

The escape velocity from the surface of the Earth depends on the radius of the Earth ($v_{\text{esc}} = \sqrt{2GM_{\text{E}}/R_{\text{E}}}$), whereas the orbital velocity of a satellite depends on the radius of its orbit ($v_{\text{orb}} = \sqrt{GM_{\text{E}}/r}$).

4. Which one of the following statements is correct about actions of A.C. and D.C. generators? (1)
- A. The voltage output of D.C. generators varies periodically whereas the voltage output of A.C generator is constant.
- B. The current outputs of both generator A.C. and D.C. generator have constant values.
- C. **The voltage induced by A.C. generator reverses its direction periodically whereas by the D.C. generators ✓ has a constant value.**
- D. The current outputs of both A.C. and D.C. generators reverse their directions periodically.

Answer: C

An AC generator produces an alternating voltage that periodically reverses its direction, whereas a DC generator uses a commutator to ensure the output voltage maintains a constant direction (polarity).

5. An electric motor exerts a constant 10 N·m torque on a grindstone, which has a moment of inertia of 5.0 kg·m² about its axis. The system starts from rest and turns. What is the work done by the motor in 4.0 s? (1)
- A. ✓ **160 J** B. 40 J
- C. 2 J D. 320 J

Answer: A

Using Newton's second law for rotation, the angular acceleration is $\alpha = \tau/I = 10/5 = 2 \text{ rad/s}^2$. The angular displacement is $\theta = \frac{1}{2}\alpha t^2 = \frac{1}{2}(2)(4.0)^2 = 16 \text{ rad}$, so the work done is $W = \tau\theta = 10 \times 16 = 160 \text{ J}$.

6. Three charges $Q_1 = 5 \times 10^{-10} \text{ C}$, $Q_2 = 2 \times 10^{-10} \text{ C}$ and $Q_3 = 3 \times 10^{-10} \text{ C}$, are placed on the x axis at points $x = 0$, $x = 2 \text{ cm}$ and $x = 4 \text{ cm}$, respectively, as shown in the figure below. What is the magnitude of electrostatic force exerted on Q_2 by the other two charges? (1)
- A. $3.6 \times 10^{-6} \text{ N}$ B. ✓ **$9 \times 10^{-7} \text{ N}$**
- C. 9 N D. $9 \times 10^{-15} \text{ N}$

Answer: B

The electrostatic force on Q_2 due to Q_1 is $F_{12} = kQ_1Q_2/r^2 = 2.25 \times 10^{-6} \text{ N}$ (to the right), and due to Q_3 is $F_{32} = kQ_3Q_2/r^2 = 1.35 \times 10^{-6} \text{ N}$ (to the left). The net force is the difference, which is $0.9 \times 10^{-6} \text{ N} = 9 \times 10^{-7} \text{ N}$.

7. Two capacitors having capacitances C_1 and C_2 are connected in series to a voltage source of potential difference V . If the total charge stored by the capacitors is Q , the total electrical energy stored by the capacitors is (1)
- A. $\frac{1}{2}(C_1 + C_2)Q^2$ B. $C_1C_2Q^2/2(C_1 + C_2)$
- C. $Q^2/2(C_1 + C_2)$ D. ✓ **$Q^2(C_1 + C_2)/2C_1C_2$**

Answer: D

For two capacitors in series, the equivalent capacitance is $C_{eq} = \frac{C_1C_2}{C_1 + C_2}$. The total energy stored is $U = \frac{Q^2}{2C_{eq}} = \frac{Q^2(C_1 + C_2)}{2C_1C_2}$.

8. An experimenter measures a current flowing through a resistor R_1 to be 1.3 A by connecting to a voltage source of a potential difference $\Delta V = 6 \text{ V}$. Next, a second resistor of R_2 is added to the circuit with parallel connection. In doing so, the current through R_1 is NOT changed but a current of $I_2 = 2 \text{ A}$ flowing through R_2 is recorded. What is the value of the effective resistance (R) of the final circuit? (1)
- A. $R = R_1 + R_2 = 1.2 \Omega$ B. $R = (R_1 + R_2)/R_1R_2 = 1.2 \Omega$
- C. ✓ **$R = (R_1R_2)/(R_1 + R_2) = 1.2 \Omega$** D. $R = R_1 + R_2 = 5$

Answer: C

The formula for the equivalent resistance of two parallel resistors is $R = \frac{R_1R_2}{R_1 + R_2}$. Correcting the typo in the first current to 3 A (instead of 1.3 A), we get $R_1 = 2 \Omega$, $R_2 = 3 \Omega$, and an effective resistance of 1.2Ω .

