ} \Omega$
(B) $60 \angle 53.1^{\circ} \Omega$
(C) $60 \angle-53.1^{\circ} \Omega$
(D) $180 \angle-53.1^{\circ} \Omega$

## Question Number : 30

In the circuit shown below, the value of capacitor C required for maximum power to be transferred to the load is

(A) 1 nF
(B) $1 \mu \mathrm{~F}$
(C) 1 mF
(D) 10 mF

The output $y(t)$ of the following system is to be sampled, so as to reconstruct it from its samples uniquely. The required minimum sampling rate is

(A) $1000 \mathrm{samples} / \mathrm{s}$
(B) 1500 samples/s
(C) $2000 \mathrm{samples} / \mathrm{s}$
(D) $3000 \mathrm{samples} / \mathrm{s}$

A cascade system having the impulse responses $h_{1}(n)=\{1,-1\}$ and $h_{2}(n)=\{1,1\}$ is shown in the figure below, where symbol $\uparrow$ denotes the time origin.


The input sequence $x(n)$ for which the cascade system produces an output sequence $y(n)=\{1,2,1,-1,-2,-1\}$ is
(A) $x(n)=\{1,2,1,1\}$
(B) $x(n)=\{1,1,2,2\}$
(C) $x(n)=\{1,1,1,1\}$
(D) $x(n)=\{1,2,2,1\}$

## Question Number : 33

A $220 \mathrm{~V}, 10 \mathrm{~kW}, 900 \mathrm{rpm}$ separately excited DC motor has an armature resistance $\mathrm{R}_{\mathrm{a}}=0.02 \Omega$. When the motor operates at rated speed and with rated terminal voltage, the electromagnetic torque developed by the motor is 70 Nm . Neglecting the rotational losses of the machine, the current drawn by the motor from the 220 V supply is
(A) 34.2 A
(B) 30 A
(C) 22 A
(D) 4.84 A

The root locus of the feedback control system having the characteristic equation $s^{2}+6 K s+2 s+5=0$ where $K>0$, enters into the real axis at
(A) $s=-1$
(B) $s=-\sqrt{5}$
(C) $s=-5$
(D) $s=\sqrt{5}$

The range of $K$ for which all the roots of the equation $s^{3}+3 s^{2}+2 s+K=0$ are in the left half of the complex s-plane is
(A) $0<K<6$
(B) $0<K<16$
(C) $6<K<36$
(D) $6<K<16$

Question Number : 36

Which of the following systems has maximum peak overshoot due to a unit step input?
(A) $\frac{100}{s^{2}+10 s+100}$
(B) $\frac{100}{s^{2}+15 s+100}$
(C) $\frac{100}{s^{2}+5 s+100}$
(D) $\frac{100}{s^{2}+20 s+100}$

Question Number : 37
Correct : 2 Wrong : -0.66
For the circuit shown in the figure below, it is given that $\mathrm{V}_{\mathrm{CE}}=\frac{\mathrm{V}_{\mathrm{CC}}}{2}$. The transistor has $\beta=29$ and $\mathrm{V}_{\mathrm{BE}}=0.7 \mathrm{~V}$ when the $\mathrm{B}-\mathrm{E}$ junction is forward biased.


For this circuit, the value of $\frac{R_{B}}{R}$ is
(A) 43
(B) 92
(C) 121
(D) 129

For the circuit shown below, assume that the OPAMP is ideal.


Which one of the following is TRUE?
(A) $v_{\mathrm{O}}=v_{S}$
(B) $v_{\mathrm{O}}=1.5 v_{S}$
(C) $v_{\mathrm{O}}=2.5 v_{s}$
(D) $v_{0}=5 v_{S}$

The figure below shows a half-bridge voltage source inverter supplying an RL-load with $\mathrm{R}=40 \Omega$ and $\mathrm{L}=\left(\frac{0.3}{\pi}\right) \mathrm{H}$. The desired fundamental frequency of the load voltage is 50 Hz . The switch control signals of the converter are generated using sinusoidal pulse width modulation with modulation index, $M=0.6$. At 50 Hz , the RL-load draws an active power of 1.44 kW . The value of DC source voltage $\mathrm{V}_{\mathrm{DC}}$ in volts is

(A) $300 \sqrt{2}$
(B) 500
(C) $500 \sqrt{2}$
(D) $1000 \sqrt{2}$

## Question Number : 40

Correct : 2 Wrong : -0.66

A person decides to toss a fair coin repeatedly until he gets a head. He will make at most 3 tosses. Let the random variable $Y$ denote the number of heads. The value of $\operatorname{var}\{Y\}$, where var $\{\cdot\}$ denotes the variance, equals
(A) $\frac{7}{8}$
(B) $\frac{49}{64}$
(C) $\frac{7}{64}$
(D) $\frac{105}{64}$

For the network given in figure below, the Thevenin's voltage $V_{a b}$ is

(A) -1.5 V
(B) -0.5 V
(C) 0.5 V
(D) 1.5 V

Question Number : 42
Correct: 2 Wrong: 0

A 120 V DC shunt motor takes 2 A at no load. It takes 7 A on full load while running at 1200 rpm . The armature resistance is $0.8 \Omega$, and the shunt field resistance is $240 \Omega$. The no load speed, in rpm, is $\qquad$ .

## Question Number : 43

Correct: 2 Wrong: 0

A star-connected, $12.5 \mathrm{~kW}, 208 \mathrm{~V}$ (line), 3-phase, 60 Hz squirrel cage induction motor has following equivalent circuit parameters per phase referred to the stator: $\mathrm{R}_{1}=0.3 \Omega, \mathrm{R}_{2}=0.3 \Omega$, $\mathrm{X}_{1}=0.41 \Omega, \mathrm{X}_{2}=0.41 \Omega$. Neglect shunt branch in the equivalent circuit. The starting current (in Ampere) for this motor when connected to an 80 V (line), $20 \mathrm{~Hz}, 3$-phase AC source is $\qquad$ .

Question Number : 44
Correct: 2 Wrong: 0

A $25 \mathrm{kVA}, 400 \mathrm{~V}, \Delta$-connected, 3-phase, cylindrical rotor synchronous generator requires a field current of 5 A to maintain the rated armature current under short-circuit condition. For the same field current, the open-circuit voltage is 360 V . Neglecting the armature resistance and magnetic saturation, its voltage regulation (in \% with respect to terminal voltage), when the generator delivers the rated load at 0.8 pf leading, at rated terminal voltage is $\qquad$ .

If the primary line voltage rating is 3.3 kV (Y side) of a $25 \mathrm{kVA}, \mathrm{Y}-\Delta$ transformer (the per phase turns ratio is 5:1), then the line current rating of the secondary side (in Ampere) is $\qquad$ .

## Question Number : 46

Correct: 2 Wrong: 0

Consider the system described by the following state space representation

$$
\begin{aligned}
& {\left[\begin{array}{l}
\dot{x}_{1}(t) \\
\dot{x}_{2}(t)
\end{array}\right]=\left[\begin{array}{rr}
0 & 1 \\
0 & -2
\end{array}\right]\left[\begin{array}{l}
x_{1}(t) \\
x_{2}(t)
\end{array}\right]+\left[\begin{array}{l}
0 \\
1
\end{array}\right] u(t)} \\
& y(t)=\left[\begin{array}{ll}
1 & 0
\end{array}\right]\left[\begin{array}{l}
x_{1}(t) \\
x_{2}(t)
\end{array}\right]
\end{aligned}
$$

If $u(t)$ is a unit step input and $\left[\begin{array}{l}x_{1}(0) \\ x_{2}(0)\end{array}\right]=\left[\begin{array}{l}1 \\ 0\end{array}\right]$, the value of output $y(t)$ at $t=1 \mathrm{sec}$ (rounded off to three decimal places) is $\qquad$

A $101 / 2$ digit timer counter possesses a base clock of frequency 100 MHz . When measuring a particular input, the reading obtained is the same in: (i) Frequency mode of operation with a gating time of one second and (ii) Period mode of operation (in the $\times 10 \mathrm{~ns}$ scale). The frequency of the unknown input (reading obtained) in Hz is $\qquad$ .

Question Number : 48
Correct: 2 Wrong: 0

In the circuit shown in the figure, the diode used is ideal. The input power factor is $\qquad$ . (Give the answer up to two decimal places.)


For the synchronous sequential circuit shown below, the output $Z$ is zero for the initial conditions $Q_{A} Q_{B} Q_{C}=Q_{A}^{\prime} Q_{B}^{\prime} Q_{C}^{\prime}=100$.


