OJEE LE Tech (Diploma) Sample Paper 01

A) Mode and Time: The exam is a Computer Based Test (CBT) lasting 120 minutes.
B) Total Questions: The exam contains 120 questions.
C) Marking Scheme & Rules:

- +4 for correct answers and -1 for incorrect responses.

Q1. If A is a square matrix of order 3 and $|A| = 5$, then the value of $|2A|$ is:

A. 10

B. 20

C. 40

D. 8

Q2. The inverse of a singular matrix is:

A. Identity matrix

B. Null matrix

C. Symmetric matrix

D. Does not exist

Q3. If $\sin\theta + \cos\theta = \sqrt{2}$, then the value of θ is:

A. $\pi/6$

B. $\pi/4$

C. $\pi/3$

D. $\pi/2$

Q4. The value of $\tan 75^\circ$ is:

A. $2 - \sqrt{3}$

B. $2 + \sqrt{3}$

C. $\sqrt{3} - 1$

D. $\sqrt{3} + 1$

Q5. The distance between the parallel lines $3x - 4y + 5 = 0$ and $3x - 4y + 15 = 0$ is:

A. 1

B. 2

C. 5

D. 10

Q6. The slope of the line perpendicular to $2x + 3y - 5 = 0$ is:

A. $-2/3$

B. $2/3$

C. $3/2$

D. $-3/2$

Q7. The center of the circle $x^2 + y^2 - 6x + 8y = 0$ is:

A. $(3, -4)$

B. $(-3, 4)$

C. $(6, -8)$

D. $(-6, 8)$

Q8. The eccentricity of the parabola $y^2 = 4ax$ is:

A. 0

B. 1

C. Less than 1

D. Greater than 1

Q9. The limit $\lim_{x \to 0} \frac{\sin 5x}{x}$ evaluates to:

A. 1

B. 5

C. 0

D. $1/5$

Q10. If $y = e^{\sin x}$, then dy/dx is:

A. $e^{\sin x} \cos x$

B. $e^{\cos x}$

C. $\sin x e^{\sin x - 1}$

D. $e^{\sin x}$

Q11. The derivative of $\log(\sec x + \tan x)$ is:

A. $\sec x$

B. $\tan x$

C. $\sec x \tan x$

D. $\sec^2 x$

Q12. The function $f(x) = x^2 - 4x + 3$ has a minimum value at $x =$:

A. 1

B. 2

C. 3

D. 4

Q13. The value of the integral $\int e^x (1 + \tan x + \tan^2 x)\, dx$ is:

A. $e^x \tan x + C$

B. $e^x \sec x + C$

C. $e^x \log(\sec x) + C$

D. $e^x + C$

Q14. The value of $\int_0^{\pi/2} \sin^3 x \cos^2 x\, dx$ is:

A. 2/15

B. 4/15

C. 1

D. 0

Q15. The area of the circle $x^2 + y^2 = 16$ is:

A. 4π

B. 8π

C. 16π

D. 64π

Q16. The order and degree of the differential equation $\left(\frac{d^2y}{dx^2}\right)^2 + \frac{dy}{dx} = x$ are respectively:

A. 2 and 1

B. 1 and 2

C. 2 and 2

D. 1 and 1

Q17. The integrating factor of the differential equation $\frac{dy}{dx} + y\cot x = \text{cosec}x$ is:

A. $\sin x$

B. $\cos x$

C. $\tan x$

D. $\cot x$

Q18. The roots of the auxiliary equation for $y'' - 5y' + 6y = 0$ are:

A. 2, 3

B. -2, -3

C. 1, 6

D. 2, -3

Q19. If $\mathbf{a} = 2\mathbf{i} - \mathbf{j} + \mathbf{k}$ and $\mathbf{b} = \mathbf{i} + 2\mathbf{j} - 3\mathbf{k}$, then $\mathbf{a} \cdot \mathbf{b}$ is:

A. -3

B. 3

C. -5

D. 5

Q20. The cross product $\mathbf{i} \times (\mathbf{j} \times \mathbf{k})$ is:

A. $\mathbf{i}$

B. $\mathbf{j}$

C. $\mathbf{k}$

D. 0

Q21. Two vectors are parallel if their:

A. Dot product is zero

B. Cross product is zero

C. Magnitudes are equal

D. Directions are opposite

Q22. The value of i^{25} (where $i = \sqrt{-1}$) is:

A. 1

B. -1

C. i

D. $-i$

Q23. The modulus of the complex number $3 + 4i$ is:

A. 5

B. 7

C. 1

D. -1

Q24. The polar form of the complex number $1 + i$ involves an argument of:

A. $\pi/6$

B. $\pi/4$

C. $\pi/3$

D. $\pi/2$

Q25. A pair of dice is thrown. The probability of getting a sum of 9 is:

A. 1/9

B. 1/12

C. 1/6

D. 1/36

Q26. The mean of the first 10 natural numbers is:

A. 5

B. 5.5

C. 6

D. 6.5

Q27. If $P(A) = 0.5$, $P(B) = 0.4$, and $P(A \cap B) = 0.2$, then $P(A \cup B)$ is:

A. 0.9

B. 0.7

C. 0.1

D. 0.8

Q28. The value of $\Gamma(1/2)$ is:

A. 1

B. 0

C. π

D. $\sqrt{\pi}$

Q29. The Laplace transform of e^{at} is:

A. $\frac{1}{s-a}$

B. $\frac{1}{s+a}$

C. $\frac{a}{s^2+a^2}$

D. $\frac{s}{s^2+a^2}$

Q30. The inverse Laplace transform of $\frac{1}{s^2+\omega^2}$ is:

A. $\sin \omega t$

B. $\frac{1}{\omega} \sin \omega t$

C. $\cos \omega t$

D. $\frac{1}{\omega} \cos \omega t$

Q31. If a matrix A is symmetric, then:

A. $A^T = A$

B. $A^T = -A$

C. $A^2 = I$

D. $|A| = 0$

Q32. The system of equations $x + y = 2$ and $2x + 2y = 4$ has:

A. Unique solution

B. No solution

C. Infinite solutions

D. Exactly two solutions

Q33. The period of the function $\sin(2x)$ is:

A. $\pi/2$

B. π

C. 2π

D. 4π

Q34. The length of the major axis of the ellipse $x^2/9 + y^2/4 = 1$ is:

A. 3

B. 6

C. 2

D. 4

Q35. Using L'Hopital's rule, $\lim_{x\to 0} \frac{e^x-1}{x}$ is:

A. 0

B. 1

C. e

D. Infinity

Q36. The integral of $1/x$ with respect to x is:

A. $-1/x^2$

B. $\log|x|$

C. x

D. e^x

Q37. The particular integral of $(D^2+1)y = e^x$ is:

A. $\frac{1}{2}e^x$

B. e^x

C. $-\frac{1}{2}e^x$

D. $\frac{1}{3}e^x$

Q38. The direction ratios of the line joining $(1, 2, 3)$ and $(4, 5, 7)$ are:

A. 3, 3, 4

B. 5, 7, 10

C. -3, -3, -4

D. 3, 3, 2

Q39. The unit vector in the direction of $3\mathbf{i} + 4\mathbf{j}$ is:

A. $\frac{3}{5}\mathbf{i} + \frac{4}{5}\mathbf{j}$

B. $3\mathbf{i} + 4\mathbf{j}$

C. $\frac{3}{25}\mathbf{i} + \frac{4}{25}\mathbf{j}$

D. $\mathbf{i} + \mathbf{j}$

Q40. If $z_1 = 2 + 3i$ and $z_2 = 1 - i$, then $z_1 + z_2$ is:

A. 3+2i

B. 3+4i

C. 1+4i

D. 1+2i

Q41. A force is completely defined by its:

A. Magnitude

B. Direction

C. Point of application

D. All of the above

Q42. The SI unit of moment of force is:

A. N/m

B. N·m

C. kg·m

D. J/s

Q43. Two forces of 3N and 4N act at right angles. Their resultant is:

A. 1N

B. 5N

C. 7N

D. 12N

Q44. Lami's theorem is applicable only for:

A. Two concurrent forces

B. Three concurrent coplanar forces in equilibrium

C. Four concurrent forces

D. Non-concurrent forces

Q45. If the resultant of two equal forces P is also P, the angle between them is:

A. 60°

B. 90°

C. 120°

D. 180°

Q46. The center of gravity of a solid cone of height h lies on its axis at a distance from the base equal to:

A. $h/2$

B. $h/3$

C. $h/4$

D. $3h/4$

Q47. The centroid of a semicircle of radius R from its diametral axis is at a distance of:

A. $3R/4\pi$

B. $4R/3\pi$

C. $2R/\pi$

D. $R/2$

Q48. Moment of inertia of a rectangular section $(b \times d)$ about its centroidal axis parallel to base b is:

A. $db^3/12$

B. $bd^3/12$

C. $bd^3/3$

D. $db^3/3$

Q49. The radius of gyration k is given by the relation (where I is moment of inertia and A is area):

A. $k = \sqrt{I/A}$

B. $k = I/A$

C. $k = \sqrt{A/I}$

D. $k = I^2/A$

Q50. The angle of friction ϕ and the coefficient of friction μ are related by:

A. $\mu = \sin\phi$

B. $\mu = \cos\phi$

C. $\mu = \tan\phi$

D. $\mu = \cot\phi$

Q51. When a body is just on the point of sliding down an inclined plane, the angle of inclination is equal to:

A. Angle of repose

B. Angle of friction

C. Critical angle

D. Zero

Q52. Frictional force is always directed:

A. In the direction of motion

B. Opposite to the impending motion

C. Perpendicular to the surface

D. Towards the center of gravity

Q53. The velocity-time graph of a body moving with uniform acceleration is a:

A. Curve

B. Parabola

C. Straight line inclined to the time axis

D. Line parallel to the time axis

Q54. A stone dropped from a height h reaches the ground in time t. The relation is:

A. $t = \sqrt{h/g}$

B. $t = \sqrt{2h/g}$

C. $t = 2h/g$

D. $t = h/2g$

Q55. The maximum range of a projectile is obtained when the angle of projection is:

A. $30°$

B. $45°$

C. $60°$

D. $90°$

Q56. Newton's second law of motion gives a measure of:

A. Inertia

B. Force

C. Momentum

D. Acceleration

Q57. D'Alembert's principle states that a moving body can be brought to dynamic equilibrium by applying:

A. An inertia force

B. A frictional force

C. A centrifugal force

D. A centripetal force

Q58. The kinetic energy of a body of mass m and momentum p is:

A. p^2/m

B. $p^2/2m$

C. $2p^2/m$

D. $p/2m$

Q59. The rate of doing work is known as:

A. Energy

B. Power

C. Momentum

D. Impulse

Q60. One horsepower (metric) is equal to:

A. 746 Watts

B. 735.5 Watts

C. 1000 Watts

D. 500 Watts

Q61. Impulse is defined as the product of:

A. Force and distance

B. Mass and velocity

C. Force and time

D. Power and time

Q62. In a perfectly elastic collision, which of the following is conserved?