9. A long straight wire passing through the origin perpendicular to the xy plane carries a current I . A compass needle is moved around in the xy plane. When it is placed at the point $(0, +y)$, it deflects towards the negative x -axis; while when it is placed at $(-x, 0)$, it deflects towards the negative y -axis. In what direction does the needle deflect when it is placed at $(0, -y)$? (1)
- A. ✓ to the positive x -axis B. to the negative y -axis
C. to the positive y -axis D. to the negative x -axis

Answer: A

By applying the right-hand rule, a current flowing out of the page ($+z$) creates a counter-clockwise magnetic field. At $(0, -y)$, the magnetic field vector points in the $+x$ direction (to the positive x -axis).

10. Which one of the following statements correctly defines a couple? Couple is a pair of equal magnitude forces acting on a body (1)
- A. in the same directions to have net torque.
B. in opposite directions at the same point.
C. in opposite directions generating a net force.
D. ✓ in opposite directions generating a net torque.

Answer: D

A couple is defined as a pair of forces of equal magnitude, acting in opposite directions along different lines of action, resulting in a net torque of zero net translational force.

11. The amount of heat energy required to change 1 kg of the substance from solid to liquid at its melting point is (1)
- A. ✓ specific latent heat of fusion B. specific heat capacity
C. specific latent heat of vaporization D. specific heat of boiling

Answer: A

The specific latent heat of fusion is defined as the amount of heat energy required to completely change 1 kg of a substance from solid to liquid at its melting point without changing its temperature.

12. Which one of the following is correct about the assumptions made in the kinetic theory of ideal gases? (1)
- A. Collisions between particles of the gas are perfectly inelastic
B. Newton's laws cannot be applied during collisions between particles of the gas
C. All particles of the gas have the same value of velocities at any instant
D. ✓ The internal energy of the gas is equal to the kinetic energy of the gas

Answer: D

An assumption of the kinetic theory of ideal gases is that there are no intermolecular forces of attraction, meaning the potential energy is zero, and thus the total internal energy of the gas is entirely composed of its kinetic energy.

13. Two points P 1 and P 2 on a rigid body are located at different distances, d_1 and d_2 respectively, from the pivot point O as shown in the figure below. If a body is set to rotate about the pivot point O, (1)
- A. P 2 completes a cycle before point P 1 . B. P 1 and P 2 have equal linear speed.
C. ✓ P 1 and P 2 have equal angular velocity. D. P 2 has greater linear speed than P 1 .

Answer: C

For any rotating rigid body, all points on the body must have the same angular velocity ω to maintain the rigid structure, even if their linear speeds differ depending on their distance from the pivot.

14. Which one of the following correctly describes the relationship between the factors affecting laminar flow? (1)
- A. A fast moving object in air makes air to expand more.
 - B. A fast moving object in air causes the air to become denser.
 - C. ✓ **The effect of temperature would be significant at low speeds.**
 - D. Viscosity has no effect in case when a fast moving object is taken.

Answer: C

At low flow speeds (laminar flow), viscous forces dominate over inertial forces. Since viscosity is strongly temperature-dependent, the effect of temperature on the fluid flow is highly significant at low speeds.

15. A body is observed to be moving with constant velocity in a straight line. One can surely conclude that for this body, (1)
- A. no external force is applied on it.
 - B. no friction force is acting on it.
 - C. constant force is applied on it.
 - D. ✓ **the net external force acting on it is zero.**

Answer: D

According to Newton's First Law of Motion, a body moves with a constant velocity in a straight line if and only if the net external force acting on it is zero.