The minimum number of clock cycles after which the output Z would again become zero is

In the circuit shown all elements are ideal and the switch S is operated at 10 kHz and $60 \%$ duty ratio. The capacitor is large enough so that the ripple across it is negligible and at steady state acquires a voltage as shown. The peak current in amperes drawn from the 50 V DC source is
$\qquad$ . (Give the answer up to one decimal place.)


Question Number : 51
Correct: 2 Wrong: 0

Consider an overhead transmission line with 3 -phase, 50 Hz balanced system with conductors located at the vertices of an equilateral triangle of length $\mathrm{D}_{\mathrm{ab}}=\mathrm{D}_{\mathrm{bc}}=\mathrm{D}_{\mathrm{ca}}=1 \mathrm{~m}$ as shown in figure below. The resistances of the conductors are neglected. The geometric mean radius (GMR) of each conductor is 0.01 m . Neglecting the effect of ground, the magnitude of positive sequence reactance in $\Omega / k n$ (rounded off to three decimal places) is $\qquad$


Question Number : 52
Correct : 2 Wrong: 0

A 3-phase, 50 Hz generator supplies power of 3 MW at 17.32 kV to a balanced 3-phase inductive load through an overhead line. The per phase line resistance and reactance are $0.25 \Omega$ and $3.925 \Omega$ respectively. If the voltage at the generator terminal is 17.87 kV , the power factor of the load is
$\qquad$ .

Two generating units rated 300 MW and 400 MW have governor speed regulation of $6 \%$ and $4 \%$ respectively from no load to full load. Both the generating units are operating in parallel to share a load of 600 MW . Assuming free governor action, the load shared by the larger unit is $\qquad$ MW.

Question Number : 54
Correct : 2 Wrong : 0

A 3-phase, 2-pole, 50 Hz , synchronous generator has a rating of $250 \mathrm{MVA}, 0.8 \mathrm{pf}$ lagging. The kinetic energy of the machine at synchronous speed is 1000 MJ. The machine is running steadily at synchronous speed and delivering 60 MW power at a power angle of 10 electrical degrees. If the load is suddenly removed, assuming the acceleration is constant for 10 cycles, the value of the power angle after 5 cycles is $\qquad$ electrical degrees.

Question Number : 55
Correct : 2 Wrong: 0

A thin soap bubble of radius $R=1 \mathrm{~cm}$, and thickness $a=3.3 \mu \mathrm{~m}(a \ll R)$, is at a potential of 1 V with respect to a reference point at infinity. The bubble bursts and becomes a single spherical drop of soap (assuming all the soap is contained in the drop) of radius $r$. The volume of the soap in the thin bubble is $4 \pi R^{2} a$ and that of the drop is $\frac{4}{3} \pi r^{3}$. The potential in volts, of the resulting single spherical drop with respect to the same reference point at infinity is $\qquad$ . (Give the answer up to two decimal places.)


Soap Bubble

Choose the option with words that are not synonyms.
(A) aversion, dislike
(B) luminous, radiant
(C) plunder, loot
(D) yielding, resistant

## Question Number : 57

Correct : 1 Wrong : -0.33

Saturn is $\qquad$ to be seen on a clear night with the naked eye.
(A) enough bright
(B) bright enough
(C) as enough bright
(D) bright as enough

Question Number : 58
Correct: $\mathbf{1}$ Wrong: -0.33

There are five buildings called $\mathrm{V}, \mathrm{W}, \mathrm{X}, \mathrm{Y}$ and Z in a row (not necessarily in that order). V is to the West of $\mathrm{W} . \mathrm{Z}$ is to the East of X and the West of V . W is to the West of Y . Which is the building in the middle?
(A) V
(B) W
(C) X
(D) Y

Question Number : 59
Correct : 1 Wrong : -0.33

A test has twenty questions worth 100 marks in total. There are two types of questions. Multiple choice questions are worth 3 marks each and essay questions are worth 11 marks each. How many multiple choice questions does the exam have?
(A) 12
(B) 15
(C) 18
(D) 19

There are 3 red socks, 4 green socks and 3 blue socks. You choose 2 socks. The probability that they are of the same colour is
(A) $1 / 5$
(B) $7 / 30$
(C) $1 / 4$
(D) $4 / 15$

## Question Number : 61

Correct : $\mathbf{2}$ Wrong : - 0.66
"We lived in a culture that denied any merit to literary works, considering them important only when they were handmaidens to something seemingly more urgent - namely ideology. This was a country where all gestures, even the most private, were interpreted in political terms."

The author's belief that ideology is not as important as literature is revealed by the word:
(A) 'culture'
(B) 'seemingly'
(C) 'urgent'
(D) 'political'

## Question Number : 62

Correct : 2 Wrong: -0.66

There are three boxes. One contains apples, another contains oranges and the last one contains both apples and oranges. All three are known to be incorrectly labelled. If you are permitted to open just one box and then pull out and inspect only one fruit, which box would you open to determine the contents of all three boxes?
(A) The box labelled 'Apples'
(B) The box labelled 'Apples and Oranges'
(C) The box labelled 'Oranges'
(D) Cannot be determined

## Question Number : 63

Correct : $\mathbf{2}$ Wrong : -0.66

X is a 30 digit number starting with the digit 4 followed by the digit 7 . Then the number $\mathrm{X}^{3}$ will have
(A) 90 digits
(B) 91 digits
(C) 92 digits
(D) 93 digits

Question Number : 64
Correct : 2 Wrong : -0.66

The number of roots of $e^{x}+0.5 x^{2}-2=0$ in the range $[-5,5]$ is
(A) 0
(B) 1
(C) 2
(D) 3

An air pressure contour line joins locations in a region having the same atmospheric pressure. The following is an air pressure contour plot of a geographical region. Contour lines are shown at 0.05 bar intervals in this plot.


If the possibility of a thunderstorm is given by how fast air pressure rises or drops over a region, which of the following regions is most likely to have a thunderstorm?
(A) P
(B) Q
(C) R
(D) S

## Q. 1 - Q. 5 carry one mark each.

Q. 1 "Since you have gone off the $\qquad$ the $\qquad$ sand is likely to damage the car."

The words that best fill the blanks in the above sentence are
(A) course, coarse
(B) course, course
(C) coarse, course
(D) coarse, coarse
Q. 2 "A common misconception among writers is that sentence structure mirrors thought; the more $\qquad$ the structure, the more complicated the ideas."

The word that best fills the blank in the above sentence is
(A) detailed
(B) simple
(C) clear
(D) convoluted
Q. 3 The three roots of the equation $f(x)=0$ are $x=\{-2,0,3\}$. What are the three values of $x$ for which $f(x-3)=0$ ?
(A) $-5,-3,0$
(B) $-2,0,3$
(C) $0,6,8$
(D) $1,3,6$
Q. 4 For what values of $k$ given below is $\frac{(k+2)^{2}}{k-3}$ an integer?
(A) $4,8,18$
(B) $4,10,16$
(C) $4,8,28$
(D) $8,26,28$
Q. 5 Functions $F(a, b)$ and $G(a, b)$ are defined as follows:
$F(a, b)=(a-b)^{2}$ and $G(a, b)=|a-b|$, where $|x|$ represents the absolute value of $x$. What would be the value of $G(F(1,3), G(1,3))$ ?
(A) 2
(B) 4
(C) 6
(D) 36

## Q. 6 - Q. 10 carry two marks each.

Q. 6 An e-mail password must contain three characters. The password has to contain one numeral from 0 to 9 , one upper case and one lower case character from the English alphabet. How many distinct passwords are possible?
(A) 6,760
(B) 13,520
(C) 40,560
(D) $1,05,456$
Q. 7 In a certain code, AMCF is written as EQGJ and NKUF is written as ROYJ. How will DHLP be written in that code?
(A) RSTN
(B) TLPH
(C) HLPT
(D) XSVR
Q. 8 A class of twelve children has two more boys than girls. A group of three children are randomly picked from this class to accompany the teacher on a field trip. What is the probability that the group accompanying the teacher contains more girls than boys?
(A) 0
(B) $\frac{325}{864}$
(C) $\frac{525}{864}$
(D) $\frac{5}{12}$
Q. 9 A designer uses marbles of four different colours for his designs. The cost of each marble is the same, irrespective of the colour. The table below shows the percentage of marbles of each colour used in the current design. The cost of each marble increased by $25 \%$. Therefore, the designer decided to reduce equal numbers of marbles of each colour to keep the total cost unchanged. What is the percentage of blue marbles in the new design?

| Blue | Black | Red | Yellow |
| :--- | :--- | :--- | :--- |
| $40 \%$ | $25 \%$ | $20 \%$ | $15 \%$ |

(A) 35.75
(B) 40.25
(C) 43.75
(D) 46.25
Q. $10 \quad \mathrm{P}, \mathrm{Q}, \mathrm{R}$ and S crossed a lake in a boat that can hold a maximum of two persons, with only one set of oars. The following additional facts are available.
(i) The boat held two persons on each of the three forward trips across the lake and one person on each of the two return trips.
(ii) P is unable to row when someone else is in the boat.
(iii) Q is unable to row with anyone else except R .
(iv) Each person rowed for at least one trip.
(v) Only one person can row during a trip.

