

NIOS Class 12 Physics Sample Paper-1

Duration: 180 Minutes

Maximum Marks: 80

Instructions

- This paper contains **43** Questions. The paper is divided into two sections: **Section A – 40** marks, **Section B – 40** marks.
- **Section A** consists of
 - **Q.No. 1 to 16** – Multiple Choice type questions (MCQs) carrying 1 mark each. Select and write the most appropriate option out of the four options given in each of these questions. An internal choice has been provided in some of these questions. You have to attempt only one of the given choices in such questions.
 - **Q. No. 17 to 28**– Objective-type questions. Q. No. 17 to 28 carry 02 marks each (with 2 sub- parts of 1 mark each). Attempt these questions as per the instructions given for each of the questions 17 –28.
- **Section B** consists of
 - **Q.No. 29 to 37** – Very Short questions carrying 02 marks each to be answered in the range of 30 to 50 words.
 - **Q.No. 38 to 41** – Short Answer type questions carrying 03 marks each to be answered in the range of 50 to 80 words.
 - **Q.No. 42 and 43** – Long Answer type questions carrying 05 marks each to be answered in the range of 80 to 120 words.
- There is **No Negative marking**.
- Use of mobile phones, smartwatches, calculators, or any electronic gadgets is strictly prohibited.

Section: A

Q1. Two identical positive charges $+q$ are fixed at points $A(-a, 0)$ and $B(a, 0)$. At the origin, which statement is correct? (1)

(A) Electric field is non-zero and potential is zero

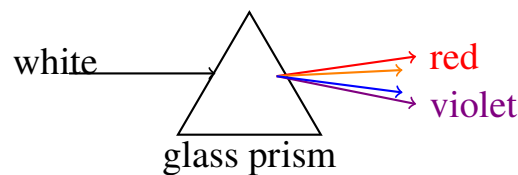


- (B) Electric field is zero and potential is positive
- (C) Electric field is zero and potential is zero
- (D) Electric field is non-zero and potential is negative

Q2. A 5 kg block on a horizontal surface is pulled by a horizontal force of 10 N. If the frictional force is 2 N, the acceleration of the block is: (1)

- (A) 0.8 m s^{-2}
- (B) 1.2 m s^{-2}
- (C) 1.6 m s^{-2}
- (D) 2.4 m s^{-2}

Q3. A narrow beam of white light passes through a glass prism as shown. Which colour deviates the most? (1)



- (A) Red
- (B) Yellow
- (C) Green
- (D) Violet

Q4. A p-n junction diode is forward biased when: (1)

- (A) p-side is connected to the positive terminal and n-side to the negative terminal
- (B) p-side is connected to the negative terminal and n-side to the positive terminal
- (C) both sides are connected to the same terminal
- (D) no external battery is connected



- Q5.** Water flows through a horizontal pipe. If the cross-sectional area becomes half, then according to the equation of continuity and Bernoulli's principle: (1)
- (A) speed becomes half and pressure increases
 - (B) speed doubles and pressure decreases
 - (C) speed remains same and pressure remains same
 - (D) speed doubles and pressure also doubles
- Q6.** In photoelectric emission, if the frequency of incident light is below the threshold frequency, then: (1)
- (A) electrons are emitted only at high intensity
 - (B) electrons are emitted only after a long delay
 - (C) no photoelectrons are emitted, whatever be the intensity
 - (D) photoelectrons are emitted with zero kinetic energy
- Q7.** A gas absorbs 200 J of heat and does 60 J of work on the surroundings. The change in its internal energy is: (1)
- (A) 260 J
 - (B) -140 J
 - (C) 140 J
 - (D) -260 J
- Q8.** A standing wave is formed on a string of wave speed 50 m s^{-1} and frequency 100 Hz. The distance between two consecutive nodes is: (1)
- (A) 0.10 m
 - (B) 0.25 m
 - (C) 0.50 m
 - (D) 1.00 m
- Q9.** The energy stored in a $4 \mu\text{F}$ capacitor charged to 50 V is: (1)



- (A) 5.0×10^{-3} J
- (B) 1.0×10^{-2} J
- (C) 2.5×10^{-3} J
- (D) 5.0×10^{-2} J

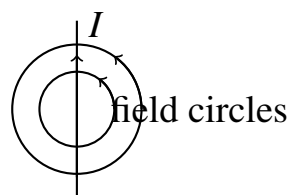
Q10. If the kinetic energy of a moving body becomes double, its speed becomes: **(1)**

- (A) double
- (B) half
- (C) $\sqrt{2}$ times
- (D) four times

Q11. For a transparent medium of refractive index 1.5, the polarising angle is approximately: **(1)**

- (A) 33.7°
- (B) 56.3°
- (C) 60.0°
- (D) 90.0°

Q12. The magnetic field lines around a long straight current-carrying conductor are best represented by: **(1)**



- (A) straight lines parallel to the conductor
- (B) radial lines away from the conductor
- (C) concentric circles centred on the conductor
- (D) random closed loops in the plane of the conductor

Q13. For using a transistor as an electronic switch, it is generally operated in: **(1)**