16. The speed of sound wave in one end closed organ pipe of length L is v . For which of the following harmonic frequencies (f_n) standing waves through the pipe are formed? (1)
- A. $f_n = nv/4L$, where $n = 1, 2, 3, \dots$
 - B. $f_n = nv/2L$, where $n = 1, 3, 5, \dots$
 - C. ✓ **$f_n = nv/4L$, where $n = 1, 3, 5, \dots$**
 - D. $f_n = nv/2L$, where $n = 1, 2, 3, \dots$

Answer: C

A pipe closed at one end only supports odd harmonics, meaning the resonance frequencies are given by $f_n = \frac{nv}{4L}$ where $n = 1, 3, 5, \dots$

17. A constant torque of 80 Nm is applied to the rim of a flywheel for 2 s. If the flywheel initially has angular momentum of 40 kg m²/s, what will be its final angular momentum? (1)
- A. ✓ **200 kg m²/s**
 - B. 40 kg m²/s
 - C. 160 kg m²/s
 - D. 120 kg m²/s

Answer: A

The change in angular momentum is equal to the angular impulse, $\Delta L = \tau \Delta t = 80 \text{ Nm} \times 2 \text{ s} = 160 \text{ kg m}^2/\text{s}$. Adding this to the initial angular momentum gives $L_f = 40 + 160 = 200 \text{ kg m}^2/\text{s}$.

18. A load of 4 kg is applied to the ends of a wire 5 m and cross sectional area 4 mm² to produce an extension of 0.40 mm. What is the Young's modulus of the wire? (1)
- A. $1.25 \times 10^{10} \text{ Nm}^{-2}$
 - B. ✓ **$1.25 \times 10^{11} \text{ Nm}^{-2}$**
 - C. $8.00 \times 10^{11} \text{ Nm}^{-2}$
 - D. $8.00 \times 10^{10} \text{ Nm}^{-2}$

Answer: B

Young's modulus is $Y = \frac{FL}{A\Delta L}$. Substituting $F = mg = 40 \text{ N}$, $L = 5 \text{ m}$, $A = 4 \times 10^{-6} \text{ m}^2$, and $\Delta L = 4 \times 10^{-4} \text{ m}$, we get $Y = \frac{200}{1.6 \times 10^{-9}} = 1.25 \times 10^{11} \text{ N m}^{-2}$.

A body is in translational (linear) equilibrium when the net external force acting on it is zero, which corresponds to the body moving with a constant velocity in a straight line or remaining at rest.

24. A car travelled 4 km towards east and then 3 km towards north. What is the angle of the resultant displacement from east? (1)
- A. $\tan^{-1}(4/3)$ B. ✓ $\tan^{-1}(3/4)$
C. $\tan^{-1}(4/5)$ D. $\tan^{-1}(3/5)$

Answer: B

The eastward displacement is the adjacent side (4 km) and the northward displacement is the opposite side (3 km). The angle θ from the east is given by $\tan \theta = \frac{\text{Opposite}}{\text{Adjacent}} = \frac{3}{4}$, so $\theta = \tan^{-1}(3/4)$.

25. A ball is dropped off from the top of a 20 m high cliff. How long it takes to hit the ground? (1)
- A. 4 s B. 10 s
C. ✓ 2 s D. 5 s

Answer: C

Using the kinematic equation for a dropped object, $h = \frac{1}{2}gt^2$, we solve for time: $20 = \frac{1}{2}(10)t^2 \implies t^2 = 4 \implies t = 2$ s.

26. A student of mass 40 kg is in a lift moving upward with an acceleration of 2.5 m/s^2 . What is the apparent weight of the student? (1)
- A. ✓ 500 N B. 800 N
C. 400 N D. 300 N

Answer: A

The apparent weight of the student in an upward accelerating lift is given by $N = m(g + a) = 40 \times (10 + 2.5) = 500 \text{ N}$ (using $g = 10 \text{ m/s}^2$).

27. A farmer pulls out a bucket of water from a well with wheel and axle with radii of 30 cm and 6 cm respectively. Assuming no energy losses, what effort should be applied on the wheel in order to lift a load of 40 N on the axle? (1)
- A. 20 N B. ✓ 8 N
C. 5 N D. 40 N

Answer: B

For a wheel and axle system, the mechanical advantage is $MA = R/r = 30/6 = 5$. The effort needed to lift the load is $\text{Effort} = \text{Load}/MA = 40 \text{ N}/5 = 8 \text{ N}$.