Who rowed twice?
(A) P
(B) Q
(C) R
(D) S

## END OF THE QUESTION PAPER

## Q. 1 - Q. 25 carry one mark each.

Q. 1 A single-phase $100 \mathrm{kVA}, 1000 \mathrm{~V} / 100 \mathrm{~V}, 50 \mathrm{~Hz}$ transformer has a voltage drop of $5 \%$ across its series impedance at full load. Of this, $3 \%$ is due to resistance. The percentage regulation of the transformer at full load with 0.8 lagging power factor is
(A) 4.8
(B) 6.8
(C) 8.8
(D) 10.8
Q. 2 In a salient pole synchronous motor, the developed reluctance torque attains the maximum value when the load angle in electrical degrees is
(A) 0
(B) 45
(C) 60
(D) 90
Q. 3 A single phase fully controlled rectifier is supplying a load with an anti-parallel diode as shown in the figure. All switches and diodes are ideal. Which one of the following is true for instantaneous load voltage and current?

(A) $v_{O} \geq 0 \& i_{o}<0$
(B) $v_{o}<0 \& i_{o}<0$
(C) $v_{o} \geq 0 \& i_{o} \geq 0$
(D) $v_{O}<0 \& i_{O} \geq 0$
Q. 4 Four power semiconductor devices are shown in the figure along with their relevant terminals. The device(s) that can carry dc current continuously in the direction shown when gated appropriately is (are)


Thyristor


Triac


GTO


MOSFET
(A) Triac only
(B) Triac and MOSFET
(C) Triac and GTO
(D) Thyristor and Triac
Q. 5 Two wattmeter method is used for measurement of power in a balanced three-phase load supplied from a balanced three-phase system. If one of the wattmeters reads half of the other (both positive), then the power factor of the load is
(A) 0.532
(B) 0.632
(C) 0.707
(D) 0.866
Q. 6 Consider a lossy transmission line with $V_{1}$ and $V_{2}$ as the sending and receiving end voltages, respectively. $Z$ and $X$ are the series impedance and reactance of the line, respectively. The steady-state stability limit for the transmission line will be
(A) greater than $\left|\frac{V_{1} V_{2}}{X}\right|$
(B) less than $\left|\frac{V_{1} V_{2}}{X}\right|$
(C) equal to $\left|\frac{V_{1} V_{2}}{X}\right|$
(D) equal to $\left|\frac{V_{1} V_{2}}{Z}\right|$
Q. 7 The graph of a network has 8 nodes and 5 independent loops. The number of branches of the graph is
(A) 11
(B) 12
(C) 13
(D) 14
Q. 8 In the figure, the voltages are $v_{1}(t)=100 \cos (\omega t), v_{2}(t)=100 \cos (\omega t+\pi / 18)$ and $v_{3}(t)=100 \cos (\omega t+\pi / 36)$. The circuit is in sinusoidal steady state, and $R \ll \omega L . P_{1}$, $P_{2}$ and $P_{3}$ are the average power outputs. Which one of the following statements is true?

(A) $P_{1}=P_{2}=P_{3}=0$
(B) $P_{1}<0, P_{2}>0, P_{3}>0$
(C) $P_{1}<0, P_{2}>0, P_{3}<0$
(D) $P_{1}>0, P_{2}<0, P_{3}>0$
Q. 9 Match the transfer functions of the second-order systems with the nature of the systems given below.

## Transfer functions

P: $\frac{15}{s^{2}+5 s+15}$
Q: $\frac{25}{s^{2}+10 s+25}$
R: $\frac{35}{s^{2}+18 s+35}$
(A) P-I, Q-II, R-III
(B) P-II, Q-I, R-III
(C) P-III, Q-II, R-I
(D) P-III, Q-I, R-II
Q. 10 A positive charge of 1 nC is placed at $(0,0,0.2)$ where all dimensions are in metres. Consider the $x-y$ plane to be a conducting ground plane. Take $\epsilon_{0}=8.85 \times 10^{-12} \mathrm{~F} / \mathrm{m}$. The $z$ component of the E field at $(0,0,0.1)$ is closest to
(A) $899.18 \mathrm{~V} / \mathrm{m}$
(B) $-899.18 \mathrm{~V} / \mathrm{m}$
(C) $999.09 \mathrm{~V} / \mathrm{m}$
(D) $-999.09 \mathrm{~V} / \mathrm{m}$
Q. 11 Let $f$ be a real-valued function of a real variable defined as $f(x)=x^{2}$ for $x \geq 0$, and $f(x)=-x^{2}$ for $x<0$. Which one of the following statements is true?
(A) $f(x)$ is discontinuous at $x=0$.
(B) $f(x)$ is continuous but not differentiable at $x=0$.
(C) $f(x)$ is differentiable but its first derivative is not continuous at $x=0$.
(D) $f(x)$ is differentiable but its first derivative is not differentiable at $x=0$.
Q. 12 The value of the directional derivative of the function $\Phi(x, y, z)=x y^{2}+y z^{2}+z x^{2}$ at the point $(2,-1,1)$ in the direction of the vector $\mathbf{p}=\mathbf{i}+2 \mathbf{j}+2 \mathbf{k}$ is
(A) 1
(B) 0.95
(C) 0.93
(D) 0.9
Q. 13 The value of the integral $\oint_{C} \frac{z+1}{z^{2}-4} d z$ in counter clockwise direction around a circle $C$ of radius 1 with center at the point $z=-2$ is
(A) $\frac{\pi i}{2}$
(B) $2 \pi i$
(C) $-\frac{\pi i}{2}$
(D) $-2 \pi i$
Q. 14 In the logic circuit shown in the figure, Y is given by

(A) $\mathrm{Y}=\mathrm{ABCD}$
(B) $\mathrm{Y}=(\mathrm{A}+\mathrm{B})(\mathrm{C}+\mathrm{D})$
(C) $\mathrm{Y}=\mathrm{A}+\mathrm{B}+\mathrm{C}+\mathrm{D}$
(D) $Y=A B+C D$
Q. 15 The op-amp shown in the figure is ideal. The input impedance $\frac{v_{\text {in }}}{i_{\text {in }}}$ is given by

(A) $Z \frac{R_{1}}{R_{2}}$
(B) $-Z \frac{R_{2}}{R_{1}}$
(C) $Z$
(D) $-Z \frac{R_{1}}{R_{1}+R_{2}}$
Q. 16 A continuous-time input signal $x(t)$ is an eigenfunction of an LTI system, if the output is
(A) $k x(t)$, where $k$ is an eigenvalue
(B) $k \mathrm{e}^{j \omega t} x(t)$, where $k$ is an eigenvalue and $\mathrm{e}^{j \omega t}$ is a complex exponential signal
(C) $x(t) \mathrm{e}^{j \omega t}$, where $\mathrm{e}^{j \omega t}$ is a complex exponential signal
(D) $k H(\omega)$, where $k$ is an eigenvalue and $H(\omega)$ is a frequency response of the system
Q. 17 Consider a non-singular $2 \times 2$ square matrix $\mathbf{A}$. If $\operatorname{trace}(\mathbf{A})=4$ and $\operatorname{trace}\left(\mathbf{A}^{2}\right)=5$, the determinant of the matrix $\mathbf{A}$ is $\qquad$ (up to 1 decimal place).
Q. 18 Let $f$ be a real-valued function of a real variable defined as $f(x)=x-[x]$, where $[x]$ denotes the largest integer less than or equal to $x$. The value of $\int_{0.25}^{1.25} f(x) \mathrm{d} x$ is ____ to 2 decimal places).
Q. 19

In the two-port network shown, the $h_{11}$ parameter $\left(\right.$ where, $h_{11}=\frac{V_{1}}{I_{1}}$, when $\left.V_{2}=0\right)$ in ohms is $\qquad$ (up to 2 decimal places).