- (A) active region only
- (B) reverse-active region only
- (C) breakdown region only
- (D) cut-off and saturation regions

Q14. A pump lifts water at a rate of 20 kg s^{-1} through a height of 5 m. If its efficiency is 50%, the input power is nearly ($g = 10 \text{ m s}^{-2}$): **(1)**

- (A) 0.5 kW
- (B) 1.0 kW
- (C) 2.0 kW
- (D) 4.0 kW

Q15. A radioactive sample has a half-life of 5 days. The fraction of the original sample left after 15 days is: **(1)**

- (A) $\frac{1}{2}$
- (B) $\frac{1}{4}$
- (C) $\frac{1}{8}$
- (D) $\frac{1}{16}$

Q16. A wooden block floats in water with 60% of its volume immersed. Its density is: **(1)**

- (A) 0.4 g cm^{-3}
- (B) 0.6 g cm^{-3}
- (C) 1.0 g cm^{-3}
- (D) 1.6 g cm^{-3}



Note: Q. No. 17 to 28 are the objective type questions of 2 marks each.

Q17. Read the passage given below and answer the following questions:

When a net external force acts on a body for a certain time interval, the momentum of the body changes. The product of force and time is called impulse. In practical cases such as catching a cricket ball, landing on a cushion, or using airbags in cars, the same change in momentum is brought about in a longer time, so the average force becomes smaller. The work done by a net force changes the kinetic energy of a body. (2)

1. State the impulse-momentum theorem.
2. Why does a player move his hands backward while catching a fast ball?

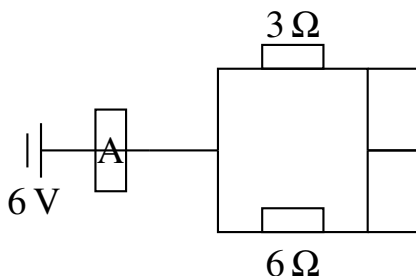
Q18. Complete the following by using the options given below:

(coherent, transverse, longitudinal, resonance, damping) (2)

1. For sustained interference, the two light sources must be
2. Light waves in vacuum are waves.

Q19. Read the passage and answer the questions that follow it.

A student connects two resistors of $3\ \Omega$ and $6\ \Omega$ in parallel with a $6\ \text{V}$ battery. An ammeter is connected in series with the battery to measure the total current. The resistance of the ammeter is negligible. (2)



1. Find the equivalent resistance of the parallel combination.
2. What current will the ammeter read?



Q20. Fill in the blanks: (2)

1. In an isothermal process, the temperature of the gas remains
2. In an adiabatic process, heat exchanged with the surroundings is

Q21. Match the items in Column I with the most appropriate items in Column II: (2)

Column I	Column II
(a) Bernoulli’s theorem	(i) Upward force due to displaced fluid
(b) Viscosity	(ii) Conservation of energy in streamline flow
(c) Buoyant force	(iii) Internal friction of a fluid
(d) Surface tension	(iv) Force per unit length along liquid surface

Q22. Fill in the blanks: (2)

1. The region near a p-n junction that is depleted of mobile charge carriers is called the layer.
2. A ...diode is commonly used for voltage regulation in reverse breakdown region.

Q23. Write TRUE (T) for the correct statement and FALSE (F) for the incorrect statement: (2)

1. According to Bohr’s model, the angular momentum of an electron in a permitted orbit is an integral multiple of $h/2\pi$.
2. In photoelectric effect, the maximum kinetic energy of emitted electrons depends only on the intensity of incident light and not on its frequency.

Q24. Match the items in Column I with the most appropriate items in Column II: (2)



Column I	Column II
(a) Coulomb's law	(i) Direction opposes the cause producing it
(b) Capacitance	(ii) $F \propto q_1q_2/r^2$
(c) Faraday's law	(iii) $C = Q/V$
(d) Lenz's law	(iv) Induced emf depends on rate of change of magnetic flux

Q25. Fill in the blanks: (2)

1. Rayleigh scattering intensity is inversely proportional to the fourth power of .
2. The ability of a prism material to separate colours is measured by its

Q26. Match the items in Column I with the most appropriate items in Column II: (2)

Column I	Column II
(a) Inertia	(i) Rate of doing work
(b) Work	(ii) Ability of a body to oppose change in its state of motion
(c) Power	(iii) Product of force and displacement in direction of force
(d) Conservative force	(iv) Work done is independent of path

Q27. Write TRUE (T) for the correct statement and FALSE (F) for the incorrect statement: (2)

1. Conventional current is taken in the direction of flow of positive charge.
2. The rms value of a sinusoidal alternating current is equal to twice its peak value.

Q28. Match the items in Column I with the most appropriate items in Column II: (2)



Column I	Column II
(a) LED	(i) Converts alternating current into direct current
(b) Photodiode	(ii) Emits light when forward biased
(c) Rectifier	(iii) Detects light intensity
(d) Repeater	(iv) Regenerates weak communication signals

Section: B

Q29. Define diffraction of waves. State the condition under which diffraction is most noticeable. Give one daily-life example. (2)

Q30. State the impulse-momentum theorem. A force of 40 N acts on a stationary trolley of mass 8 kg for 2 s. Find its final speed, neglecting friction. (2)

Q31. (i) State Gauss’s law in electrostatics. Write its mathematical form.