28. A square shaped body of side length l_0 is heated to raise its temperature by ΔT in Kelvin. If α stands for coefficient of linear expansion and β being coefficient of area expansion, which one of the following expressions is correct for area (A) of the body, after the temperature changed by ΔT ? (1)
- A. ✓ $A = l_0^2(1 + 2\alpha\Delta T)$ B. $A = l_0^2(1 + \alpha\Delta T)$
C. $A = l_0^2(1 + 2\beta\Delta T)$ D. $A = l_0^2(1 + \beta\Delta T)$

Answer: A

The area after thermal expansion is $A = A_0(1 + \beta\Delta T)$, where $A_0 = l_0^2$. Since the coefficient of area expansion β is approximately equal to 2α , we get $A = l_0^2(1 + 2\alpha\Delta T)$.

29. In order to measure atmospheric pressure in a given location, a student used a dish with mercury, a test tube of 4 mm radius closed at one end and a meter stick. The student inserted the open end of the tube in mercury inside the dish and left the dish open to the atmosphere as shown in the figure below. If the mercury was observed to be pushed up to raise in the tube by 500 mm, what is the atmospheric pressure in that location? ($\rho_{\text{mercury}} = 13600 \text{ kg/m}^3$) (1)

- A. 101 kPa
B. 340 kPa
C. ✓ 68 kPa
D. 27 kPa

Answer: C

The atmospheric pressure is balanced by the pressure of the mercury column, which is $P = \rho gh = 13600 \text{ kg/m}^3 \times 10 \text{ m/s}^2 \times 0.5 \text{ m} = 68 \text{ kPa}$.

30. Which one of the following statements is correct about Biot-Savart law? (1)

- A. It describes the values of magnetic torque on a coil of wire
B. ✓ It is used to determine the values for magnetic field strength of a current carrying element
C. It describes the relationship between electric fields and magnetic fields
D. It is used to determine the magnetic force on a current carrying conductor

Answer: B

The Biot-Savart law relates the magnetic field produced at a point in space to the current-carrying element that generates it.

31. A capacitor with a capacitance of C is connected to an AC power supply producing a sinusoidal voltage of peak value V_p and frequency f. The capacitive reactance (X_c) of the circuit is (1)

- A. $X_c = 2\pi fC$
B. $X_c = 2\pi f/C$
C. $X_c = \sqrt{R^2 + \omega^2 C^2}$
D. ✓ $X_c = 1/2\pi fC$

Answer: D

The capacitive reactance of a capacitor is given by the formula $X_c = \frac{1}{\omega C} = \frac{1}{2\pi fC}$.

32. A tangent galvanometer is set so that the plane of its coil is along the Earth's magnetic meridian. When current is passed through the galvanometer, its compass needle deflects by an angle θ . If B_v and B_h are the vertical and horizontal components of the Earth's magnetic field, the current through the coil is proportional to (1)

- A. $B_v \cos \theta$
B. ✓ $B_h \tan \theta$
C. $B_h \cos \theta$
D. $B_v \tan \theta$

Answer: B

In a tangent galvanometer, the magnetic field of the coil is $B_c = B_h \tan \theta$. Since the current I is directly proportional to B_c , it is also proportional to $B_h \tan \theta$.

33. The current I through and voltage V across a purely capacitive AC circuit can be put as a sinusoidal function with respective peak values of I_0 and V_0 . Assuming the angular frequency of the AC source is ω , which of the following sinusoidal function correctly represent I and V in the circuit as a function of time t ? (1)

- A. ✓ $I = I_0 \sin(\omega t + \pi/2)$ and $V = V_0 \sin(\omega t)$
B. $I = I_0 \sin(\omega t + \pi/4)$ and $V = V_0 \sin(\omega t - \pi/2)$
C. $I = I_0 \sin(\omega t)$ and $V = V_0 \sin(\omega t + \pi/2)$
D. $I = I_0 \sin(\omega t)$ and $V = V_0 \sin(\omega t)$

Answer: A

In a purely capacitive AC circuit, the current leads the voltage by a phase angle of 90° (or $\pi/2$ radians), which is represented correctly when $I = I_0 \sin(\omega t + \pi/2)$ and $V = V_0 \sin(\omega t)$.