A. Only momentum

B. Only kinetic energy

C. Both momentum and kinetic energy

D. Neither

Q63. The coefficient of restitution e for a perfectly inelastic collision is:

A. 1

B. 0

C. Between 0 and 1

D. Infinity

Q64. The mechanical advantage (MA) of a simple machine is the ratio of:

A. Load to Effort

B. Effort to Load

C. Distance moved by effort to distance moved by load

D. Output work to Input work

Q65. Velocity ratio (VR) of a machine is defined as:

A. Distance moved by effort / Distance moved by load

B. Load / Effort

C. Efficiency $\times$ MA

D. Output / Input

Q66. A machine is said to be reversible if its efficiency is:

A. Less than 50%

B. Exactly 50%

C. Greater than 50%

D. 100%

Q67. In a simple wheel and axle, the velocity ratio is (where D is dia of wheel, d is dia of axle):

A. d/D

B. D/d

C. $D \times d$

D. $D - d$

Q68. The condition for a machine to be self-locking is that its efficiency must be:

A. $< 50\%$

B. $> 50\%$

C. $= 50\%$

D. $= 100\%$

Q69. Angular velocity is expressed in:

A. m/s

B. rad/s

C. rev/min (only)

D. degrees/s^2

Q70. The relation between linear velocity v and angular velocity ω for a particle moving in a circle of radius r is:

A. $v = \omega/r$

B. $v = r/\omega$

C. $v = r\omega$

D. $v = r^2\omega$

Q71. Centripetal force acting on a particle of mass m moving with velocity v in a circle of radius r is:

A. mv/r

B. mv^2/r

C. $mr^2\omega$

D. $m\omega^2/r$

Q72. The work done by a force of 10N moving a body through 2m in its own direction is:

A. 5 J

B. 12 J

C. 20 J

D. 100 J

Q73. Potential energy of a spring with spring constant k compressed by distance x is:

A. kx

B. kx^2

C. $\frac{1}{2}kx^2$

D. $2kx^2$

Q74. The principle of conservation of energy states that:

A. Energy can be created

B. Energy can be destroyed

C. Total energy of an isolated system remains constant

D. Kinetic energy is always conserved

Q75. If a body is rotating about a fixed axis, its kinetic energy is given by:

A. $\frac{1}{2}mv^2$

B. $\frac{1}{2}I\omega^2$

C. $I\omega$

D. $m\omega^2$

Q76. A couple consists of:

A. Two equal and collinear forces

B. Two equal, opposite, and parallel forces

C. Three concurrent forces

D. Two unequal parallel forces

Q77. The moment of a couple is:

A. Dependent on the axis of rotation

B. Independent of the axis of rotation

C. Zero

D. Equal to the resultant force

Q78. A rigid body is in equilibrium under the action of coplanar forces if:

A. $\sum F_x = 0$

B. $\sum F_y = 0$

C. $\sum M = 0$

D. All of the above

Q79. The normal reaction on a body placed on a horizontal surface is equal to:

A. Its mass

B. Its weight

C. Zero

D. Frictional force

Q80. The center of percussion of a rigid body is also known as the:

A. Center of gravity

B. Center of mass

C. Center of oscillation

D. Centroid

Q81. Ohm's law states that at constant temperature, the current flowing through a conductor is directly proportional to the:

A. Resistance

B. Potential difference

C. Time

D. Charge

Q82. The equivalent resistance of two resistors R_1 and R_2 connected in parallel is:

A. $R_1 + R_2$

B. $\frac{R_1 R_2}{R_1 + R_2}$

C. $\frac{R_1 + R_2}{R_1 R_2}$

D. $R_1 - R_2$

Q83. Kirchhoff's Current Law (KCL) is based on the principle of conservation of:

A. Energy

B. Momentum

C. Charge

D. Mass

Q84. The SI unit of electrical resistivity is:

A. Ohm

B. Ohm·meter

C. Siemens

D. Ohm/meter

Q85. Superposition theorem is applicable only to:

A. Linear networks

B. Non-linear networks

C. Active networks only

D. Passive networks only

Q86. The RMS value of a sinusoidal alternating voltage $V = V_m \sin \omega t$ is:

A. $V_m/2$

B. $V_m/\sqrt{2}$

C. $2V_m/\pi$

D. V_m

Q87. The power factor of an AC circuit is defined as the ratio of:

A. True power to apparent power

B. Apparent power to true power

C. Reactive power to true power

D. True power to reactive power

Q88. In a purely capacitive AC circuit, the current:

A. Lags the voltage by 90°

B. Leads the voltage by 90°

C. Is in phase with the voltage

D. Lags the voltage by 45°

Q89. The frequency of the standard domestic AC supply in India is:

A. 60 Hz

B. 50 Hz

C. 100 Hz

D. 120 Hz

Q90. In a 3-phase star connection, the relation between line voltage (V_L) and phase voltage (V_{ph}) is:

A. $V_L = V_{ph}$

B. $V_L = \sqrt{3}V_{ph}$

C. $V_L = V_{ph}/\sqrt{3}$

D. $V_L = 3V_{ph}$

Q91. The unit of magnetic flux is:

A. Tesla

B. Weber

C. Ampere-turn

D. Henry

Q92. Reluctance in a magnetic circuit is analogous to which quantity in an electric circuit?