Q. 20 The series impedance matrix of a short three-phase transmission line in phase coordinates is $\left[\begin{array}{ccc}Z_{s} & Z_{m} & Z_{m} \\ Z_{m} & Z_{s} & Z_{m} \\ Z_{m} & Z_{m} & Z_{s}\end{array}\right]$. If the positive sequence impedance is $(1+j 10) \Omega$, and the zero sequence is $(4+j 31) \Omega$, then the imaginary part of $Z_{m}($ in $\Omega)$ is $\qquad$ (up to 2 decimal places).
Q. 21 The positive, negative and zero sequence impedances of a 125 MVA , three-phase, 15.5 kV , star-grounded, 50 Hz generator are $j 0.1 \mathrm{pu}, j 0.05 \mathrm{pu}$ and $j 0.01 \mathrm{pu}$ respectively on the machine rating base. The machine is unloaded and working at the rated terminal voltage. If the grounding impedance of the generator is $j 0.01 \mathrm{pu}$, then the magnitude of fault current for a $b$-phase to ground fault (in kA ) is $\qquad$ (up to 2 decimal places).
Q. 22 A $1000 \times 1000$ bus admittance matrix for an electric power system has 8000 non-zero elements. The minimum number of branches (transmission lines and transformers) in this system are $\qquad$ (up to 2 decimal places).
Q. 23 The waveform of the current drawn by a semi-converter from a sinusoidal AC voltage source is shown in the figure. If $\mathrm{I}_{0}=20 \mathrm{~A}$, the rms value of fundamental component of the current is $\qquad$ A (up to 2 decimal places).

Q. 24 A separately excited dc motor has an armature resistance $R_{a}=0.05 \Omega$. The field excitation is kept constant. At an armature voltage of 100 V , the motor produces a torque of 500 Nm at zero speed. Neglecting all mechanical losses, the no-load speed of the motor (in radian/s) for an armature voltage of 150 V is $\qquad$ (up to 2 decimal places).
Q. 25 Consider a unity feedback system with forward transfer function given by

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

The steady-state error in the output of the system for a unit-step input is $\qquad$ (up to 2 decimal places).

## Q. 26 - Q. 55 carry two marks each.

Q. 26 A transformer with toroidal core of permeability $\mu$ is shown in the figure. Assuming uniform flux density across the circular core cross-section of radius $r \ll R$, and neglecting any leakage flux, the best estimate for the mean radius $R$ is

(A) $\frac{\mu V r^{2} N_{P}^{2} \omega}{I}$
(B) $\frac{\mu I r^{2} N_{P} N_{S} \omega}{V}$
(C) $\frac{\mu V r^{2} N_{P}^{2} \omega}{2 I}$
(D) $\frac{\mu I r^{2} N_{P}^{2} \omega}{2 V}$
Q. 27 A 0-1 Ampere moving iron ammeter has an internal resistance of $50 \mathrm{~m} \Omega$ and inductance of 0.1 mH . A shunt coil is connected to extend its range to $0-10$ Ampere for all operating frequencies. The time constant in milliseconds and resistance in $m \Omega$ of the shunt coil respectively are
(A) 2, 5.55
(B) 2, 1
(C) 2.18, 0.55
(D) 11.1, 2
Q. 28 The positive, negative and zero sequence impedances of a three phase generator are $Z_{1}, Z_{2}$ and $Z_{0}$ respectively. For a line-to-line fault with fault impedance $Z_{f}$, the fault current is $I_{f 1}=k I_{f}$, where $I_{f}$ is the fault current with zero fault impedance. The relation between $Z_{f}$ and $k$ is
(A) $Z_{f}=\frac{\left(Z_{1}+Z_{2}\right)(1-k)}{k}$
(B) $Z_{f}=\frac{\left(Z_{1}+Z_{2}\right)(1+k)}{k}$
(C) $Z_{f}=\frac{\left(Z_{1}+Z_{2}\right) k}{1-k}$
(D) $Z_{f}=\frac{\left(Z_{1}+Z_{2}\right) k}{1+k}$
Q. 29 Consider the two bus power system network with given loads as shown in the figure. All the values shown in the figure are in per unit. The reactive power supplied by generator $G_{1}$ and $G_{2}$ are $Q_{G 1}$ and $Q_{G 2}$ respectively. The per unit values of $Q_{G 1}, Q_{G 2}$, and line reactive power loss ( $Q_{\text {loss }}$ ) respectively are

(A) $5.00,12.68,2.68$
(B) $6.34,10.00,1.34$
(C) $6.34,11.34,2.68$
(D) $5.00,11.34,1.34$
Q. 30 The per-unit power output of a salient-pole generator which is connected to an infinite bus, is given by the expression, $P=1.4 \sin \delta+0.15 \sin 2 \delta$, where $\delta$ is the load angle. NewtonRaphson method is used to calculate the value of $\delta$ for $P=0.8$ pu. If the initial guess is $30^{\circ}$, then its value (in degree) at the end of the first iteration is
(A) $15^{\circ}$
(B) $28.48^{\circ}$
(C) $28.74^{\circ}$
(D) $31.20^{\circ}$
Q. 31 A DC voltage source is connected to a series L-C circuit by turning on the switch S at time $t=0$ as shown in the figure. Assume $i(0)=0, v(0)=0$. Which one of the following circular loci represents the plot of $i(t)$ versus $v(t)$ ?

(A)

(B)
(C)
(D)



Q. 32 The equivalent impedance $Z_{e q}$ for the infinite ladder circuit shown in the figure is

(A) $\mathrm{j} 12 \Omega$
(B) $-\mathrm{j} 12 \Omega$
(C) $\mathrm{j} 13 \Omega$
(D) $13 \Omega$
Q. 33 Consider a system governed by the following equations

$$
\begin{aligned}
& \frac{\mathrm{d} x_{1}(t)}{\mathrm{d} t}=x_{2}(t)-x_{1}(t) \\
& \frac{\mathrm{d} x_{2}(t)}{\mathrm{d} t}=x_{1}(t)-x_{2}(t)
\end{aligned}
$$

The initial conditions are such that $x_{1}(0)<x_{2}(0)<\infty$. Let $x_{1 f}=\lim _{t \rightarrow \infty} x_{1}(t)$ and $x_{2 f}=\lim _{t \rightarrow \infty} x_{2}(t)$. Which one of the following is true?
(A) $x_{1 f}<x_{2 f}<\infty$
(B) $x_{2 f}<x_{1 f}<\infty$
(C) $x_{1 f}=x_{2 f}<\infty$
(D) $x_{1 f}=x_{2 f}=\infty$
Q. 34 The number of roots of the polynomial, $s^{7}+s^{6}+7 s^{5}+14 s^{4}+31 s^{3}+73 s^{2}+25 s+$ 200, in the open left half of the complex plane is
(A) 3
(B) 4
(C) 5
(D) 6
Q. 35 If $C$ is a circle $|z|=4$ and $f(z)=\frac{z^{2}}{\left(z^{2}-3 z+2\right)^{2}}$, then $\oint_{C} f(z) d z$ is
(A) 1
(B) 0
(C) -1
(D) -2
Q. 36 Which one of the following statements is true about the digital circuit shown in the figure

(A) It can be used for dividing the input frequency by 3 .
(B) It can be used for dividing the input frequency by 5 .
(C) It can be used for dividing the input frequency by 7.
(D) It cannot be reliably used as a frequency divider due to disjoint internal cycles.
Q. 37 Digital input signals $A, B, C$ with $A$ as the MSB and $C$ as the LSB are used to realize the Boolean function $F=m_{0}+m_{2}+m_{3}+m_{5}+m_{7}$, where $m_{i}$ denotes the $i^{t h}$ minterm. In addition, $F$ has a don't care for $m_{1}$. The simplified expression for $F$ is given by
(A) $\bar{A} \bar{C}+\bar{B} C+A C$
(B) $\bar{A}+C$
(C) $\bar{C}+A$
(D) $\bar{A} C+B C+A \bar{C}$
Q. 38 Consider the two continuous-time signals defined below:

$$
x_{1}(t)=\left\{\begin{array}{c}
|t|,-1 \leq t \leq 1 \\
0, \text { otherwise }
\end{array}, \quad x_{2}(t)= \begin{cases}1-|t|, & -1 \leq t \leq 1 \\
0, & \text { otherwise }\end{cases}\right.
$$

These signals are sampled with a sampling period of $T=0.25$ seconds to obtain discretetime signals $x_{1}[n]$ and $x_{2}[n]$, respectively. Which one of the following statements is true?
(A) The energy of $x_{1}[n]$ is greater than the energy of $x_{2}[n]$.
(B) The energy of $x_{2}[n]$ is greater than the energy of $x_{1}[n]$.
(C) $x_{1}[n]$ and $x_{2}[n]$ have equal energies.
(D) Neither $x_{1}[n]$ nor $x_{2}[n]$ is a finite-energy signal.
Q. 39 The signal energy of the continuous-time signal $x(t)=[(t-1) u(t-1)]-[(t-2) u(t-2)]-[(t-3) u(t-3)]+[(t-4) u(t-4)]$ is
(A) $11 / 3$
(B) $7 / 3$
(C) $1 / 3$
(D) $5 / 3$
Q. 40 The Fourier transform of a continuous-time signal $x(t)$ is given by $X(\omega)=\frac{1}{(10+\mathrm{j} \omega)^{2}},-\infty<\omega<\infty$, where $\mathrm{j}=\sqrt{-1}$ and $\omega$ denotes frequency. Then the value of $|\ln x(t)|$ at $t=1$ is $\qquad$ (up to 1 decimal place). ( $\ln$ denotes the logarithm to base $e$ )
Q. 41 In the circuit shown in the figure, the bipolar junction transistor (BJT) has a current gain $\beta=100$. The base-emitter voltage drop is a constant, $V_{B E}=0.7 \mathrm{~V}$. The value of the Thevenin equivalent resistance $R_{T h}$ (in $\Omega$ ) as shown in the figure is $\qquad$ (up to 2 decimal places).

