

Physics, 2016 EC, natural science, entrance exam, round 1, Tigray

Grade 12 · Physics · 2016 E.C.

MARKING KEY: CONFIDENTIAL

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Questions: 45

Total marks: 45

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1. In physics, dynamics is understood as a branch of mechanics which describes the motion of particles (1)
- A. without considering the effects of forces.
 - B. ✓ **together with the effects of forces.**
 - C. on which only a constant resultant force is applied.
 - D. on which no resultant force is applied.

Answer: B

Dynamics is the branch of mechanics that studies forces and their effects on the motion of bodies, whereas kinematics describes motion without considering its causes (forces).

2. After doing a background research, a researcher formulates a hypothesis. If the researcher proceeds with his/her study following the scientific method, which one of the following is the correct ordering of the steps the researcher should follow? (1)
- A. Design an experiment → Make predictions → Analyze the collected data → Draw conclusions
 - B. Design an experiment → Analyze the collected data → Make predictions → Draw conclusions
 - C. Analyze the collected data → Make predictions → Design an experiment → Draw conclusions
 - D. ✓ **Make predictions → Design an experiment → Analyze the collected data → Draw conclusions**

Answer: D

Following the scientific method, after formulating a hypothesis, a researcher makes predictions, designs and conducts experiments to test those predictions, analyzes the collected data, and then draws conclusions.

3. Among the following concepts of physics, which one of the following is commonly used in analyzing forces on the bridge, motion of airplane, motion of planets and magnetic fields? (1)
- A. kinematics
 - B. ✓ **Vectors**
 - C. Thermodynamics
 - D. Optics

Answer: B

Vectors are essential mathematical tools used to analyze physical quantities that have both magnitude and direction, such as forces on a bridge, velocity/acceleration of an airplane, gravitational forces on planets, and magnetic fields.

4. In a certain class student A measured the acceleration due to gravity, while student B measured electric current in a circuit. Each student did the measurement four times. Two readings of student A are below the accepted value, while the other two are above the accepted value. On the other hand, all the readings of student B are below the accepted value. Which one of the following is correct about the types of errors associated with the two experiments? (1)

- A. ✓ **Systematic error to experiment done by B**
B. Systematic error to experiment done by A
C. Random error to experiment done by B
D. Both systematic and random errors to experiments done by both A and B

Answer: A

Systematic errors consistently skew measurements in one direction (such as all readings being below the accepted value, as in student B's experiment), whereas random errors cause readings to scatter both above and below the true value.

5. The instantaneous acceleration of a particle is the (1)
- A. change of position divided by the total time taken for the change to take place.
B. ✓ **rate change of velocity in a very short time interval that approaches zero.**
C. average velocity in a very short time interval that approaches zero.
D. change of velocity divided by the total time taken for the change to take place.

Answer: B

Instantaneous acceleration is defined as the limit of the average acceleration as the time interval approaches zero, which represents the rate of change of velocity at a specific instant.

6. Consider two objects A and B; object A undergoes a uniform circular motion while object B performs a non-uniform circular motion. Which one of the following is correct about the motions of the two objects? (1)
- A. The velocities and accelerations of both objects are perpendicular to each other.
B. the velocity of object A is constant whereas the velocity of object B is not.
C. Both objects have constant accelerations.
D. ✓ **the speed of object A is constant whereas the speed of object B is not.**

Answer: D

In uniform circular motion (object A), the speed remains constant while the direction of velocity changes. In non-uniform circular motion (object B), both the speed and direction of velocity change.

7. The unit vector in the direction of vector $\vec{A}$ is $\frac{1}{3}(2\hat{i} + \hat{j} - 2\hat{k})$. If $\vec{A}$ has the same magnitude as vector $\vec{B} = (3\hat{i} - 4\hat{j})$, then what is vector $\vec{A}$? (1)
- A. $\vec{A} = (2\hat{i} + \hat{j} - 2\hat{k})$
B. $\vec{A} = (10\hat{i} + 5\hat{j} - 10\hat{k})$
C. ✓ $\vec{A} = \frac{1}{3}(10\hat{i} + 5\hat{j} - 10\hat{k})$
D. $\vec{A} = \frac{1}{3}(3\hat{i} - 4\hat{j})$

Answer: C

The magnitude of vector $\vec{B}$ is $|\vec{B}| = \sqrt{3^2 + (-4)^2} = 5$. Since $\vec{A}$ has the same magnitude and its direction is given by the unit vector, we find $\vec{A} = 5 \times \frac{1}{3}(2\hat{i} + \hat{j} - 2\hat{k}) = \frac{1}{3}(10\hat{i} + 5\hat{j} - 10\hat{k})$.