OR

(ii) Two capacitors of $3\ \mu\text{F}$ and $6\ \mu\text{F}$ are connected in series across a battery. Find their equivalent capacitance. (2)

Q32. (i) What is dispersion of light? Why does violet light deviate more than red light in a glass prism?

OR

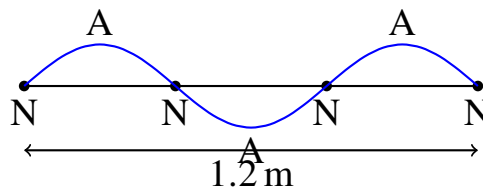
(ii) State Huygens’ principle. What is meant by a wavefront? (2)

Q33. A cell of emf 12 V and internal resistance $1\ \Omega$ is connected to an external resistance of $5\ \Omega$. Calculate the current in the circuit and the terminal voltage of the cell. (2)

Q34. The diagram shows a stationary wave on a stretched string fixed at both ends. If



the total length of the string is 1.2 m, find the wavelength of the wave and mark the nodes and antinodes. (2)



Q35. (i) State two postulates of Bohr’s model of the hydrogen atom.

OR

(ii) Define mass defect and binding energy of a nucleus. (2)

Q36. State the equation of continuity for an ideal fluid. Water flows through a pipe whose area decreases from 8 cm^2 to 2 cm^2 . If the speed in the wider part is 0.5 m s^{-1} , find the speed in the narrower part. (2)

Q37. An ideal gas expands at constant pressure $2 \times 10^5 \text{ Pa}$ from volume $2 \times 10^{-3} \text{ m}^3$ to $5 \times 10^{-3} \text{ m}^3$. Calculate the work done by the gas. (2)

Q38. Define the following terms with one example each:

A. Intrinsic semiconductor

B. p-type semiconductor

C. Rectifier

(3)

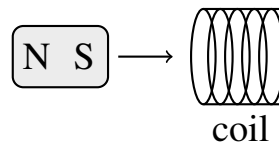
Q39. (i) In Young’s double-slit experiment, the slit separation is 0.5 mm and the screen is 1.5 m away. If light of wavelength 600 nm is used, calculate the fringe width.

OR

(ii) An object is placed 20 cm in front of a convex lens of focal length 10 cm . Find the image distance and magnification. (3)

Q40. State Faraday’s law of electromagnetic induction and Lenz’s law. In the arrangement below, a bar magnet is moved towards a coil. Explain the direction of induced current qualitatively. (3)





Q41. (i) State and prove the work-energy theorem for a constant force acting along the displacement. A 2 kg body speeds up from 3 m s^{-1} to 5 m s^{-1} . Find the net work done.

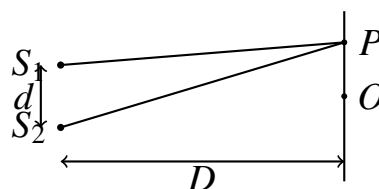
OR

(ii) Explain conservation of mechanical energy for a freely falling body. A stone of mass 0.5 kg falls from rest through 10 m. Find its kinetic energy just before hitting the ground. Take $g = 10 \text{ m s}^{-2}$. **(3)**

Q42. (i) (a) With the help of the idea of path difference, derive the condition for bright fringes in Young’s double-slit experiment and calculate the distance of the second bright fringe from the centre when $D = 2 \text{ m}$, $d = 0.8 \text{ mm}$ and $\lambda = 500 \text{ nm}$.
 (b) Write Einstein’s photoelectric equation and explain the meaning of work function.

OR

(ii) (a) Explain angular dispersion and dispersive power of a prism. Why is a prism able to split white light?
 (b) A radioactive substance has half-life 10 hours. What fraction remains after 30 hours? **(5)**



Q43. (i) (a) A block slides down a smooth inclined plane of height h . Show that its speed at the bottom is $\sqrt{2gh}$.
 (b) For one complete thermodynamic cycle, what is the relation between heat absorbed and work done?
 (c) What are beats? Write one use of beats.



(d) Draw the circuit symbol of a p-n junction diode and mention one application.

OR

(ii) (a) A force F pulls a mass m on a smooth horizontal surface. Derive $v^2 = u^2 + 2as$ using work-energy theorem.

(b) State the zeroth law of thermodynamics.

(c) What is resonance? Give one example.

(d) Mention the function of a NOT gate in digital electronics. **(5)**



Detailed Solutions

Q1.

Solution

Concept: The electric field is a vector quantity, meaning fields due to multiple charges must be added vectorially by considering both magnitude and direction. Conversely, electric potential is a scalar quantity, allowing contributions to be combined through simple algebraic addition. For a point charge, $E = kq/r^2$ and $V = kq/r$.