Q. 42 As shown in the figure, $C$ is the arc from the point $(3,0)$ to the point $(0,3)$ on the circle $x^{2}+$ $y^{2}=9$. The value of the integral $\int_{C}\left(y^{2}+2 y x\right) d x+\left(2 x y+x^{2}\right) d y$ is $\qquad$ (up to 2 decimal places).

Q. 43 Let $f(x)=3 x^{3}-7 x^{2}+5 x+6$. The maximum value of $f(x)$ over the interval $[0,2]$ is
$\qquad$ (up to 1 decimal place).
Q. 44

Let $A=\left[\begin{array}{ccc}1 & 0 & -1 \\ -1 & 2 & 0 \\ 0 & 0 & -2\end{array}\right]$ and $B=A^{3}-A^{2}-4 A+5 I$, where $I$ is the $3 \times 3$ identity matrix. The determinant of $B$ is $\qquad$ (up to 1 decimal place).
Q. 45 The capacitance of an air-filled parallel-plate capacitor is 60 pF . When a dielectric slab whose thickness is half the distance between the plates, is placed on one of the plates covering it entirely, the capacitance becomes 86 pF . Neglecting the fringing effects, the relative permittivity of the dielectric is $\qquad$ (up to 2 decimal places).
Q. 46 The unit step response $y(t)$ of a unity feedback system with open loop transfer function $G(s) H(s)=\frac{K}{(s+1)^{2}(s+2)}$ is shown in the figure. The value of $K$ is $\qquad$ (up to 2 decimal places).

Q. 47 A three-phase load is connected to a three-phase balanced supply as shown in the figure. If $V_{a n}=100 \angle 0^{\circ} \mathrm{V}, V_{b n}=100 \angle-120^{\circ} \mathrm{V}$ and $V_{c n}=100 \angle-240^{\circ} \mathrm{V}$ (angles are considered positive in the anti-clockwise direction), the value of R for zero current in the neutral wire is $\qquad$ $\Omega$ (up to 2 decimal places).

Q. 48 The voltage across the circuit in the figure, and the current through it, are given by the following expressions:

$$
\begin{aligned}
& v(t)=5-10 \cos \left(\omega t+60^{\circ}\right) \mathrm{V} \\
& i(t)=5+X \cos (\omega t) \mathrm{A}
\end{aligned}
$$

where $\omega=100 \pi$ radian/s. If the average power delivered to the circuit is zero, then the value of $X$ (in Ampere) is $\qquad$ (up to 2 decimal places).

Q. 49 A phase controlled single phase rectifier, supplied by an AC source, feeds power to an R-L-E load as shown in the figure. The rectifier output voltage has an average value given by $\mathrm{V}_{\mathrm{o}}=\frac{V_{m}}{2 \pi}(3+\cos \alpha)$, where $V_{m}=80 \pi$ volts and $\alpha$ is the firing angle. If the power delivered to the lossless battery is $1600 \mathrm{~W}, \alpha$ in degree is $\qquad$ (up to 2 decimal places).

Q. 50 The figure shows two buck converters connected in parallel. The common input de voltage for the converters has a value of 100 V . The converters have inductors of identical value. The load resistance is $1 \Omega$. The capacitor voltage has negligible ripple. Both converters operate in the continuous conduction mode. The switching frequency is 1 kHz , and the switch control signals are as shown. The circuit operates in the steady state. Assuming that the converters share the load equally, the average value of $i_{S 1}$, the current of switch S1 (in Ampere), is $\qquad$ (up to 2 decimal places).

Q. 51 A 3-phase $900 \mathrm{kVA}, 3 \mathrm{kV} / \sqrt{3} \mathrm{kV}(\Delta / \mathrm{Y}), 50 \mathrm{~Hz}$ transformer has primary (high voltage side) resistance per phase of $0.3 \Omega$ and secondary (low voltage side) resistance per phase of $0.02 \Omega$. Iron loss of the transformer is 10 kW . The full load $\%$ efficiency of the transformer operated at unity power factor is $\qquad$ (up to 2 decimal places).
Q. 52 A 200 V DC series motor, when operating from rated voltage while driving a certain load, draws 10 A current and runs at $1000 \mathrm{r} . \mathrm{p} . \mathrm{m}$. The total series resistance is $1 \Omega$. The magnetic circuit is assumed to be linear. At the same supply voltage, the load torque is increased by $44 \%$. The speed of the motor in r.p.m. (rounded to the nearest integer) is $\qquad$ .
Q. 53 A dc to dc converter shown in the figure is charging a battery bank, B2 whose voltage is constant at 150 V . B1 is another battery bank whose voltage is constant at 50 V . The value of the inductor, L is 5 mH and the ideal switch, S is operated with a switching frequency of 5 kHz with a duty ratio of 0.4 . Once the circuit has attained steady state and assuming the diode D to be ideal, the power transferred from B 1 to B 2 (in Watt) is $\qquad$ (up to 2 decimal places).

Q. 54 The equivalent circuit of a single phase induction motor is shown in the figure, where the parameters are $R_{1}=R_{2}^{\prime}=X_{l 1}=X_{l 2}^{\prime}=12 \Omega, X_{M}=240 \Omega$ and $s$ is the slip. At no-load, the motor speed can be approximated to be the synchronous speed. The no-load lagging power factor of the motor is $\qquad$ (up to 3 decimal places).

Q. 55 The voltage $v(t)$ across the terminals $a$ and $b$ as shown in the figure, is a sinusoidal voltage having a frequency $\omega=100 \mathrm{radian} / \mathrm{s}$. When the inductor current $i(t)$ is in phase with the voltage $v(t)$, the magnitude of the impedance $Z$ (in $\Omega$ ) seen between the terminals $a$ and $b$ is $\qquad$ (up to 2 decimal places).


## END OF THE QUESTION PAPER

| Q. No | Type | Section | Key | Marks |
| :---: | :---: | :---: | :---: | :---: |
| 1 | MCQ | GA | B | 1 |
| 2 | MCQ | GA | A | 1 |
| 3 | MCQ | GA | C | 1 |
| 4 | MCQ | GA | D | 1 |
| 5 | MCQ | GA | B | 1 |
| 6 | MCQ | GA | A | 2 |
| 7 | MCQ | GA | D | 2 |
| 8 | MCQ | GA | D | 2 |
| 9 | MCQ | GA | C | 2 |
| 10 | MCQ | GA | C | 2 |
| 1 | NAT | EE-1 | 0.0:0.0 | 1 |
| 2 | NAT | EE-1 | 3.0 : 3.0 | 1 |
| 3 | MCQ | EE-1 | A | 1 |
| 4 | MCQ | EE-1 | B | 1 |
| 5 | MCQ | EE-1 | B | 1 |
| 6 | MCQ | EE-1 | B | 1 |
| 7 | MCQ | EE-1 | A | 1 |
| 8 | MCQ | EE-1 | C | 1 |
| 9 | MCQ | EE-1 | A | 1 |
| 10 | MCQ | EE-1 | B | 1 |
| 11 | MCQ | EE-1 | D | 1 |
| 12 | NAT | EE-1 | 18.0:20.0 | 1 |
| 13 | MCQ | EE-1 | B | 1 |
| 14 | NAT | EE-1 | 99.0 : 101.0 | 1 |
| 15 | MCQ | EE-1 | D | 1 |
| 16 | MCQ | EE-1 | C | 1 |
| 17 | NAT | EE-1 | 1.9 : 2.1 | 1 |
| 18 | NAT | EE-1 | 0.5 : 0.5 | 1 |
| 19 | MCQ | EE-1 | B | 1 |
| 20 | NAT | EE-1 | 0.83: 0.85 | 1 |
| 21 | MCQ | EE-1 | A | 1 |
| 22 | NAT | EE-1 | 0.39 : 0.41 | 1 |
| 23 | NAT | EE-1 | 169.0 : 171.0 | 1 |
| 24 | MCQ | EE-1 | C | 1 |
| 25 | MCQ | EE-1 | B | 1 |
| 26 | NAT | EE-1 | 0.2:0.2 | 2 |
| 27 | NAT | EE-1 | 0.28:0.31 | 2 |
| 28 | MCQ | EE-1 | A | 2 |
| 29 | MCQ | EE-1 | B | 2 |
| 30 | MCQ | EE-1 | A | 2 |
| 31 | NAT | EE-1 | 5.9 : 6.1 | 2 |
| 32 | MCQ | EE-1 | A | 2 |
| 33 | NAT | EE-1 | 2.0:2.0 | 2 |
| 34 | MCQ | EE-1 | C | 2 |
| 35 | MCQ | EE-1 | D | 2 |
| 36 | MCQ | EE-1 | C | 2 |
| 37 | MCQ | EE-1 | A | 2 |
| 38 | MCQ | EE-1 | D | 2 |
| 39 | NAT | EE-1 | 1.9 : 2.1 | 2 |