8. Vector $\vec{A}$ has a magnitude of 30 units and points in the positive x direction. When a second vector $\vec{B}$ is added to $\vec{A}$ their resultant $\vec{R} = \vec{A} + \vec{B}$ has a magnitude of 15 units in the negative x direction. The magnitude and direction of vector $\vec{B}$ must be (1)
- A. ✓ **45 units in the direction of negative x.** B. 15 units in the direction of negative x.
 C. 45 units in the direction of positive x. D. 15 units in the direction of positive x.

Answer: A

Using vector addition, $\vec{R} = \vec{A} + \vec{B} \implies -15\hat{i} = 30\hat{i} + \vec{B} \implies \vec{B} = -45\hat{i}$, which represents a magnitude of 45 units in the negative x direction.

9. A car travelling in straight line decelerates uniformly from a speed of 60 m/s to zero in 12 seconds. What distance does it travel during this time? (1)
- A. 1,080 m B. 720 m
 C. 690 m D. ✓ **360 m**

Answer: D

Using the kinematic equation for uniform acceleration, the distance traveled is $d = v_{\text{avg}}t = \frac{v_i + v_f}{2}t = \frac{60+0}{2} \times 12 = 360 \text{ m}$.

10. A car is moving due east with a speed of 15 m/s and at the same time a motorcycle is moving due north at a constant speed of 20 m/s. What is the velocity of the car relative to the motorcycle? (1)
- A. 25 m/s at 53° North of east B. 5 m/s at 37° North of east
 C. ✓ **25 m/s at 53° south of east** D. 5 m/s at 37° south of east

Answer: C

The relative velocity of the car to the motorcycle is $\vec{v}_{C/M} = \vec{v}_C - \vec{v}_M = 15\hat{i} - 20\hat{j}$. This has a magnitude of $\sqrt{15^2 + (-20)^2} = 25 \text{ m/s}$ at an angle of $\arctan(-20/15) = -53^\circ$ (or 53° south of east).

11. A torque applied on a body is (1)
- A. a vector quantity and has similar dimension with that of a force.
 B. **the vector product of an applied force and the position vector from the pivot point to the point of application of the force.**
 C. the scalar product of an applied force and the position vector from the pivot point to the point of application of the force.
 D. a scalar quantity and has similar dimension with that of energy or work.

Answer: B

Torque is a vector quantity defined as the vector (cross) product of the position vector from the pivot to the point of application of the force and the force vector ($\vec{\tau} = \vec{r} \times \vec{F}$).

12. A ball of mass m moving with a velocity $\vec{v}_1$ collides with a wall and rebounds with a velocity $\vec{v}_2$. During the collision, it is subjected to an average force of $\vec{F}$ over a time interval Δt . The impulse delivered to the ball during the collision is (1)
- A. $\vec{I} = m(\vec{v}_1 + \vec{v}_2)$ B. $\vec{I} = m\left(\frac{\vec{v}_2 - \vec{v}_1}{\Delta t}\right)$
 C. $\vec{I} = \frac{\vec{F}}{\Delta t}$ D. ✓ **$\vec{I} = \vec{F}(\Delta t)$**

Answer: D

By definition, the impulse delivered to an object is the product of the average force $\vec{F}$ acting on it and the duration Δt of the collision, which also equals the change in its momentum.

13. Which one of the following is true about energy, work and force?

(1)

- A. Work, energy and force have the same dimension.
- B. A person carrying 100 kg object and moving horizontally is doing work without expending energy
- C. **A force is a vector quantity and different in dimension from that of both work and energy which are scalars.**
- D. The work done on an object is the product of an applied force and the displacement it produces, and is a vector quantity.

Answer: C

Force is a vector quantity with dimensions MLT^{-2} , whereas work and energy are scalar quantities sharing the same dimension of ML^2T^{-2} .