Step 1: The origin (0, 0) sits symmetrically on the x -axis, equidistant at a from both source charges. The electric field vector from the positive charge at $(-a, 0)$ points along the $+x$ -axis, while the field from the charge at $(a, 0)$ points along the $-x$ -axis.

Step 2: The magnitudes are identical since the charges and distances are equal ($E_1 = E_2 = kq/a^2$). Because these fields point in exactly opposite directions along the same line, they cancel out completely, making the net electric field zero.

Step 3: Potential is scalar, so directions are ignored. Each positive charge contributes a positive potential of kq/a . Summing them algebraically gives a total potential of $V = kq/a + kq/a = 2kq/a$, which is a net positive value.

Final Answer: Electric field is zero and potential is positive.

Answer: (B)

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Q2.

Solution

Concept: Newton’s second law dictates that the net acceleration is proportional to the net external force and inversely proportional to its mass ($F_{\text{net}} = ma$). Friction opposes motion and must be subtracted from the applied force to find the net driving force.

Step 1: A block experiences an external forward pulling force of 10 N and an opposing kinetic frictional force of 2 N along the contact surface.

Step 2: To find the net accelerating force, subtract the opposing friction from the forward force: $F_{\text{net}} = 10 \text{ N} - 2 \text{ N} = 8 \text{ N}$ in the direction of motion.

Step 3: Using Newton’s second law ($a = F_{\text{net}}/m$), substitute the net force of 8 N and the mass of 5 kg to find the acceleration: $a = 8/5 = 1.6 \text{ m s}^{-2}$.

Final Answer: 1.6 m s^{-2}

Answer: (C)

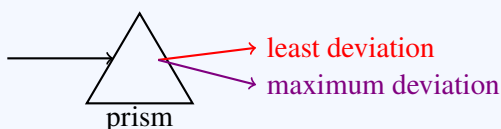
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Q3.

Solution

Concept: Optical dispersion occurs because the refractive index of glass varies for different wavelengths of light. Shorter wavelengths experience a higher refractive index and bend more. Within the visible spectrum, violet light has the shortest wavelength and red light has the longest.



Step 1: When white light enters a glass prism, the angular deviation suffered by a component color depends directly on the glass medium’s refractive index for that particular color.

Step 2: The refractive index increases as wavelength decreases. Consequently, optical glass exhibits a significantly higher refractive index for violet light than it does for red light.

Step 3: Due to this higher refractive index, the violet component is bent much more sharply toward the base of the prism, leading to the maximum total angular deviation.

Final Answer: Violet

Answer: (D)

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Q4.

Solution

Concept: A *p-n* junction diode allows significant current to flow only when biased in the forward direction. Forward bias narrows the depletion layer and lowers the potential barrier, enabling majority carriers to diffuse across the boundary.

Step 1: For a forward bias configuration, the *p*-type region must be connected to the positive terminal of an external voltage source. This positive potential repels the majority holes in the *p*-region toward the junction.

Step 2: Simultaneously, the *n*-type region must be connected to the negative terminal of the external battery. This negative potential repels the majority free electrons in the *n*-region toward the junction.

Step 3: As both types of majority carriers are driven toward the interface, the opposing internal electric field of the depletion region is neutralized, the barrier breaks down, and a forward current is established.

Final Answer: p-side to positive terminal and n-side to negative terminal

Answer: (A)

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Q5.

Solution

Concept: For steady flow of an ideal incompressible fluid, mass conservation yields the equation of continuity, $A_1v_1 = A_2v_2$. Bernoulli's principle states that for a horizontal flow line, an increase in velocity occurs with a decrease in fluid pressure.

Step 1: Fluid flows through a horizontal pipe that constricts to a narrower section where the cross-sectional area is reduced to exactly half of its initial value: $A_2 = A_1/2$.

Step 2: From the equation of continuity, $A_1v_1 = (A_1/2)v_2$. Canceling the area terms reveals that the velocity in the narrow section must double: $v_2 = 2v_1$.

Step 3: Since the pipeline remains strictly horizontal, there is no change in potential energy. To balance the increased kinetic energy in the narrow section, Bernoulli's equation dictates that the fluid pressure must drop.

Final Answer: Speed doubles and pressure decreases.

Answer: (B)

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Q6.

Solution

Concept: In the photoelectric effect, an individual photon transfers its entire energy $h\nu$ to a single bound electron. Photoelectric emission occurs only if this photon energy is greater than or equal to the metal's work function ϕ . The threshold frequency ν_0 is defined by $h\nu_0 = \phi$.

Step 1: When the frequency of the incident light ν is strictly lower than the threshold frequency ν_0 of the metal surface ($\nu < \nu_0$), the individual photon energy is less than the work function ($h\nu < \phi$).

Step 2: Under this condition, every arriving photon lacks the minimum energy required to liberate an electron. Consequently, no electron can gain enough energy from a single impact to escape the surface.

Step 3: Boosting the light intensity only increases the number of photons hitting the surface per second; it does not alter the energy of each photon. Therefore, no photoelectrons are emitted.

Final Answer: No photoelectrons are emitted.

Answer: (C)

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Q7.