A. Voltage

B. Current

C. Resistance

D. Conductance

Q93. Faraday's laws of electromagnetic induction mathematically define the induced emf as:

A. $e = L\frac{di}{dt}$

B. $e = -N\frac{d\phi}{dt}$

C. $e = B \cdot l \cdot v$

D. $e = M\frac{di}{dt}$

Q94. Lenz's law is a consequence of the law of conservation of:

A. Charge

B. Mass

C. Energy

D. Momentum

Q95. The core of a transformer is laminated to reduce:

A. Copper loss

B. Hysteresis loss

C. Eddy current loss

D. Flux leakage

Q96. A transformer operates on the principle of:

A. Self-induction

B. Mutual induction

C. Electrostatic induction

D. Electromagnetic repulsion

Q97. In a step-down transformer, the number of turns in the primary winding is:

A. Less than the secondary

B. Greater than the secondary

C. Equal to the secondary

D. Zero

Q98. The rotating part of a DC machine is called the:

A. Stator

B. Field winding

C. Armature

D. Commutator

Q99. The function of a commutator in a DC generator is to:

A. Convert AC to DC

B. Convert DC to AC

C. Reduce sparking

D. Increase voltage

Q100. Which motor is best suited for traction purposes (like electric trains)?

A. DC Shunt Motor

B. DC Series Motor

C. Synchronous Motor

D. Squirrel Cage Induction Motor

Q101. An intrinsic semiconductor at absolute zero temperature behaves as a:

A. Good conductor

B. Superconductor

C. Perfect insulator

D. Variable resistor

Q102. P-type semiconductor is formed by doping silicon with a:

A. Pentavalent impurity (e.g., Phosphorus)

B. Trivalent impurity (e.g., Boron)

C. Tetravalent impurity

D. Hexavalent impurity

Q103. In a heavily doped PN junction diode, the depletion layer becomes:

A. Wider

B. Narrower

C. Remains unchanged

D. Disappears completely

Q104. A half-wave rectifier uses how many diodes?

A. 1

B. 2

C. 3

D. 4

Q105. The ripple factor of a full-wave rectifier is approximately:

A. 1.21

B. 0.48

C. 0.81

D. 0.12

Q106. In a Bipolar Junction Transistor (BJT), the heavily doped region is the:

A. Base

B. Collector

C. Emitter

D. Gate

Q107. For a transistor in the common-emitter configuration, the current gain β is the ratio of:

A. I_C/I_E

B. I_C/I_B

C. I_E/I_B

D. I_B/I_C

Q108. The active region of a transistor is used primarily for:

A. Switching

B. Amplification

C. Rectification

D. Oscillation

Q109. An ideal operational amplifier (Op-Amp) has an input impedance of:

A. Zero

B. 100 Ω

C. 1 kΩ

D. Infinity

Q110. The Common Mode Rejection Ratio (CMRR) of an ideal Op-Amp is:

A. Zero

B. 1

C. Infinity

D. Negative

Q111. If the inverting input of an Op-Amp is grounded and a signal is applied to the non-inverting input, the phase shift in the output is:

A. 180°

B. 90°

C. 0°

D. 270°

Q112. Which logic gate is known as the "Universal Gate"?

A. AND

B. OR

C. NAND

D. XOR

Q113. The Boolean expression for an OR gate with inputs A and B is:

A. $Y = A \cdot B$

B. $Y = A + B$

C. $Y = \overline{A \cdot B}$

D. $Y = A \oplus B$

Q114. In the binary number system, the decimal number 10 is represented as:

A. 1010

B. 1100

C. 1001

D. 1011

Q115. De Morgan's First Theorem states that $\overline{A \cdot B}$ is equivalent to:

A. $\overline{A} \cdot \overline{B}$

B. $\overline{A} + \overline{B}$

C. $A + B$

D. $A \cdot B$

Q116. A flip-flop is a fundamental building block of digital circuits capable of storing:

A. 1 bit of data

B. 1 byte of data

C. 4 bits of data

D. Analog signals

Q117. In an AC circuit, the active power (P) is given by the formula:

A. $VI \sin \phi$

B. $VI \cos \phi$

C. VI

D. V^2/R

Q118. The efficiency of a full-wave rectifier is approximately:

A. 40.6%

B. 81.2%

C. 100%

D. 50%

Q119. A Zener diode is primarily used for:

A. Amplification

B. Voltage regulation

C. Rectification

D. Light emission

Q120. The standard color of the earth wire in domestic electrical wiring is:

A. Red

B. Black

C. Green

D. Blue

Solutions

1. C
Explanation: For a matrix A of order n, $|kA| = k^n|A|$. Here $n = 3, k = 2$, so $|2A| = 2^3 \times 5 = 8 \times 5 = 40$.

2. D
Explanation: A singular matrix has a determinant equal to 0. Since $A^{-1} = \text{adj}(A)/|A|$, division by zero means the inverse does not exist.

3. B
Explanation: Squaring both sides gives $\sin^2\theta + \cos^2\theta + 2\sin\theta\cos\theta = 2$. This simplifies to $1 + \sin 2\theta = 2 \implies \sin 2\theta = 1$, which means $2\theta = \pi/2$ or $\theta = \pi/4$.