14. When a constant force is applied horizontally on an object of mass m placed on a horizontal frictionless surface, its velocity is changed from an initial velocity v_1 to a final velocity v_2 . The mechanical work done by the force is

(1)

- A. $\frac{1}{2}m(v_2^2 - v_1^2)$
- B. $\frac{1}{2}m(v_2 - v_1)^2$
- C. $\frac{d}{dt}(v_2^2 + v_1^2)$
- D. $\frac{1}{2}m(v_2 + v_1)^2$

Answer: A

By the work-energy theorem, the work done by the net force is equal to the change in the object's kinetic energy: $W = \Delta KE = \frac{1}{2}m(v_2^2 - v_1^2)$.

15. An object is thrown vertically upward and after reaching maximum height, it falls down to the point it was thrown. If there is a considerable air resistance of a medium, which one of the following is correct about energies associated to the object?

(1)

- A. Mechanical energy of the object is constant throughout its path.
- B. There is work done by gravity when the object returns back to the point it was thrown.
- C. The kinetic energy of the object at the point of throw is equal to its potential energy at its maximum height.
- D. **Work done by air resistance is equal to the loss of kinetic energy of the object in the round trip.**

Answer: D

According to the work-energy theorem, the total work done on a round trip is $W_{\text{total}} = W_{\text{gravity}} + W_{\text{air}} = \Delta KE$. Since gravity does zero net work over a closed loop, the work done by air resistance is equal to the net loss of kinetic energy.

16. A wheel of rotational inertia $I = 12 \text{ kg}\cdot\text{m}^2$ rotates with an angular speed of 300 rev/min about a fixed axis through its center. What is the kinetic energy of the wheel?

(1)

- A. $60\pi^2 \text{ J}$
- B. $720\pi \text{ J}$
- C. $600\pi^2 \text{ J}$
- D. 720000 J

Answer: C

First, convert the angular speed to rad/s: $\omega = 300 \text{ rev/min} = 10\pi \text{ rad/s}$. Then, the rotational kinetic energy is $K = \frac{1}{2}I\omega^2 = \frac{1}{2}(12 \text{ kg}\cdot\text{m}^2)(10\pi \text{ rad/s})^2 = 600\pi^2 \text{ J}$.

- 17.** The moment of inertia of a uniform solid disc of radius $R = 30\text{ cm}$ and mass $M = 4\text{ kg}$ about an axis perpendicular to the disc area and passing through its center of mass is $I_c = \frac{1}{2}MR^2$. The moment of inertia of the disc about an axis perpendicular to the disc area and passing through a point at a distance 20 cm from its center of mass is
- A. 0.08 kg m^2
- B. 0.16 kg m^2
- C. 0.18 kg m^2
- D. ✓ 0.34 kg m^2

Answer: D

By the parallel axis theorem, the moment of inertia about the parallel axis is $I = I_c + Md^2 = \frac{1}{2}MR^2 + Md^2 = \frac{1}{2}(4)(0.3)^2 + 4(0.2)^2 = 0.18 + 0.16 = 0.34 \text{ kg m}^2$.

- 18.** Suppose a point mass m tied to a string of length r is whirled in horizontal circle on a frictionless table. If it is moving with a constant tangential velocity of ωr , then what is its angular momentum?
- A. ✓ $L = mr^2\omega$
- B. $L = mr\omega/2$
- C. $L = mr\omega$
- D. $L = mr^2\omega/2$

Answer: A

The angular momentum of a point mass m rotating at a distance r with tangential velocity $v = \omega r$ is $L = mvr = mr(\omega r) = mr^2\omega$.

- 19.** An object is pulled horizontally at a constant velocity by a force of 20.0 N acting 30° above the horizontal. If the coefficient of kinetic friction between the object and the surface is 0.4 , what is the mass of the object? ($g = 10.0\text{ m/s}^2$)
- A. 10.70 kg
- B. ✓ 5.35 kg
- C. 3.35 kg
- D. 6.70 kg

Answer: B

Since velocity is constant, horizontal forces balance: $F \cos 30^\circ = \mu_k F_N = \mu_k (mg - F \sin 30^\circ)$. Substituting values gives $20(0.866) = 0.4(10m - 10) \Rightarrow m \approx 5.35 \text{ kg}$.