Solution

Concept: The first law of thermodynamics represents the law of conservation of energy applied to thermal systems: $\Delta U = Q - W$, where ΔU is the change in internal energy, Q is heat transferred into the system, and W is work performed by the system.

Step 1: When a gas system absorbs heat from its external environment, the heat energy added is positive. Therefore, we write the heat transfer value as $Q = +200 \text{ J}$.

Step 2: Similarly, when the gas expands and does mechanical work against external pressure, the work done by the system is given a positive sign. Hence, the work term is set to $W = +60 \text{ J}$.

Step 3: Substituting these parameters directly into the first law equation yields $\Delta U = 200 \text{ J} - 60 \text{ J} = 140 \text{ J}$. This positive result indicates an increase in the internal energy of the gas.

Final Answer: 140 J

Answer: (C)

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Q8.

Solution

Concept: The wave equation links wave speed, frequency, and wavelength through $v = f\lambda$. In a standing wave pattern formed by the superposition of traveling waves, the linear distance separating any two consecutive nodes is exactly half a wavelength ($\lambda/2$).

Step 1: A standing wave is generated on a medium where the propagation speed of the component waves is $v = 50 \text{ m s}^{-1}$ and the continuous driving frequency is maintained at $f = 100 \text{ Hz}$.

Step 2: Rearranging the fundamental wave equation to solve for the system's wavelength gives $\lambda = v/f$. Substituting the provided values yields a wavelength of $\lambda = 50/100 = 0.50 \text{ m}$.

Step 3: Because nodes correspond to points of zero amplitude that repeat every half-cycle, the spatial distance between consecutive nodes is half of a full wave: $\text{Distance} = \lambda/2 = 0.50/2 = 0.25 \text{ m}$.

Final Answer: 0.25 m

Answer: (B)

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Q9.

Solution

Concept: The electrostatic potential energy stored within a charged capacitor is given by $U = \frac{1}{2}CV^2$, where C represents the capacitance and V represents the potential difference. All parameters must be in standard SI units before calculation.

Step 1: The capacitance value is initially provided in microfarads. To convert it into standard farads (F), multiply by 10^{-6} : $C = 4 \mu\text{F} = 4 \times 10^{-6} \text{ F}$.

Step 2: Substituting the converted capacitance and the given potential difference of $V = 50 \text{ V}$ into the energy formula, we obtain: $U = \frac{1}{2} \cdot (4 \times 10^{-6} \text{ F}) \cdot (50 \text{ V})^2$.

Step 3: Squaring the voltage term gives $50^2 = 2500 \text{ V}^2$. Multiplying this by the remaining terms yields $U = 2 \times 10^{-6} \times 2500 = 5000 \times 10^{-6} \text{ J} = 5.0 \times 10^{-3} \text{ J}$.

Final Answer: $5.0 \times 10^{-3} \text{ J}$

Answer: (A)

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Q10.

Solution

Concept: The translational kinetic energy of a moving object is defined by $K = \frac{1}{2}mv^2$, where m is mass and v is speed. For a single unchanging body, its mass remains completely constant, establishing a direct proportionality where $K \propto v^2$.

Step 1: Let the initial speed of the object be v and its initial kinetic energy be K . The new speed after acceleration is denoted as v' , and its corresponding kinetic energy is denoted as K' .

Step 2: The problem states that the kinetic energy of the body is doubled, meaning $K' = 2K$. Writing this out using the kinetic energy definition gives the relationship: $\frac{1}{2}m(v')^2 = 2 \cdot \left(\frac{1}{2}mv^2\right)$.

Step 3: Since the mass m and the factor $\frac{1}{2}$ appear on both sides of the expression, they cancel out entirely. This leaves the simplified relation $(v')^2 = 2v^2$, which yields $v' = \sqrt{2}v$.

Final Answer: $\sqrt{2}$ times

Answer: (C)

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Q11.

Solution

Concept: Brewster’s law states that when unpolarized light is incident on a transparent medium at a specific angle, the reflected light becomes completely plane-polarized. This unique angle is known as the polarizing angle, i_p , and its tangent is mathematically equal to the refractive index n of the medium relative to the surrounding air, expressed by the formula $\tan i_p = n$.

Step 1: The problem provides the refractive index of the transparent medium as $n = 1.5$, which represents a typical value for standard optical glass.

Step 2: According to the mathematical formulation of Brewster’s law, we take the inverse tangent of both sides to isolate the polarizing angle variable, which gives the expression $i_p = \tan^{-1}(1.5)$.

Step 3: Using standard inverse trigonometric function tables or a scientific calculator approximation, evaluating $\tan^{-1}(1.5)$ yields a value of approximately 56.31° , which rounds cleanly to a single decimal place.

Final Answer: 56.3°

Answer: (B)

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Q12.

Solution

Concept: A straight current-carrying conductor generates an external magnetic field in its surrounding space. The resulting magnetic field lines form a pattern of concentric circles lying in planes perpendicular to the wire, centered on the conductor. The directional orientation of these circular fields is determined using the right-hand thumb rule.



Step 1: To find the field direction, point the thumb of the right hand along the straight wire pointing in the direction of the conventional electric current.