4. B
Explanation: $\tan 75° = \tan(45° + 30°) = (\tan 45° + \tan 30°)/(1 - \tan 45° \tan 30°) = (1 + 1/\sqrt{3})/(1 - 1/\sqrt{3}) = (\sqrt{3} + 1)/(\sqrt{3} - 1)$. Rationalizing gives $2 + \sqrt{3}$.

5. B
Explanation: The distance between parallel lines $Ax + By + C_1 = 0$ and $Ax + By + C_2 = 0$ is $|C_1 - C_2|/\sqrt{A^2 + B^2}$. Here, $|5 - 15|/\sqrt{3^2 + (-4)^2} = 10/5 = 2$.

6. C
Explanation: The slope of $2x + 3y - 5 = 0$ is $-2/3$. The slope of a perpendicular line is the negative reciprocal, which is $3/2$.

7. A
Explanation: The standard equation of a circle is $x^2 + y^2 + 2gx + 2fy + c = 0$, with center $(-g, -f)$. Here $2g = -6 \implies g = -3$ and $2f = 8 \implies f = 4$. The center is $(3, -4)$.

8. B
Explanation: By definition, the eccentricity of any standard parabola is strictly equal to 1.

9. B
Explanation: Multiplying and dividing by 5 gives $\lim_{x\to 0} 5\frac{\sin 5x}{5x}$. Since $\lim_{\theta\to 0} \frac{\sin\theta}{\theta} = 1$, the answer is $5 \times 1 = 5$.

10. A
Explanation: Using the chain rule, $\frac{d}{dx}(e^{\sin x}) = e^{\sin x} \cdot \frac{d}{dx}(\sin x) = e^{\sin x}\cos x$.

11. A
Explanation: The derivative is $\frac{1}{\sec x + \tan x} \cdot (\sec x \tan x + \sec^2 x)$. Factoring out $\sec x$ in the numerator allows cancellation, leaving exactly $\sec x$.

12. B
Explanation: For a minimum, $f'(x) = 2x - 4 = 0$, giving $x = 2$. The second derivative $f''(x) = 2$, which is positive, confirming a minimum.

13. A
Explanation: The integrand can be written as $e^x(\tan x + (1 + \tan^2 x)) = e^x(\tan x + \sec^2 x)$. This is of the form $\int e^x(f(x) + f'(x))dx$, which evaluates to $e^x f(x) = e^x \tan x + C$.

14. A

Explanation: Using the Beta/Gamma function or Walli's formula: $\int_0^{\pi/2} \sin^m x \cos^n x\, dx = \frac{[(m-1)(m-3)...][(n-1)(n-3)...]}{(m+n)(m+n-2)...}$. Here $m = 3, n = 2$, yielding $(2 \cdot 1)/(5 \cdot 3 \cdot 1) = 2/15$.

15. C
Explanation: The circle equation $x^2 + y^2 = 16$ has a radius $r^2 = 16$. The area is $\pi r^2 = 16\pi$.

16. A
Explanation: The highest order derivative is d^2y/dx^2 (Order = 2). The power raised to this highest order derivative is 2 (Degree = 2). Wait, option is C. Let me self-correct: the question says 2 and 1 in Option A, 2 and 2 in Option C. My answer says A but explanation proves C. Let me write C. *(Self-correction output string adjustment)*: **16. C**
Explanation: Order is the highest derivative present (d^2y/dx^2, so order 2). Degree is the highest power of this derivative, which is 2. Thus, Order 2, Degree 2.

17. A
Explanation: The integrating factor (IF) is $e^{\int P\, dx}$, where $P = \cot x$. Thus, IF $= e^{\int \cot x\, dx} = e^{\log \sin x} = \sin x$.

18. A
Explanation: The auxiliary equation is $m^2 - 5m + 6 = 0$. Factoring this gives $(m-2)(m-3) = 0$, so the roots are $m = 2, 3$.

19. A
Explanation: The dot product is $(2)(1) + (-1)(2) + (1)(-3) = 2 - 2 - 3 = -3$.

20. D
Explanation: The cross product $\mathbf{j} \times \mathbf{k} = \mathbf{i}$. Then, $\mathbf{i} \times (\mathbf{i})$ represents the cross product of parallel vectors, which is strictly 0.

21. B
Explanation: The cross product of two vectors involves the sine of the angle between them. If they are parallel, the angle is $0°$ or $180°$, making $\sin\theta = 0$, thus the cross product is the zero vector.

22. C
Explanation: The powers of i cycle every 4 steps. Since $25 = 4 \times 6 + 1$, $i^{25} = (i^4)^6 \cdot i = (1)^6 \cdot i = i$.

23. A
Explanation: The modulus of a complex number $a + bi$ is $\sqrt{a^2 + b^2}$. For $3 + 4i$, it is $\sqrt{3^2 + 4^2} = \sqrt{25} = 5$.

24. B
Explanation: The argument $\theta = \tan^{-1}(y/x)$. For $1 + i$, both x and y are 1. Thus $\theta = \tan^{-1}(1/1) = \tan^{-1}(1) = \pi/4$.

25. A
Explanation: Favorable outcomes for a sum of 9 are (3,6), (4,5), (5,4), and (6,3). That's 4 out of 36 total possible outcomes. The probability is $4/36 = 1/9$.

26. B
Explanation: The sum of the first 10 natural numbers is $(10 \times 11)/2 = 55$. Their mean is $55/10 = 5.5$.

27. B
Explanation: Using the formula $P(A \cup B) = P(A) + P(B) - P(A \cap B)$, we get $0.5 + 0.4 - 0.2 = 0.7$.

28. D
Explanation: A well-known mathematical identity states that the Gamma function evaluated at one-half, $\Gamma(1/2)$, is exactly equal to $\sqrt{\pi}$.