- 20.** Three dogs named A, B, and C are quarreling on a bone and pulling it apart in three different directions in air. Assume that the weight of the bone is negligible compared to the forces exerted on it by the dogs, and the forces are lying in the xy plane. Dog A is pulling with 26 N force along a direction that makes 53° to the north of positive x axis, Dog B is pulling with F_B force along the negative x direction, and Dog C is pulling with F_C force along the negative y direction. If the bone is in static equilibrium, the magnitudes of the forces that Dogs B and C have applied are
- A.** $F_B = 20.8 \text{ N}$ and $F_C = 15.6 \text{ N}$
B. ✓ $F_B = 15.6 \text{ N}$ and $F_C = 20.8 \text{ N}$
C. $F_B = 10.0 \text{ N}$ and $F_C = 24.0 \text{ N}$
D. $F_B = 24.0 \text{ N}$ and $F_C = 10.0 \text{ N}$

Answer: B

For static equilibrium, the sum of forces along each axis must be zero: $\sum F_x = 26 \cos 53^\circ - F_B = 0 \implies F_B = 15.6 \text{ N}$, and $\sum F_y = 26 \sin 53^\circ - F_C = 0 \implies F_C = 20.8 \text{ N}$.

21. Consider a heat engine consisting of gas as its working substance. Which of the following processes does NOT occur during the operation of the engine? (1)

- A. ✓ **absorption of heat energy by the gas from a low-temperature reservoir**
- B. the working substance doing work on its surroundings
- C. absorption of heat energy by the gas from a high-temperature reservoir
- D. expulsion of energy by heat engine to a lower-temperature reservoir

Answer: A

A heat engine absorbs heat from a high-temperature reservoir and expels waste heat to a low-temperature reservoir; absorbing heat from a low-temperature reservoir is characteristic of a refrigerator or heat pump.

22. Which one of the following statements is correct about the states of equilibrium of a bottle placed on a horizontal surface? (1)

- A. A bottle lying on its side is in a stable equilibrium because small torque acting on it will cause it to move but stops when it is removed.
- B. A bottle standing upright is in a neutral equilibrium because small torque acting on it will cause its center of mass to lie inside a point vertically above its base.
- C. **A bottle standing on its neck is in unstable equilibrium because a small torque acting on it will cause its center of mass to lie outside a point vertically above its neck.**
- D. A bottle lying on its side is in an unstable equilibrium because a small torque acting on it will cause it to roll over the surface.

Answer: C

A bottle standing on its neck has a very narrow base and high center of mass, making it highly unstable because a small tilt quickly shifts its center of mass outside its base, causing it to fall over.

23. Surface tension is defined as (1)

- A. ✓ **a cohesive effect at the surface of a liquid due to the forces between atoms or molecules of the liquid.**
- B. a cohesive effect at a point inside a liquid due to the forces between atoms or molecules of the liquid.
- C. an adhesive effect at the contact surfaces between a container and a liquid due to the forces between atoms or molecules of the liquid and that of the container.
- D. a cohesive effect at the contact surfaces between a container and a liquid due to the forces between atoms or molecules of the container.

Answer: A

Surface tension is a cohesive effect occurring at the surface of a liquid due to intermolecular attractive forces, which causes the surface layer to behave like an elastic membrane.

24. The height h with which a liquid rises in a liquid column due to capillary action is (1)

- A. ✓ **inversely proportional to the radius of the tube.**
- B. directly proportional to the density of the liquid.
- C. inversely proportional to the liquid-air surface tension.
- D. directly proportional to the sine of the contact angle between the liquid and tube.

Answer: A

The capillary rise height is given by $h = \frac{2\gamma \cos \theta}{\rho g r}$, which shows that h is inversely proportional to the radius r of the tube.

25. Which one of the following statements is correct about the rate of heat flow in metallic bar through conduction? (1)
- A. The rate of heat flow is inversely proportional to the cross-sectional area of the bar.
 - B. ✓ **The rate of heat flow is directly proportional to the temperature gradient along the bar.**
 - C. The rate of heat flow is directly proportional to the square of the cross-sectional area of the bar.
 - D. The rate of heat flow is inversely proportional to the square of the length of the bar.

Answer: B

The rate of heat conduction is given by Fourier's Law, $H = -kA \frac{dT}{dx}$, which shows that the rate of heat flow is directly proportional to the temperature gradient along the bar.