Step 2: As you maintain this orientation, the fingers of your right hand naturally curl around the straight conductor, mapping out the rotational path of the magnetic field vector.

Step 3: Since the physical paths traced by the curled fingers are perfectly circular and orbit the longitudinal axis of the wire, the field lines form continuous concentric circles.

Final Answer: Concentric circles centred on the conductor

Answer: (C)

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Q13.

Solution

Concept: When operated as an electronic switch, a bipolar junction transistor must fluctuate between two distinct, stable states: the completely OFF state and the fully ON state. The OFF state corresponds to the cut-off region, where current is zero, while the ON state corresponds to the saturation region, where conduction is maximum.

Step 1: In the cut-off region, the base-emitter and collector-base junctions are reverse-biased. The base current is zero, forcing the collector current to nearly zero, which causes the transistor to mimic an open circuit switch.

Step 2: In the saturation region, both semiconductor junctions are forward-biased. A small base current drives the collector current to its maximum, dropping the collector-emitter voltage to near zero and acting like a closed circuit switch.

Step 3: The intermediate active region is characterized by a linear relationship between input and output currents, making it ideal for signal amplification but entirely unsuited for digital switching applications.

Final Answer: Cut-off and saturation regions

Answer: (D)

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Q14.

Solution

Concept: The useful mechanical power output required to lift a continuous stream of water equals the time rate of increase of its gravitational potential energy, given by $P_{\text{out}} = \dot{m}gh$, where \dot{m} is the mass flow rate. The total input power required depends on the pump's efficiency, defined as $\eta = P_{\text{out}}/P_{\text{in}}$.

Step 1: The parameters are given as a mass flow rate $\dot{m} = 20 \text{ kg s}^{-1}$, local gravitational acceleration $g = 10 \text{ m s}^{-2}$, and a vertical lifting height $h = 5 \text{ m}$.

Step 2: Substituting these values into the potential energy rate formula yields the useful power output: $P_{\text{out}} = 20 \text{ kg s}^{-1} \times 10 \text{ m s}^{-2} \times 5 \text{ m} = 1000 \text{ W} = 1 \text{ kW}$.

Step 3: Given that the mechanical pump operates at an efficiency of 50%, we rearrange the efficiency formula to solve for the total power input: $P_{\text{in}} = P_{\text{out}}/\eta = 1 \text{ kW}/0.5 = 2.0 \text{ kW}$.

Final Answer: 2.0 kW

Answer: (C)

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Q15.

Solution

Concept: Radioactive decay is governed by statistical probability, where the total mass of the parent nuclide decreases exponentially over time. After the passage of each discrete half-life period, the remaining quantity of the radioactive isotope is halved. After n half-lives, the remaining fraction is given by $(1/2)^n$.

Step 1: The problem states that the specific radioisotope has a half-life period of 5 days, and the total elapsed time allowed for the decay process is 15 days.

Step 2: To determine the number of half-life cycles that have passed during this timeframe, we divide the total time by the half-life duration: $n = 15/5 = 3$ half-lives.

Step 3: Using the fractional remaining formula with $n = 3$, the fraction of the initial radioactive material surviving decay is calculated as Fraction = $(1/2)^3 = 1/8$ of the original amount.

Final Answer: $1/8$

Answer: (C)

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Q16.

Solution

Concept: According to Archimedes' principle, a body floating freely in static equilibrium displaces a volume of fluid whose total weight matches the entire weight of the object. Consequently, the fraction of the object's volume that remains submerged is equal to the ratio of the object's density to the liquid's density.

Step 1: The problem states that a solid block floats with an immersed volume fraction of 0.60, meaning exactly 60% of its total geometric volume is submerged beneath the surface.

Step 2: Under standard conditions, the reference density of pure liquid water is a known constant, which is expressed in metric units as $\rho_{\text{water}} = 1 \text{ g cm}^{-3}$.

Step 3: Setting up the floating ratio, Fraction Immersed = $\rho_{\text{block}}/\rho_{\text{water}}$, we substitute the knowns to find the density of the block: $\rho_{\text{block}} = 0.60 \times 1 \text{ g cm}^{-3} = 0.60 \text{ g cm}^{-3}$.

Final Answer: 0.6 g cm^{-3}

Answer: (B)

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Q17.

Solution

Concept: Linear impulse relates a force acting over a finite duration to the resulting net change in an object’s linear momentum. This concept explains collisions where large forces act over brief intervals. For a constant average force, impulse is expressed mathematically as $J = F\Delta t = \Delta p$.

Step 1: The impulse-momentum theorem states that the net impulse imparted to an object equals its total change in momentum. In a catching scenario, the ball decelerates from a high initial velocity to rest.

Step 2: Because the initial mass, initial velocity, and final zero velocity of the ball are predetermined, the required change in momentum (Δp) remains constant regardless of how the catch is executed.

Step 3: When a cricket player relaxes and moves his hands backward along the path of the incoming ball, he extends the time interval (Δt) over which the stopping deceleration occurs.