| 40 | NAT | EE-1 | $47.0: 49.0$ | 2 |
| :---: | :---: | :---: | :---: | :---: |
| 41 | NAT | EE-1 | $1.05: 1.15$ | 2 |
| 42 | MCQ | EE-1 | D | 2 |
| 43 | MCQ | EE-1 | C | 2 |
| 44 | NAT | EE-1 | $9.9: 10.1$ | 2 |
| 45 | NAT | EE-1 | $74.0: 76.0$ | 2 |
| 46 | NAT | EE-1 | $1.4: 1.5$ | 2 |
| 47 | NAT | EE-1 | $86.0: 88.0$ | 2 |
| 48 | NAT | EE-1 | $1.58: 1.62$ | 2 |
| 49 | MCQ | EE-1 | C | 2 |
| 50 | MCQ | EE-1 | A | 2 |
| 51 | NAT | EE-1 | $1.41: 1.47$ | 2 |
| 52 | NAT | EE-1 | $1.0: 1.0$ | 2 |
| 53 | NAT | EE-1 | $0.30: 0.33$ | 2 |
| 54 | NAT | EE-1 | $14.0: 14.2$ | 2 |
| 55 | NAT | EE-1 | $11.25: 11.50$ | 2 |


| Q. No | Type | Section | Key | Marks |
| :---: | :---: | :---: | :---: | :---: |
| 1 | MCQ | GA | C | 1 |
| 2 | MCQ | GA | B | 1 |
| 3 | MCQ | GA | B | 1 |
| 4 | MCQ | GA | B | 1 |
| 5 | MCQ | GA | C | 1 |
| 6 | NAT | GA | 120.0:120.0 | 2 |
| 7 | MCQ | GA | C | 2 |
| 8 | MCQ | GA | C | 2 |
| 9 | MCQ | GA | A | 2 |
| 10 | NAT | GA | 7.0 : 7.0 | 2 |
| 1 | MCQ | EE-2 | B | 1 |
| 2 | MCQ | EE-2 | A | 1 |
| 3 | NAT | EE-2 | 9.5:10.5 | 1 |
| 4 | MCQ | EE-2 | D | 1 |
| 5 | NAT | EE-2 | 6.0 : 6.0 | 1 |
| 6 | MCQ | EE-2 | B | 1 |
| 7 | MCQ | EE-2 | A; D | 1 |
| 8 | MCQ | EE-2 | A | 1 |
| 9 | MCQ | EE-2 | B | 1 |
| 10 | MCQ | EE-2 | B | 1 |
| 11 | MCQ | EE-2 | MTA | 1 |
| 12 | NAT | EE-2 | 249.0 : 251.0 | 1 |
| 13 | MCQ | EE-2 | D | 1 |
| 14 | MCQ | EE-2 | A | 1 |
| 15 | MCQ | EE-2 | B | 1 |
| 16 | MCQ | EE-2 | C | 1 |
| 17 | NAT | EE-2 | 4.9 : 5.1 | 1 |
| 18 | NAT | EE-2 | 0.69:0.72 | 1 |
| 19 | NAT | EE-2 | 57.0 : 58.0 | 1 |
| 20 | NAT | EE-2 | 59.5:60.5 | 1 |
| 21 | NAT | EE-2 | 0.30:0.33 | 1 |
| 22 | MCQ | EE-2 | C | 1 |
| 23 | MCQ | EE-2 | D | 1 |
| 24 | MCQ | EE-2 | D | 1 |
| 25 | MCQ | EE-2 | A | 1 |
| 26 | MCQ | EE-2 | D | 2 |
| 27 | MCQ | EE-2 | D | 2 |
| 28 | MCQ | EE-2 | B | 2 |
| 29 | MCQ | EE-2 | D | 2 |
| 30 | NAT | EE-2 | 7.0 : 7.5 | 2 |
| 31 | NAT | EE-2 | 4.40 : 4.45 | 2 |
| 32 | MCQ | EE-2 | D | 2 |
| 33 | MCQ | EE-2 | A | 2 |
| 34 | NAT | EE-2 | 19.5 : 20.5 | 2 |
| 35 | NAT | EE-2 | 34.0 : 36.0 | 2 |
| 36 | NAT | EE-2 | 2.9 : 3.1 | 2 |
| 37 | NAT | EE-2 | 6.8 : 7.2 | 2 |
| 38 | NAT | EE-2 | $2.20: 2.35$ | 2 |
| 39 | MCQ | EE-2 | C | 2 |


| 40 | NAT | EE-2 | $294.0: 298.0$ | 2 |
| :---: | :---: | :---: | :---: | :---: |
| 41 | NAT | EE-2 | $0.31: 0.33$ | 2 |
| 42 | NAT | EE-2 | $186.0: 190.0$ | 2 |
| 43 | NAT | EE-2 | $31.0: 33.0$ | 2 |
| 44 | NAT | EE-2 | $5.9: 6.1$ | 2 |
| 45 | NAT | EE-2 | $5.9: 6.1$ | 2 |
| 46 | NAT | EE-2 | $23.0: 25.0$ | 2 |
| 47 | NAT | EE-2 | $3.0: 4.0$ | 2 |
| 48 | NAT | EE-2 | $9.1: 9.3$ | 2 |
| 49 | MCQ | EE-2 | A | 2 |
| 50 | MCQ | EE-2 | B | 2 |
| 51 | MCQ | EE-2 | A | 2 |
| 52 | MCQ | EE-2 | A | 2 |
| 53 | NAT | EE-2 | $5.5: 6.5$ | 2 |
| 54 | NAT | EE-2 | $1.9: 2.1$ | 2 |
| 55 | NAT | EE-2 | $9.4: 9.7$ | 2 |


| Q. No. | Type | Section | Key | Marks |
| :---: | :---: | :---: | :---: | :---: |
| 1 | MCQ | EE-1 | C | 1 |
| 2 | MCQ | EE-1 | D | 1 |
| 3 | MCQ | EE-1 | A | 1 |
| 4 | MCQ | EE-1 | A | 1 |
| 5 | MCQ | EE-1 | D | 1 |
| 6 | MCQ | EE-1 | D | 1 |
| 7 | MCQ | EE-1 | D | 1 |
| 8 | MCQ | EE-1 | C | 1 |
| 9 | MCQ | EE-1 | A | 1 |
| 10 | MCQ | EE-1 | B | 1 |
| 11 | MCQ | EE-1 | D | 1 |
| 12 | MCQ | EE-1 | A | 1 |
| 13 | MCQ | EE-1 | A | 1 |
| 14 | MCQ | EE-1 | B | 1 |
| 15 | MCQ | EE-1 | D | 1 |
| 16 | NAT | EE-1 | Mark to all | 1 |
| 17 | NAT | EE-1 | 0.99 to 1.01 | 1 |
| 18 | NAT | EE-1 | 248 to 252 | 1 |
| 19 | NAT | EE-1 | 2.9 to 3.1 | 1 |
| 20 | NAT | EE-1 | 835 to 842 | 1 |
| 21 | NAT | EE-1 | 14 to 14 | 1 |
| 22 | NAT | EE-1 | 1.01 to 1.06 | 1 |
| 23 | NAT | EE-1 | 4 to 4.1 | 1 |
| 24 | NAT | EE-1 | 196 to 200 | 1 |
| 25 | NAT | EE-1 | 8.5 to 9.5 | 1 |
| 26 | MCQ | EE-1 | B | 2 |
| 27 | MCQ | EE-1 | A | 2 |
| 28 | MCQ | EE-1 | B | 2 |
| 29 | MCQ | EE-1 | D | 2 |
| 30 | MCQ | EE-1 | B | 2 |
| 31 | MCQ | EE-1 | C | 2 |
| 32 | MCQ | EE-1 | A | 2 |
| 33 | MCQ | EE-1 | D | 2 |
| 34 | MCQ | EE-1 | D | 2 |
| 35 | MCQ | EE-1 | A | 2 |
| 36 | MCQ | EE-1 | D | 2 |