26. An ideal fluid is pumped through a long inflexible pipe of uniform cross-section of 10 cm in diameter. If 3140 m^3 of this fluid is pumped per day, what is the speed of the fluid in the pipe? (1)
- A. 111.11 m/s
 - B. 1.16 m/s
 - C. 0.04 m/s
 - D. ✓ **4.63 m/s**

Answer: D

The volume flow rate is $Q = 3140 \text{ m}^3 / 86400 \text{ s} \approx 0.03634 \text{ m}^3/\text{s}$. Using the continuity equation $Q = Av$ where $A = \pi r^2 = \pi(0.05)^2 \approx 0.00785 \text{ m}^2$, we find $v = Q/A \approx 4.63 \text{ m/s}$.

27. A wall of a house has surface area 1.2 m^2 and thickness of Δx . The wall is made of an insulating material of thermal conductivity $0.02 \text{ W/m } ^\circ\text{C}$, and is used as a boundary that separates the inside and outside of the house. If heat flows through the wall at the rate of 10 watt and maintains a temperature difference of $15 ^\circ\text{C}$ between the outside and inside of the house, the thickness of the wall is (1)
- A. 36 cm.
 - B. ✓ **3.6 cm.**
 - C. 27 cm.
 - D. 40 m.

Answer: B

Using the heat conduction formula $H = kA \frac{\Delta T}{\Delta x}$, we rearrange for thickness to get $\Delta x = \frac{kA\Delta T}{H} = \frac{0.02 \times 1.2 \times 15}{10} = 0.036 \text{ m} = 3.6 \text{ cm}$.

28. An ideal gas is compressed from an initial volume of 12.0 liters to a final volume of 4.0 liters at a constant pressure of 1.2 atm. What is the total work done on the gas? (1 atm = $1.013 \times 10^5 \text{ Pa}$ and 1 liter = 10^{-3} m^3) (1)
- A. 486.2 J
 - B. 1,945.0 J
 - C. ✓ **972.5 J**
 - D. 1,458.7 J

Answer: C

The work done on the gas during compression is given by $W = P(V_i - V_f) = 1.2 \text{ atm} \times (12.0 - 4.0) \text{ L} = 9.6 \text{ atm} \cdot \text{L}$. Converting to Joules, $W = 9.6 \times 101.3 \text{ J} \approx 972.5 \text{ J}$.

29. Gauss's law states that (1)
- A. ✓ **the electric flux through any closed surface is directly proportional to the charge contained inside the surface.**
 - B. the electric flux through a closed surface is zero when a nonzero net charge is enclosed by the surface.
 - C. the electric flux through any closed surface is inversely proportional to the charge contained inside the surface.
 - D. the electric flux through a closed surface is a nonzero constant when the net charge enclosed by the surface is zero.

Answer: A

Gauss's law states that the net electric flux through any closed surface is equal to the net charge enclosed divided by the permittivity of free space, meaning the flux is directly proportional to the enclosed charge.

30. Which of the following is true about the electric field of a charged conductor? The electric field (1)
- A. just outside a charged conductor is different from zero and parallel to the surface of the conductor.
 - B. inside an isolated conductor is different from zero if the conductor carries a charge but zero if the conductor is neutral.
 - C. **just outside a charged conductor is different from zero and perpendicular to the surface of the conductor.** ✓
 - D. inside an isolated conductor is different from zero whether or not the conductor carries a charge or neutral.

Answer: C

For any conductor in electrostatic equilibrium, the electric field inside is zero, and the electric field just outside the surface is non-zero and perpendicular to the surface at every point.

31. A sound wave with a frequency f from a stationary source reaches a listener with a frequency (1)
- A. less than f if the listener is also stationary.
 - B. **less than f if the listener is moving away from the source.** ✓
 - C. greater than f if the listener is moving away from the source.
 - D. equal to f if the listener is moving away from the source.

Answer: B

According to the Doppler effect, when a listener moves away from a stationary source, they encounter fewer wave crests per unit time, resulting in a lower observed frequency than the source frequency.

32. A dielectric placed in an external electric field (1)
- A. **forms an electric field in it in the opposite direction of the external field due to induced polarization in the molecules.** ✓
 - B. forms an electric field in it in the same direction of the external field due to induced polarization in the molecules.
 - C. contains dipoles which are randomly oriented.
 - D. contains partially aligned dipoles with the external electric field whose alignment decreases when the external electric field increases.

Answer: A

An external electric field polarizes the molecules of a dielectric, inducing a charge distribution that produces an internal electric field in the direction opposite to the external field.