Step 4: Rearranging the equation to $F = \Delta p / \Delta t$ demonstrates that maximizing the contact time interval reduces the average impact force felt by the player’s hands, preventing injury.

Final Answer: $J = \Delta p$; moving hands backward increases stopping time and reduces force.

Answer: (See above)

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Q18.

Solution

Concept: Sustained optical interference requires the participating light sources to maintain a constant phase relationship over time; such sources are termed coherent. Furthermore, electromagnetic waves traveling through a vacuum are transverse because their electric and magnetic field vectors oscillate perpendicular to the direction of propagation.

Step 1: To observe a distinct, stable interference pattern, the relative phase difference between overlapping light waves must remain constant. Independent random sources fluctuate too quickly, meaning the overlapping sources must be strictly coherent.

Step 2: Physical characterization shows that light propagates as a self-sustaining electromagnetic wave where the fluctuating electric field and magnetic field components are oriented mutually perpendicular to one another.

Step 3: Because both of these field vectors oscillate exclusively within a plane that lies at a right angle to the direction of wave energy travel, light behaves as a transverse wave.

Final Answer: coherent; transverse

Answer: (See above)

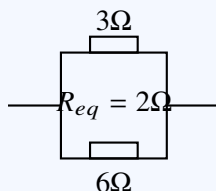
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Q19.

Solution

Concept: In a parallel circuit network, the potential difference across each individual resistor branch is identical. The total equivalent resistance (R) of two parallel resistors is calculated using the reciprocal sum formula $1/R = 1/R_1 + 1/R_2$, and total circuit current is found via Ohm's law ($I = V/R$).



Step 1: Substituting the given parallel resistors into the reciprocal formula yields: $1/R = 1/3 + 1/6 = (2 + 1)/6 = 3/6 = 1/2$. Taking the reciprocal gives an equivalent resistance of $R = 2\Omega$.

Step 2: The total network resistance is lower than that of either individual branch. Next, we record the total EMF supplied by the external battery, which is given as $V = 6\text{ V}$.

Step 3: Using Ohm's law to calculate the total current drawn from the source, we divide the source voltage by the net resistance: $I = V/R = 6\text{ V}/2\Omega = 3\text{ A}$.

Final Answer: $R_{eq} = 2\Omega$, $I = 3\text{ A}$

Answer: (See above)

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Q20.

Solution

Concept: Thermodynamic processes are classified based on which state variable remains constant or what specific energy exchange is blocked. In an isothermal process, the system's thermal state is fixed, while an adiabatic process restricts any thermal exchange with the surroundings.

Step 1: The prefix "iso-" means equal, and the root "-thermal" refers to temperature. Consequently, an isothermal process is defined as a thermodynamic change during which the system temperature remains constant.

Step 2: An adiabatic process occurs within a thermally insulated boundary that prevents heat transfer. This restriction ensures that no heat energy enters or leaves the system, which satisfies the condition $Q = 0$.

Final Answer: constant; zero

Answer: (See above)

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Q21.

Solution

Concept: Properties of fluids encompass key mechanical and thermal characteristics including pressure-energy relations, internal viscous resistance, buoyant force, and surface tension. Matching these terms successfully requires connecting each specialized fluid behavior with its underlying core physical principle and foundational governing equation.

Step 1: Bernoulli’s theorem states that for an incompressible, non-viscous fluid flowing in a steady streamline, the sum of pressure energy, kinetic energy, and potential energy per unit volume remains completely constant at every point, which matches description (a)–(ii).

Step 2: Viscosity describes the internal frictional force that arises between adjacent layers of a fluid moving at different velocities, resisting relative lateral motion and bringing flowing fluids to rest, which matches description (b)–(iii).

Step 3: Buoyant force is the net upward force exerted by a static fluid on any object wholly or partially immersed in it, and its magnitude is precisely equal to the total weight of the fluid displaced, matching description (c)–(i).

Step 4: Surface tension is a microscopic property of liquids arising from intermolecular cohesive forces, measured macroscopically as the parallel force acting per unit length along an imaginary line drawn on the liquid’s surface, matching description (d)–(iv).

Final Answer: (a)-(ii), (b)-(iii), (c)-(i), (d)-(iv)

Answer: (See above)

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Q22.

Solution

Concept: A p - n junction forms an interface that possesses a narrow, specialized boundary known as a depletion region, which contains fixed immobile ions but is completely devoid of free mobile charge carriers. A Zener diode is a heavily doped semiconductor device specifically designed to safely operate within this reverse breakdown regime without thermal destruction to maintain a steady output voltage.

Step 1: When a p -type and an n -type semiconductor are brought into close contact, majorities diffuse across the boundary and recombine near the interface. This process uncovers fixed donor and acceptor ions, creating a narrow region left entirely without free mobile charge carriers called the depletion layer.

Step 2: Standard diodes can be easily destroyed if forced into reverse breakdown due to excessive heat generation. However, a heavily doped silicon p - n junction diode that is manufactured to operate continuously and safely under reverse breakdown conditions for steady voltage regulation is called a Zener diode.

Final Answer: depletion; Zener

Answer: (See above)

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Q23.