29. A
Explanation: By definition, the Laplace transform $\mathcal{L}\{e^{at}\} = \int_0^\infty e^{-st}e^{at}\,dt = \frac{1}{s-a}$, provided $s > a$.

30. B
Explanation: The standard Laplace transform of $\sin(\omega t)$ is $\frac{\omega}{s^2+\omega^2}$. Therefore, the inverse transform of $\frac{1}{s^2+\omega^2}$ requires dividing by ω, yielding $\frac{1}{\omega}\sin\omega t$.

31. A
Explanation: A square matrix A is defined as symmetric if it is identical to its transpose, meaning $A^T = A$.

32. C
Explanation: The second equation $2x + 2y = 4$ is exactly twice the first equation $x + y = 2$. Since they represent the exact same line, they geometrically overlap, resulting in infinite solutions.

33. B
Explanation: The fundamental period of $\sin(x)$ is 2π. For $\sin(kx)$, the period is $2\pi/|k|$. Here $k = 2$, so the period is $2\pi/2 = \pi$.

34. B
Explanation: The standard ellipse equation is $x^2/a^2 + y^2/b^2 = 1$. Here $a^2 = 9 \implies a = 3$. The major axis length is $2a = 2(3) = 6$.

35. B
Explanation: This is a $0/0$ form. Applying L'Hopital's rule, differentiate the numerator and denominator: $\lim_{x\to 0} \frac{e^x}{1} = e^0 = 1$.

36. B
Explanation: By standard integration rules, the integral of x^{-1} (or $1/x$) with respect to x is the natural logarithm $\log|x| + C$.

37. A
Explanation: For $(f(D))y = e^{ax}$, the Particular Integral is $1/f(a)e^{ax}$. Here $f(D) = D^2 + 1$ and $a = 1$. Thus, PI $= 1/(1^2 + 1)e^x = \frac{1}{2}e^x$.

38. A
Explanation: The direction ratios are the differences in coordinates: $(x_2 - x_1), (y_2 - y_1), (z_2 - z_1) = (4-1), (5-2), (7-3) = 3, 3, 4$.

39. A
Explanation: The magnitude of $3\mathbf{i} + 4\mathbf{j}$ is $\sqrt{3^2 + 4^2} = 5$. The unit vector is obtained by dividing the vector by its magnitude, yielding $\frac{3}{5}\mathbf{i} + \frac{4}{5}\mathbf{j}$.

40. A
Explanation: To add complex numbers, simply add their real parts and imaginary parts respectively: $(2 + 1) + (3 - 1)i = 3 + 2i$.

41. D
Explanation: A force is a vector quantity and a localized vector. It is completely defined by its magnitude, direction, and specific point of application (or line of action).

42. B
Explanation: Moment of force (Torque) is the product of force and perpendicular distance. Its SI unit is Newton-meter (N·m).

43. B
Explanation: For two forces at right angles, the resultant magnitude is $R = \sqrt{F_1^2 + F_2^2} = \sqrt{3^2 + 4^2} = \sqrt{25} = 5\text{N}$.

44. B
Explanation: Lami's theorem strictly applies to a system of exactly three concurrent, coplanar forces that are in static equilibrium.

45. C
Explanation: From $R^2 = P^2 + Q^2 + 2PQ\cos\theta$, we have $P^2 = P^2 + P^2 + 2P^2\cos\theta$, which gives $\cos\theta = -1/2$, corresponding to $120°$.

46. C
Explanation: The center of gravity of a solid right circular cone lies on its central axis at a height of $h/4$ from its base.

47. B
Explanation: For a semicircle of radius R, the centroid is situated on its axis of symmetry at a distance of $4R/3\pi$ from its diametral base.

48. B
Explanation: The area moment of inertia for a rectangle of width b and depth d about its centroidal axis parallel to the base is $bd^3/12$.

49. A
Explanation: Radius of gyration k is defined such that the moment of inertia $I = Ak^2$. Rearranging yields $k = \sqrt{I/A}$.

50. C
Explanation: The coefficient of friction (μ) is mathematically equal to the tangent of the angle of friction (ϕ), thus $\mu = \tan\phi$.

51. A
Explanation: The angle of repose is defined as the minimum angle of an inclined plane at which a body placed on it is just on the verge of sliding down.

52. B
Explanation: Friction is a resistive force that always acts in a direction exactly opposite to the actual or impending relative motion between two surfaces.

53. C
Explanation: For uniform acceleration, $v = u + at$. This forms a linear equation ($y = mx + c$), representing a straight line inclined to the time axis on a v-t graph.

54. B
Explanation: Using the kinematic equation $s = ut + \frac{1}{2}gt^2$. With initial velocity $u = 0$ and distance $s = h$, we get $h = \frac{1}{2}gt^2$, which yields $t = \sqrt{2h/g}$.

55. B
Explanation: The range is $R = u^2 \sin(2\theta)/g$. The sine function maximizes at 1 (when $2\theta = 90°$), which occurs precisely when the projection angle $\theta = 45°$.

56. B
Explanation: Newton's second law fundamentally states that the rate of change of momentum is directly proportional to the applied external Force ($F = ma$).

57. A
Explanation: D'Alembert's principle introduces a fictitious 'inertia force' (equal to $-ma$) to reduce a complex dynamics problem into a simpler static equilibrium problem.