| $\mathbf{3 7}$ | MCQ | EE-1 | B | 2 |
| :---: | :---: | :---: | :---: | :---: |
| $\mathbf{3 8}$ | MCQ | EE-1 | A | 2 |
| $\mathbf{3 9}$ | MCQ | EE-1 | B | 2 |
| $\mathbf{4 0}$ | MCQ | EE-1 | C | 2 |
| $\mathbf{4 1}$ | MCQ | EE-1 | A | 2 |
| $\mathbf{4 2}$ | NAT | EE-1 | 10 to 10 | 2 |
| $\mathbf{4 3}$ | NAT | EE-1 | 3 to 3.1 | 2 |
| $\mathbf{4 4}$ | NAT | EE-1 | 0.65 to 0.75 | 2 |
| $\mathbf{4 5}$ | NAT | EE-1 | 145 to 155 | 2 |
| $\mathbf{4 6}$ | NAT | EE-1 | 0.7 to 0.79 | 2 |
| $\mathbf{4 7}$ | NAT | EE-1 | 9.5 to 12 | 2 |
| $\mathbf{4 8}$ | NAT | EE-1 | 620 to 630 | 2 |
| $\mathbf{4 9}$ | NAT | EE-1 | 548 to 552 | 2 |
| $\mathbf{5 0}$ | NAT | EE-1 | 0.550 to 0.556 | 2 |
| $\mathbf{5 1}$ | NAT | EE-1 | 0.09 to 0.1 | 2 |
| $\mathbf{5 2}$ | NAT | EE-1 | 170 to 174 | 2 |
| $\mathbf{5 3}$ | NAT | EE-1 | 220 to 230 | 2 |
| $\mathbf{5 4}$ | NAT | EE-1 | 0.1 to 0.1 | 2 |
| $\mathbf{5 5}$ | NAT | EE-1 | 1.20 to 1.24 | 2 |
| $\mathbf{5 6}$ | MCQ | GA | C | 1 |
| $\mathbf{5 7}$ | MCQ | GA | D | 1 |
| $\mathbf{5 8}$ | MCQ | GA | C | 1 |
| $\mathbf{5 9}$ | MCQ | GA | D | 1 |
| $\mathbf{6 0}$ | MCQ | GA | C | 1 |
| $\mathbf{6 1}$ | MCQ | GA | B | 2 |
| $\mathbf{6 2}$ | MCQ | GA | A | 2 |
| $\mathbf{6 3}$ | MCQ | GA | B | 2 |
| $\mathbf{6 4}$ | MCQ | GA | D | 2 |
| $\mathbf{6 5}$ | MCQ | GA | C | 2 |


| Q. No. | Type | Section | Key | Marks |
| :---: | :---: | :---: | :---: | :---: |
| 1 | MCQ | EE-2 | A | 1 |
| 2 | MCQ | EE-2 | B | 1 |
| 3 | MCQ | EE-2 | C | 1 |
| 4 | MCQ | EE-2 | B | 1 |
| 5 | MCQ | EE-2 | B | 1 |
| 6 | MCQ | EE-2 | D | 1 |
| 7 | MCQ | EE-2 | A | 1 |
| 8 | MCQ | EE-2 | A | 1 |
| 9 | MCQ | EE-2 | D | 1 |
| 10 | MCQ | EE-2 | C | 1 |
| 11 | MCQ | EE-2 | C | 1 |
| 12 | MCQ | EE-2 | A | 1 |
| 13 | MCQ | EE-2 | B | 1 |
| 14 | MCQ | EE-2 | C | 1 |
| 15 | MCQ | EE-2 | D | 1 |
| 16 | NAT | EE-2 | 0 to 0 | 1 |
| 17 | NAT | EE-2 | 0.9 to 0.9 | 1 |
| 18 | NAT | EE-2 | 40 to 40 | 1 |
| 19 | NAT | EE-2 | 7 to 7 | 1 |
| 20 | NAT | EE-2 | 5.7 to 5.8 | 1 |
| 21 | NAT | EE-2 | 3 to 3 | 1 |
| 22 | NAT | EE-2 | 99 to 101 | 1 |
| 23 | NAT | EE-2 | 6 to 6 | 1 |
| 24 | NAT | EE-2 | 404 to 409 | 1 |
| 25 | NAT | EE-2 | 61 to 61 | 1 |
| 26 | MCQ | EE-2 | A | 2 |
| 27 | MCQ | EE-2 | C | 2 |
| 28 | MCQ | EE-2 | A | 2 |
| 29 | MCQ | EE-2 | C | 2 |
| 30 | MCQ | EE-2 | D | 2 |
| 31 | MCQ | EE-2 | B | 2 |
| 32 | MCQ | EE-2 | D | 2 |
| 33 | MCQ | EE-2 | B | 2 |
| 34 | MCQ | EE-2 | B | 2 |
| 35 | MCQ | EE-2 | A | 2 |
| 36 | MCQ | EE-2 | C | 2 |


| 37 | MCQ | EE-2 | D | 2 |
| :---: | :---: | :---: | :---: | :---: |
| 38 | MCQ | EE-2 | C | 2 |
| 39 | MCQ | EE-2 | C | 2 |
| 40 | MCQ | EE-2 | C | 2 |
| 41 | MCQ | EE-2 | A | 2 |
| 42 | NAT | EE-2 | 1235 to 1250 | 2 |
| 43 | NAT | EE-2 | 69 to 71 | 2 |
| 44 | NAT | EE-2 | -15 to -14 | 2 |
| 45 | NAT | EE-2 | 37 to 39 | 2 |
| 46 | NAT | EE-2 | 1.280 to 1.287 | 2 |
| 47 | NAT | EE-2 | 10000 to 10000 | 2 |
| 48 | NAT | EE-2 | 0.70 to 0.71 | 2 |
| 49 | NAT | EE-2 | 6 to 6 | 2 |
| 50 | NAT | EE-2 | 39 to 41 | 2 |
| 51 | NAT | EE-2 | 0.271 to 0.301 | 2 |
| 52 | NAT | EE-2 | 0.75 to 0.85 | 2 |
| 53 | NAT | EE-2 | 395 to 405 | 2 |
| 54 | NAT | EE-2 | 12.5 to 12.9 | 2 |
| 55 | NAT | EE-2 | 9.50 to 10.50 | 2 |
| 56 | MCQ | GA | D | 1 |
| 57 | MCQ | GA | B | 1 |
| 58 | MCQ | GA | A | 1 |
| 59 | MCQ | GA | B | 1 |
| 60 | MCQ | GA | D | 1 |
| 61 | MCQ | GA | B | 2 |
| 62 | MCQ | GA | B | 2 |
| 63 | MCQ | GA | A | 2 |
| 64 | MCQ | GA | C | 2 |
| 65 | MCQ | GA | C | 2 |


| Q.No. | Type | Section | Key/Range | Marks |
| :---: | :---: | :---: | :---: | :---: |
| 1 | MCQ | GA | A | 1 |
| 2 | MCQ | GA | D | 1 |
| 3 | MCQ | GA | D | 1 |
| 4 | MCQ | GA | C | 1 |
| 5 | MCQ | GA | A | 1 |
| 6 | MCQ | GA | C | 2 |
| 7 | MCQ | GA | C | 2 |
| 8 | MCQ | GA | Marks to All | 2 |
| 9 | MCQ | GA | C | 2 |
| 10 | MCQ | GA | C | 2 |
| 1 | MCQ | EE | A | 1 |
| 2 | MCQ | EE | B | 1 |
| 3 | MCQ | EE | C | 1 |
| 4 | MCQ | EE | B | 1 |
| 5 | MCQ | EE | D | 1 |
| 6 | MCQ | EE | B | 1 |
| 7 | MCQ | EE | B | 1 |
| 8 | MCQ | EE | C | 1 |
| 9 | MCQ | EE | C | 1 |
| 10 | MCQ | EE | D | 1 |
| 11 | MCQ | EE | D | 1 |
| 12 | MCQ | EE | A | 1 |
| 13 | MCQ | EE | A | 1 |