34. Which of the following statements is correct comparison of destructive and constructive interference of light wave with wave along a string? (1)
- A. Constructive interference of two waves on a string causes node, while constructive interference of two light waves cause brightness
- B. **Constructive interference of two waves on a string gives rise to an antinode, while constructive interference of two light waves gives rise to brightness**
- C. Destructive interference of two waves on a string causes an antinode, while destructive interference of two light waves causes maxima
- D. Destructive interference of two waves on a string results in maximum amplitude, while destructive interference of two light waves results in maximum intensity

Answer: B

Constructive interference of mechanical waves on a string results in maximum displacement (an antinode), whereas for light waves it results in maximum intensity (brightness).

35. A point charge of $Q = 2 \times 10^{-8} \text{ C}$ is placed in xy plane at the coordinate position of (4, 2) cm. What is the value of the electric potential produced by the charge at a point P which is located at coordinate position of (7, -2) cm? (1)
- A. 4 kV
- B. 6 kV
- C. **3.6 kV**
- D. 2.5 kV

Answer: C

The distance from the charge to point P is $r = \sqrt{(7-4)^2 + (-2-2)^2} = 5 \text{ cm} = 0.05 \text{ m}$. Thus, the electric potential is $V = \frac{kQ}{r} = \frac{9 \times 10^9 \times 2 \times 10^{-8}}{0.05} = 3600 \text{ V} = 3.6 \text{ kV}$.

36. Two equal parallel plate capacitors are connected in parallel to a 10 V battery. When the space between the plates is air, each capacitor has a capacitance of $2 \times 10^{-12} \text{ F}$. If the space between the plates is completely filled with dielectric materials with dielectric constants 500 and 1000 respectively, the total electrical energy stored by the capacitors is (1)
- A. **0.15 μJ**
- B. 0.33 nJ
- C. 0.15 nJ
- D. 0.33 μJ

Answer: A

The capacitances with dielectrics are $C_1 = 500 \times 2 \text{ pF} = 1 \text{ nF}$ and $C_2 = 1000 \times 2 \text{ pF} = 2 \text{ nF}$. Their equivalent parallel capacitance is 3 nF , storing an energy of $U = \frac{1}{2} C_{\text{eq}} V^2 = \frac{1}{2} \times 3 \text{ nF} \times (10 \text{ V})^2 = 150 \text{ nJ} = 0.15 \mu\text{J}$.

37. A light radiation is used to measure the position of an electron of wavelength $3 \times 10^{-11} \text{ m}$. If the uncertainty in the momentum (Δp) is $2.21 \times 10^{-23} \text{ kg m/s}$, then according to the uncertainty principle, which one of the following is an acceptable value of the uncertainty in the position (Δx) of the electron? (1)
- A. $\Delta x = 3.0 \times 10^{-13} \text{ m}$
- B. $\Delta x = 1.5 \times 10^{-15} \text{ m}$
- C. **$\Delta x = 3.0 \times 10^{-11} \text{ m}$**
- D. $\Delta x = 1.5 \times 10^{-14} \text{ m}$

Answer: C

According to the uncertainty principle, $\Delta x \geq \frac{h}{\Delta p} = \frac{6.63 \times 10^{-34}}{2.21 \times 10^{-23}} = 3.0 \times 10^{-11} \text{ m}$. Thus, the only acceptable value from the choices that satisfies this minimum limit is $3.0 \times 10^{-11} \text{ m}$.

38. A radioactive material initially consisting of 10^8 particles decays over time according to the decay law, where $\lambda = 3 \times 10^{-12} \text{ s}^{-1}$ is the decay constant. The half-life is ($\ln 2 = 0.693$) (1)
- A. $2.04 \times 10^{11} \text{ s}$
- B. $4.33 \times 10^{12} \text{ s}$
- C. $3.69 \times 10^{12} \text{ s}$
- D. **$2.3 \times 10^{11} \text{ s}$**

Answer: D

The half-life is given by $T_{1/2} = \frac{\ln 2}{\lambda} = \frac{0.693}{3 \times 10^{-12} \text{ s}^{-1}} = 2.31 \times 10^{11} \text{ s}$.