58. B
Explanation: Kinetic energy $K = \frac{1}{2}mv^2$. Multiplying and dividing by m gives $K = \frac{1}{2}(mv)^2/m$. Since momentum $p = mv$, $K = p^2/2m$.

59. B
Explanation: Power is strictly defined in physics as the time rate at which work is done or energy is transferred.

60. B
Explanation: The metric horsepower is standardized as exactly 735.5 Watts, while the Imperial (mechanical) horsepower is approximately 746 Watts.

61. C
Explanation: Impulse is defined as the integral of a force over the time interval it acts, effectively representing the product of average force and time ($J = F \cdot \Delta t$).

62. C
Explanation: By definition, a perfectly elastic collision uniquely conserves both the total momentum of the system and the total kinetic energy.

63. B
Explanation: In a perfectly inelastic collision, the colliding bodies stick together and move with a common velocity, meaning relative separation velocity is zero. Thus, $e = 0$.

64. A
Explanation: Mechanical Advantage (MA) measures the force amplification of a machine and is strictly the ratio of the Load lifted to the Effort applied.

65. A
Explanation: Velocity Ratio (VR) is the purely geometric ratio of the distance moved by the effort force to the corresponding distance moved by the load.

66. C
Explanation: A machine is defined as reversible if it is capable of doing work in the reverse direction when the effort is removed. This strictly requires its efficiency to be greater than 50**67. B**
Explanation: For a wheel and axle, one revolution moves the effort by πD and the load by πd. The velocity ratio is $\pi D/\pi d = D/d$.

68. A
Explanation: A machine is self-locking (non-reversible) if the friction is sufficient

to hold the load when the effort is removed. This definitively occurs when efficiency is less than 50**69. B**
Explanation: The standard SI unit for angular velocity (ω) is radians per second (rad/s), measuring the rate of change of angular displacement.

70. C
Explanation: Linear velocity v and angular velocity ω are directly related by the radius of the circular path, fundamentally expressed as $v = r\omega$.

71. B
Explanation: Centripetal force acts towards the center to maintain circular motion. Its magnitude is fundamentally given by $F_c = mv^2/r$.

72. J
(Correction): Option C is 20 J. **72. C**
Explanation: Work done is Force $\times$ distance in the direction of force. $W = 10\text{N} \times 2\text{m} = 20$ Joules.

73. C
Explanation: The elastic potential energy stored in a compressed or stretched spring is derived by integrating Hooke's Law ($F = kx$), yielding $U = \frac{1}{2}kx^2$.

74. C
Explanation: The law of conservation of energy states that energy can neither be created nor destroyed; the total energy of an isolated, closed system remains rigidly constant.

75. B
Explanation: For a body rotating about a fixed axis with moment of inertia I and angular velocity ω, its rotational kinetic energy is mathematically $\frac{1}{2}I\omega^2$.

76. B
Explanation: In mechanics, a couple is strictly defined as a system of exactly two parallel forces that are equal in magnitude, completely opposite in direction, and non-collinear.

77. B
Explanation: The unique property of a couple is that it produces pure rotation. Its moment (torque) is completely constant and entirely independent of the chosen axis of rotation.

78. D
Explanation: For a rigid body to remain in complete static equilibrium under coplanar forces, there must be no net force ($\sum F_x = 0, \sum F_y = 0$) and no net moment ($\sum M = 0$).

79. B
Explanation: For a body resting on a flat, horizontal surface with no vertical acceleration, the upward normal reaction force strictly balances the downward weight of the body.

80. C
Explanation: The center of percussion of a rigid compound pendulum is dynamically identical to the center of oscillation; a blow at this point produces zero reactive shock at the pivot.

81. B

Explanation: Ohm's law explicitly states that current I is directly proportional to the applied potential difference V across a conductor, provided temperature remains constant ($V = IR$).

82. B

Explanation: For two parallel resistors, the equivalent resistance is $1/R_{eq} = 1/R_1 + 1/R_2$. Solving this algebraically yields $R_{eq} = \frac{R_1 R_2}{R_1 + R_2}$.

83. C

Explanation: KCL states that the total current entering a junction equals the total current leaving it, fundamentally upholding the principle of conservation of electric charge.

84. B

Explanation: Resistivity $\rho = RA/l$. With resistance R in Ohms, Area A in m^2, and length l in m, the strictly derived SI unit is Ohm·meter ($\Omega \cdot m$).

85. A

Explanation: The Superposition Theorem relies completely on linear proportionality. Therefore, it is strictly valid and applicable only to linear bilateral electrical networks.

86. B

Explanation: The Root Mean Square (RMS) value of a pure sinusoidal waveform is exactly its peak (maximum) value divided by $\sqrt{2}$, thus $V_{rms} = V_m/\sqrt{2}$.

87. A

Explanation: The power factor in an AC circuit ($\cos\phi$) is the strict ratio of the True Power (Watts) consumed to the Apparent Power (Volt-Amperes) drawn.

88. B

Explanation: In a purely capacitive circuit, the alternating current strictly leads the applied alternating voltage by a phase angle of exactly 90° ($\pi/2$ radians).

89. B

Explanation: The standardized frequency for domestic AC mains power supply in India (and many other countries) is precisely 50 Hertz.

90. B

Explanation: In a balanced 3-phase Star (Y) connected system, the line voltage (V_L) is vectorially $\sqrt{3}$ times larger than the phase voltage (V_{ph}), while line current equals phase current.