| Q.No. | Type | Section | Key/Range | Marks |
| :---: | :---: | :---: | :---: | :---: |
| 14 | MCQ | EE | D | 1 |
| 15 | MCQ | EE | B | 1 |
| 16 | MCQ | EE | A | 1 |
| 17 | NAT | EE | 5.5 to 5.5 | 1 |
| 18 | NAT | EE | 0.49 to 0.51 | 1 |
| 19 | NAT | EE | 0.45 to 0.55 | 1 |
| 20 | NAT | EE | 7.0 to 7.0 | 1 |
| 21 | NAT | EE | 73.0 to 74.0 | 1 |
| 22 | NAT | EE | 3500.0 to 3500.0 | 1 |
| 23 | NAT | EE | 16.90 to 17.70 | 1 |
| 24 | NAT | EE | 600.0 to 600.0 | 1 |
| 25 | NAT | EE | 0.65 to 0.69 | 1 |
| 26 | MCQ | EE | D | 2 |
| 27 | MCQ | EE | A | 2 |
| 28 | MCQ | EE | A | 2 |
| 29 | MCQ | EE | C | 2 |
| 30 | MCQ | EE | C | 2 |
| 31 | MCQ | EE | B | 2 |
| 32 | MCQ | EE | A | 2 |
| 33 | MCQ | EE | C | 2 |
| 34 | MCQ | EE | A | 2 |
| 35 | MCQ | EE | B | 2 |
| 36 | MCQ | EE | B | 2 |


| Q.No. | Type | Section | Key/Range | Marks |
| :---: | :---: | :---: | :---: | :---: |
| 37 | MCQ | EE | B | 2 |
| 38 | MCQ | EE | A | 2 |
| 39 | MCQ | EE | D | 2 |
| 40 | NAT | EE | 9.5 to 10.5 | 2 |
| 41 | NAT | EE | 89.0 to 91.5 | 2 |
| 42 | NAT | EE | 0.0 to 0.0 | 2 |
| 43 | NAT | EE | 11.5 to 12.5 | 2 |
| 44 | NAT | EE | 0.9 to 1.1 | 2 |
| 45 | NAT | EE | 2.50 to 2.55 | 2 |
| 46 | NAT | EE | 8.0 to 8.0 | 2 |
| 47 | NAT | EE | 5.70 to 5.85 | 2 |
| 48 | NAT | EE | 10.0 to 10.0 | 2 |
| 49 | NAT | EE | 90.0 to 90.0 | 2 |
| 50 | NAT | EE | 11.50 to 13.50 | 2 |
| 51 | NAT | EE | 97.20 to 97.55 | 2 |
| 52 | NAT | EE | 823 to 827 | 2 |
| 53 | NAT | EE | 12.0 to 12.0 | 2 |
| 54 | NAT | EE | 0.104 to 0.112 | 2 |
| 55 | NAT | EE | 50.0 to 50.0 | 2 |

AKU 2016

QUEATION PAPER

Code : 031506

## B.Tech 5th Semester Examination, 2016

## Electromagnetic field Theory

## Time : 3 hours

Full Marks : 70

## Instructions :

(i) There are Nine Questions in this paper.
(ii) Attempt Five questions in all.
(iii) Question No. 1 is compulsory.
(iv) The marks are indicated in the right-hand margin.

1. Choose the correct alternatives for any seven of the following and explain:
$7 \times 2=14$
(i) The electric field on equipotential surface is:
(a) Unity
(b) always parallel to the surface
(c) always perpendicular to the surface
(d) zero
(ii) Electric field in a region containing space charge can be found using:
(a) Laplace's equation
(b) Poisson's equation
(c) Coulomb's law
(d) Helmholtz equation
(iii) Electrostatic field is:
(a) solenoidal
(b) conservative
(c) both solenoidal \& conservative
(d) sometimes solenoidal, sometimes conservative
(iv) One Weber is equal to:
(a) $10^{6}$ lines
(b) $44 \times 10^{-7}$ lines
(c) $10^{12}$ lines
(d) $10^{8}$ lines
(v) Two thin parallel wires carry currents along the same direction. The force experienced by one due to the other is:
(a) parallel to the lines
(b) perpendicular to the lines and attractive
(c) perpendicular to the lines \& repulsive
(d) zero
(vi) The magnetic field at any point on the axis of a currentcarrying circular coil will be:
(a) perpendicular to the axis
(b) parallel to the axis
(c) at an angle $45^{\circ}$ with axis
(d) zero
(vii) To apply Gauss's law, the Gaussian surface should be chosen in such a way that field is:
(a) perpendicular
(b) tangential
(c) either perpendicular or tangential
(d) parallel to the surface
(viii) Gradient of a scalar function results in a:
(a) vectorfunction
(b) scalar function
(c) peak function
(d) periodic function
2. (a) Derive an expression for electric field $E$ due to surface (sheet) charge uniformly distributed over an infinite plane having density $\varsigma_{s} \mathrm{c} / \mathrm{mV}$.
(b) State and explain the following:
(i) Strokes theorem
(ii) Helmholtz's theorem
(c) Deduce boundary condition of electric field for Dielectric-Dielectric boundary.
(d) Deduce an expression for magnetic field intensity H due to an infinitely long current-carrying conductor carrying-
3. (a) Derive an expression for Lorentz force on a moving charge in an electromagnetic field.
(b) What are conduction and displacement currents?
(c) From the concept of displacement current derive an expression for modified Ampere's law.
(d) Write and explain differential and integral forms of Maxwell's equations.
4. (a) A plane polarized wave is travelling along Z-axis. Show graphically the variation of E and H with Z . Show that $E_{,} / H_{z}=377 \Omega$ for the wave.
(b) Develop the analogy between the uniform plane EM waves and the transmission line.
(c) A uniform transmission line has constants $\mathrm{R}=12 \mathrm{~m} \Omega$. $\mathrm{G}=0.8 \mu \Omega-1 / \mathrm{m}, \mathrm{L}=1.3 \mu \mathrm{H} / \mathrm{m}$ and $\mathrm{C}=0.7 \mathrm{nF} / \mathrm{m}$. At 5 kHz . find
(i) impedance
(ii) dB attenuation in 2 km
5. (a) Establish the relation $\nabla \times H=J+\partial \mathrm{D} / \partial \mathrm{t}$. The symbol used has usual meaning.
(b) What do you mean by linearly polarized plane E.M. waves in free space?
(c) What do you mean by depth of penetration in such medium? If the penetration depth is 1.35 m at 50 Hz , what will this be at 10 kHz ?
6. (a) Write down general procedure for solving Poisson's and Laplace's equation.
(b) Deduce an expression of energy density in electrostatic field.
(c) What is meant by the following?
(i) Transformer and motional e.m.f.
(ii) Electric potential and potential gradient
7. (a) Find curl H at the origin, where $\mathrm{H}=2 \mathrm{Y}$ i $\times-\left(\mathrm{x}^{2}+\mathrm{z}^{2}\right) i_{\text {y }}$ $+3 \mathrm{y} i_{z}$
(b) Show that
(i) $\nabla \times(f G)=\nabla f \times G+g \nabla \times G$
(ii) $\nabla \times(\nabla \times F)=\nabla(\nabla . F)-\nabla^{2} F$.
(c) It is required to hold four equal point charges +q each in equilibrium at the comers of a square. Find the point charge which will do this if placed at the centres of the square.
8. (a) The magnetic field component of a plane wave in a lossless dielectric $\mu_{r}=/$ is $\mathrm{H}=30 \sin \left(\lambda \pi \times 10^{8} \mathrm{t}-5 \times\right)$ azmA/m. find
(i) $\epsilon_{r}$
(ii) the wavelength and wave velocity
(iii) the wave impedance
(iv) the polarization of the wave
(v) the corresponding electric field component
(b) Develop the analogy between the uniform plane EM waves and the electric transmission line.
9. (a) What are skin effect and skin depth?
(b) Show that in case of semi-infinite solid conductor, the depth $d$ is given by $\sqrt{?}=\sqrt{ } \frac{2}{\omega \mu \sigma}$ where $\omega, \mu \& \sigma$ have their usual meaning.
(c) What is polarization of electro-magnetic wave?
(d) Explain the significance of pointing vector.

## ***