33. A cord of 0.5 m long is fixed at both ends. If a standing wave is formed by a wave travelling with a speed of $250 \frac{\text{m}}{\text{s}}$, what is the fundamental frequency of vibrating cord? (1)
- A. 500.0 Hz
 - B. 62.5 Hz
 - C. 125.0 Hz
 - D. **250.0 Hz** ✓

Answer: D

For a cord fixed at both ends, the fundamental wavelength is $\lambda_1 = 2L = 2(0.5 \text{ m}) = 1.0 \text{ m}$. The fundamental frequency is then $f_1 = v/\lambda_1 = 250 \text{ m/s}/1.0 \text{ m} = 250 \text{ Hz}$.

34. In a Young's double slits experiment, when an adjustable double slit is illuminated with a monochromatic light a diffraction pattern is produced on a viewing screen. Which one of the following is correct about the width of the pattern produced on the screen? The width of the diffraction pattern (1)
- A. decreases if the distance between the slits and the viewing screen is increased.
 - B. ✓ **increases if the wavelength of the light source illuminating the slits is increased.**
 - C. increases if the distance between the two slits is increased.
 - D. is independent of the both wavelength of the light and slit distance.

Answer: B

The width of the fringes (which determines the scale of the pattern) in Young's double slit experiment is $\beta = \frac{\lambda D}{d}$. Thus, the width increases when the wavelength λ increases.

35. In Young's double slit experiment, a viewing screen is separated from a double slit by 4.5 m. The distance between the two slits is 0.04 mm. If a monochromatic light of wavelength 560 nm is directed toward the double slit and forms an interference pattern on the screen, the distance between adjacent dark fringes will be (1)
- A. 3.15 cm.
 - B. 9.45 cm.
 - C. ✓ **6.30 cm.**
 - D. 12.6 cm.

Answer: C

The distance between adjacent dark fringes is equal to the fringe width $\beta = \frac{\lambda D}{d}$. Plugging in the values gives $\beta = \frac{(5.6 \times 10^{-7} \text{ m})(4.5 \text{ m})}{4 \times 10^{-5} \text{ m}} = 6.3 \times 10^{-2} \text{ m} = 6.30 \text{ cm}$.

36. A galvanometer can be modified and converted into (1)
- A. a voltmeter by adding a large resistance in parallel with that of the galvanometer.
 - B. ✓ **an ammeter by adding a low resistance in parallel to the resistance of the galvanometer.**
 - C. an ammeter by adding a small resistance in series with that of the galvanometer.
 - D. a voltmeter by adding a small resistance in parallel to that of the galvanometer.

Answer: B

A galvanometer is converted into an ammeter by placing a low-resistance shunt in parallel with it, allowing most of the current to bypass the delicate galvanometer coil.

37. When placed in an applied magnetic field, (1)
- A. both paramagnetic and diamagnetic materials show a tendency that opposes the applied magnetic field.
 - B. both paramagnetic and diamagnetic materials show a tendency that reinforces the applied magnetic field.
 - C. ✓ **a paramagnetic material shows a tendency that reinforces the applied magnetic field in contrast to the diamagnetic one which opposes the applied magnetic field.**
 - D. a paramagnetic material shows a tendency that opposes the applied magnetic field in contrast to the diamagnetic one that reinforces the applied magnetic field.

Answer: C

Paramagnetic materials have weak magnetic dipole moments that align with the external field (reinforcing it), whereas diamagnetic materials develop induced dipoles that oppose the external field.

38. The process in which two light nuclei combine to form a heavier nucleus is called (1)
- A. nuclear fission
 - B. ✓ **nuclear fusion**
 - C. nuclear reaction
 - D. binding energy

Answer: B

Nuclear fusion is defined as the process where lighter atomic nuclei combine to form a single heavier nucleus, releasing a large amount of energy in the process.

39. When electrons from an electron gun are accelerated through a vacuum towards a layer of graphite a circular diffraction pattern is observed. The occurrence of this phenomenon shows (1)
- A. ✓ **wave properties of particles.** B. particle properties of electrons.
C. wave properties of light. D. particle properties of waves.

Answer: A

Diffraction is a characteristic wave phenomenon. Observing a circular diffraction pattern when electrons (which are particles) pass through graphite demonstrates the wave properties of particles (de Broglie's wave-particle duality).