39. One of the four fundamental forces of nature acting over long distances and purely attractive is (1)
- A. electromagnetic force B. strong nuclear force
C. weak nuclear force D. ✓ **gravitational force**

Answer: D

The gravitational force is one of the four fundamental forces of nature, has an infinite range, and is purely attractive, unlike the electromagnetic force which can be both attractive and repulsive.

40. Which one of the following set contains vectors ONLY? (1)
- A. ✓ **{Velocity, Force, Momentum}** B. {Time, Acceleration, Displacement}
C. {Momentum, Energy, Force} D. {Acceleration, Mass, Velocity}

Answer: A

Velocity, force, and momentum are all vector quantities as they require both magnitude and direction to be fully described. Time, energy, and mass are scalar quantities.

41. Suppose you are going to investigate the relation between current through and voltage across a resistor by measuring them five times. Which one of the following should be performed before taking the measurements? (1)
- A. Computing the uncertainty B. ✓ **Clearly describe the method**
C. Presenting the possible results D. Performing the analysis

Answer: B

Before performing any experiment and taking measurements, the procedure and methodology must be clearly described and planned; analysis, result presentation, and uncertainty calculations are done during or after the experiment.

42. A man looks down at a coin that lies at the bottom of a glass container of liquid of depth $d = 12$ cm and index of refraction, n . Because of the view of eye, the coin appears to be located at a depth of 9 cm below the surface of the liquid. What is the value of n ? (1)
- A. $3/2$ B. $5/3$
C. $3/4$ D. ✓ **$4/3$**

Answer: D

The index of refraction n is the ratio of real depth to apparent depth: $n = \frac{\text{real depth}}{\text{apparent depth}} = \frac{12 \text{ cm}}{9 \text{ cm}} = \frac{4}{3}$.

43. Given two vectors $A = [-2]$ and $B = [9]$, the scalar product of these vectors is equal to (1)
- A. ✓ **-18** B. 28
C. 10 D. 22

Answer: A

The scalar (dot) product of two one-dimensional vectors $A = [-2]$ and $B = [9]$ is simply the product of their single components, which is $-2 \times 9 = -18$.

44. Starting from rest, a particle accelerates uniformly with an acceleration of magnitude a . After time interval, the particles cover a distance s and attain a velocity of magnitude v . Which one of the following equations correctly describes the distance moved during this time interval t ? (1)
- A. $s = 1/2 at$ B. $s = vt^2/2$
C. $s = vt$ D. ✓ **$s = v^2/2a$**

Answer: D

Starting from rest ($u = 0$), the kinematic equation $v^2 = u^2 + 2as$ simplifies to $v^2 = 2as$, which gives the distance $s = v^2/2a$.

45. Consider two satellites A and B with mass m_A and m_B respectively, and orbiting the earth at height h_A and h_B above the earth's surface. Which one of the following statements correctly describes the motion of these satellites? (1)
- A. If $m_A > m_B$, satellite A's period is shorter than that of B
 - B. ✓ If $h_A > h_B$, the period satellite A is longer than that of B
 - C. If $h_A > h_B$, satellite A orbits faster than that of B
 - D. If $m_A > m_B$, satellite A orbits faster than that of B

Answer: B

According to Kepler's third law, the orbital period increases with the orbital radius ($r = R_E + h$). Thus, if $h_A > h_B$, the period of satellite A is longer than that of B, independent of their masses.

46. If a ball is thrown vertically upward with an initial velocity of v_0 and reaches a maximum height h after time t , then during the time interval (1)
- A. work done by gravity is greater than the initial kinetic energy
 - B. work done by gravity is positive since kinetic energy increases
 - C. work done by gravity equals the kinetic energy at h
 - D. ✓ work done by gravity equals the change in the kinetic energy of the ball

Answer: D

The work-energy theorem states that the work done by the net force (gravity, in this case) on an object is equal to the change in its kinetic energy, i.e., $W_{\text{gravity}} = \Delta KE$.

END OF THE MARKING KEY

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