91. B

Explanation: The SI unit of magnetic flux is the Weber (Wb). Tesla is the unit for magnetic flux density (Webers per square meter).

92. C

Explanation: Reluctance physically opposes the creation of magnetic flux in a magnetic circuit, acting in direct analogy to electrical Resistance which opposes current flow in an electric circuit.

93. B

Explanation: Faraday's Law states that the induced electromotive force (emf)

in a coil is directly proportional to the rate of change of magnetic flux linkages, expressed as $e = -N\frac{d\phi}{dt}$.

94. C
Explanation: Lenz's Law dictates that induced emf opposes the change producing it. This mechanical opposition requires work to be done, which physically manifests as electrical energy, thus conserving energy.

95. C
Explanation: Laminating the iron core with thin insulated steel sheets drastically increases the electrical resistance of the core, thereby significantly reducing circulating eddy current losses.

96. B
Explanation: A transformer transfers electrical energy between two isolated circuits using a shared magnetic field, fundamentally operating on the principle of electromagnetic mutual induction.

97. B
Explanation: A step-down transformer strictly reduces the output voltage. Since voltage is proportional to the number of turns ($V_p/V_s = N_p/N_s$), the primary winding heavily requires more turns than the secondary.

98. C
Explanation: In a conventional DC machine (motor or generator), the stationary outer part is the stator (containing field poles), and the rotating inner core is exclusively termed the armature.

99. A
Explanation: The armature coils inherently produce alternating current (AC). In a DC generator, the mechanical commutator acts as a rotary switch to strictly rectify this internal AC into external unidirectional DC.

100. B
Explanation: A DC Series Motor develops an extremely high starting torque (torque is proportional to the square of current), making it absolutely ideal for heavy-duty traction applications like electric locomotives.

101. C
Explanation: At absolute zero (0 K), all valence electrons are tightly bound in covalent bonds. With zero thermal energy to excite electrons into the conduction band, an intrinsic semiconductor acts as a perfect insulator.

102. B
Explanation: Doping a tetravalent semiconductor (like Silicon) with a trivalent impurity (like Boron) creates a deficiency of one electron (a 'hole'), specifically forming a Positive (P-type) semiconductor.

103. B
Explanation: Heavy doping vastly increases the density of majority charge carriers. This means a much thinner spatial volume of fixed ions is required to establish the barrier potential, strictly making the depletion layer narrower.

104. A
Explanation: A standard half-wave rectifier circuit fundamentally requires only a

single PN junction diode to clip off the negative half-cycles of the AC input.

105. B
Explanation: The ripple factor indicates the amount of residual AC in the DC output. For a standard full-wave rectifier, it is mathematically derived to be exactly 0.48 (or 48**106. C**
Explanation: In a BJT, the Emitter region is intentionally the most heavily doped. Its primary function is to massively inject majority charge carriers into the base region.

107. B
Explanation: In the Common Emitter (CE) configuration, the input current is the base current (I_B) and output is collector current (I_C). The forward current gain β is strictly the ratio I_C/I_B.

108. B
Explanation: To operate as a linear signal amplifier, a transistor must be biased strictly in its active region, where the base-emitter junction is forward-biased and the base-collector is reverse-biased.

109. D
Explanation: An ideal Operational Amplifier is theoretically designed to draw absolutely zero current from the input signal source, which strictly requires it to have an infinite input impedance.

110. C
Explanation: CMRR is the ratio of differential gain to common-mode gain. An ideal Op-Amp perfectly rejects any common-mode signals (noise), meaning common-mode gain is zero, making CMRR theoretically infinite.

111. C
Explanation: Applying a signal to the non-inverting (+) terminal of an Op-Amp precisely produces an amplified output signal that is exactly in-phase (0° phase shift) with the applied input.

112. C
Explanation: Both NAND and NOR gates are uniquely classified as Universal Gates because any other basic Boolean logic gate (AND, OR, NOT) can be entirely synthesized using only them.

113. B
Explanation: The OR gate performs logical addition. Its output is True if at least one input is True, which is mathematically represented by the Boolean expression $Y = A + B$.

114. A
Explanation: Decimal 10 translates to binary by division: $10/2 = 5(R0)$, $5/2 = 2(R1)$, $2/2 = 1(R0)$, $1/2 = 0(R1)$. Reading remainders bottom-up gives exactly 1010.

115. B
Explanation: De Morgan's First Theorem mathematically dictates that the complement of a logical product (NAND) is strictly equivalent to the logical sum of the individual complements ($\overline{A \cdot B} = \overline{A} + \overline{B}$).

116. A
Explanation: A flip-flop (or latch) is a fundamental bistable multivibrator circuit. Its primary function in digital electronics is to reliably store exactly 1 bit (a single 0 or 1) of binary data.

117. B
Explanation: In AC circuits, the True (or Active) power P, which represents actual useful work done, is strictly calculated as $P = VI\cos\phi$, where $\cos\phi$ is the power factor.

118. B
Explanation: Rectifier efficiency is the ratio of DC output power to AC input power. For an ideal full-wave rectifier, this is theoretically calculated to reach a maximum of $8/\pi^2$ or precisely 81.2 per cent.

119. B
Explanation: A Zener diode is heavily doped to operate reliably in reverse-bias breakdown. Once in breakdown, it maintains a remarkably constant voltage across its terminals, making it an excellent voltage regulator.

120. C
Explanation: In standardized electrical wiring color codes (both historical and modern IEC standards), the Earth (ground) wire is strictly identified by a solid Green color or Green with Yellow stripes.