40. Consider a piece of copper tube of 1 m long, piece of a magnet, and a piece of nonmagnetic metal of the same size as the magnet. The magnet and nonmagnetic substances are dropped simultaneously and allowed to fall through the tube. Which of the following is correct about the times required by the two substances to fall through the length of the tube? (1)
- A. Both the magnet and nonmagnetic substance take equal time to reach the bottom of the tube because the only force acting on both is the gravitational force.
B. The magnet takes shorter time than the nonmagnetic substance because the magnet induces a magnetic field in the tube that speeds up motion.
C. **The magnet takes longer time than the nonmagnetic substance because the magnet induces a**
✓ **magnetic field in the tube that slows its motion.**
D. The magnet takes shorter time than the nonmagnetic substance because the drag force on the magnet is larger than that on the nonmagnetic substance.

Answer: C

As the magnet falls through the copper tube, the changing magnetic flux induces eddy currents in the conductor. According to Lenz's law, these currents produce a magnetic field opposing the magnet's descent, slowing it down.

41. A proton is moving perpendicular to the magnetic and electric fields in a velocity selector which is operating with a magnetic field of 2.5 T and an electric field of 5.0 kV/m. What is the speed of the proton? (1)
- A. 5.0×10^4 m/s B. 5.0×10^3 m/s
C. 2.0×10^4 m/s D. ✓ 2.0×10^3 m/s

Answer: D

In a velocity selector, the electric and magnetic forces balance out, so $qE = qvB \implies v = E/B = (5.0 \times 10^3 \text{ V/m})/(2.5 \text{ T}) = 2.0 \times 10^3 \text{ m/s}$.

42. Consider two parallel long straight conductors carrying equal current I along the positive y direction as shown below. The net magnetic field due to the two current-carrying conductors is (1)
- A. ✓ **zero at a point midway between the conductors.**
B. in the direction of the currents in the region between the two wires (at point Q).
C. directed out of the page of the paper at point R.
D. directed into the page of the paper at point P.

Answer: A

For parallel wires carrying equal currents in the same direction, the magnetic field of one wire points into the page and the other points out of the page in the region between them. Exactly midway, their magnitudes are equal and thus cancel to zero.

43. Suppose the figure shown below represents the schematic diagram of an a.c. generator depicting its main components. Which one of the following is correct about the a.c. generator? (1)
- A. Both X and Y represents the North poles of two bar magnets.
 - B. Both X and Y represents the South poles of two bar magnets.
 - C. Z represents a rectangular coil made of insulators.
 - D. ✓ **Z represents a rectangular coil made of conductors.**

Answer: D

An alternating current (a.c.) generator utilizes a rotating rectangular coil (Z) made of conductive wire to cut through a magnetic field and induce an electromotive force.

44. Consider a series RLC circuit that consists of a resistor $R = 200\ \Omega$, an inductor $L = 0.5\ H$, a capacitor $C = 4\ \mu F$, and an a.c. source of frequency $f = 60\ Hz$ (with maximum voltage $V_{rms} = 100\ V$), as shown in the diagram. Which one of the following is correct about the parameters of the circuit? (1)
- A. The phase angle of the circuit is -76° .
 - B. ✓ **The reactance of the capacitor is $663.5\ \Omega$.**
 - C. The resonant frequency of the circuit is $159\ Hz$.
 - D. The current lags behind the applied voltage.

Answer: B

The capacitive reactance is $X_C = \frac{1}{2\pi fC} = \frac{1}{2\pi(60)(4 \times 10^{-6})} \approx 663.5\ \Omega$ (using $\pi \approx 3.14$). This matches option B perfectly.

45. If the isotope carbon-14 is radioactive and has a half-life of 5775 years, the decay constant of this sample will be (use $\ln 2 = 0.693$) (1)
- A. $8.3 \times 10^3/\text{year}$
 - B. ✓ $1.2 \times 10^{-4}/\text{year}$
 - C. $1.2 \times 10^{-1}/\text{year}$
 - D. $4.0 \times 10^3/\text{year}$

Answer: B

The decay constant is calculated using $\lambda = \frac{\ln 2}{T_{1/2}} = \frac{0.693}{5775\ \text{years}} \approx 1.2 \times 10^{-4} / \text{year}$.

END OF THE MARKING KEY

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