Solution

Concept: Bohr's atomic model restricts orbital states by quantizing orbital angular momentum as an integral multiple of Planck's constant divided by 2π , written as $mvr = nh/2\pi$. Conversely, the photoelectric effect obeys Einstein's equation $K_{\max} = h\nu - \phi$, which proves that the maximum kinetic energy of escaping electrons depends strictly on the frequency of incident photons.

Step 1: The first statement asserts that electrons can only move in specific non-radiating paths where orbital angular momentum matches an integral multiple of $h/2\pi$. This matches Bohr's famous angular momentum quantization postulate exactly, so the statement is true.

Step 2: The second statement claims that the maximum kinetic energy of emitted photoelectrons depends exclusively on the intensity of the light beam. According to Einstein's photoelectric equation, $K_{\max} = h\nu - \phi$, kinetic energy scales linearly with frequency, while intensity determines the total current. Thus, this statement is false.

Final Answer: T; F

Answer: (See above)

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Q24.

Solution

Concept: Every fundamental law in classical electrostatics and electromagnetic induction is characterized by a specific mathematical formula or a statement governing directional behavior. Coulomb's law establishes an inverse-square force relationship, electrical capacitance defines charge storage per unit potential, Faraday's law determines induced electromotive force, and Lenz's law dictates the directional orientation of induced currents.

Step 1: Coulomb's law states that the electrostatic force acting between two stationary point charges is directly proportional to the product of their magnitudes and inversely proportional to the square of their separation distance, $F \propto q_1q_2/r^2$, matching statement (a)–(ii).

Step 2: Electrical capacitance measures a conductor's ability to store electric charge per unit potential difference established across it, given mathematically by the ratio $C = Q/V$, which directly connects with statement (b)–(iii).

Step 3: Faraday's law of electromagnetic induction states that the magnitude of the electromotive force induced within a closed conducting loop is directly proportional to the time rate of change of magnetic flux, matching statement (c)–(iv).

Step 4: Lenz's law provides the directional orientation of an induced electromotive force, stating that the induced current will always flow in a direction that generates a magnetic field opposing the original change in flux, matching statement (d)–(i).

Final Answer: (a)-(ii), (b)-(iii), (c)-(iv), (d)-(i)

Answer: (See above)

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Q25.

Solution

Concept: Rayleigh scattering explains the characteristic blue color of the sky through a strong, inverse fourth-power dependence on wavelength, expressed as $I \propto 1/\lambda^4$. Separating composite white light into its constituent colors via a glass prism occurs because the refractive index varies across wavelengths, an inherent optical capability known as dispersive power.

Step 1: In the phenomenon of Rayleigh scattering, when light interacts with particles smaller than its wavelength, shorter wavelengths scatter far more efficiently than longer ones because the scattered light intensity varies inversely with the fourth power of the wavelength.

Step 2: When composite white light enters an optical prism, each constituent color undergoes a different amount of angular deviation. The exact mathematical measure of this color-separating capability, which depends heavily on the variation of refractive index, is called the dispersive power.

Final Answer: wavelength; dispersive power

Answer: (See above)

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Q26.

Solution

Concept: Classical mechanics terms are categorized based on rigorous operational definitions. Inertia represents a body’s intrinsic resistance to any alteration in its state of rest or uniform motion, work defines energy transfer via force application across a displacement, power measures the work rate, and conservative forces feature path-independent work.

Step 1: Inertia is an intrinsic property of matter that quantifies an object’s natural capacity to oppose any external attempt to modify its current velocity vector or state of rest, which matches description (a)–(ii).

Step 2: Mechanical work is defined mathematically as the scalar dot product of an applied force vector and the resulting displacement vector in the direction of that force, matching description (b)–(iii).

Step 3: Power is defined as the time rate at which mechanical work is performed or energy is converted within a system, matching description (c)–(i).

Step 4: A conservative force is a specific type of force field where the net work done in moving a mass between two spatial locations is completely independent of the choice of path taken, matching description (d)–(iv).

Final Answer: (a)–(ii), (b)–(iii), (c)–(i), (d)–(iv)

Answer: (See above)

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Q27.

Solution

Concept: The direction of conventional electric current is historically defined by the vector along which positive charge carriers would move through a circuit loop. For a sinusoidal alternating current system, the root-mean-square value represents the effective steady direct current equivalent, which equals the peak current divided by $\sqrt{2}$, rather than twice the peak value.

Step 1: The first statement asserts that the conventional direction of electric current in a circuit is defined as the path that a positive test charge would naturally follow. This perfectly matches the historical international sign convention for current flow, meaning it is true.

Step 2: The second statement claims that the root-mean-square value of a standard alternating current is equal to double its peak value. For a sinusoidal current wave $I = I_0 \sin \omega t$, the mathematical relation is $I_{\text{rms}} = I_0/\sqrt{2} \approx 0.707I_0$. Thus, this statement is false.

Final Answer: T; F

Answer: (See above)

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Q28.

Solution

Concept: Different semiconductor devices are engineered to execute specific energy conversion or operational control tasks. A light-emitting diode converts electrical energy directly into light, a photodiode measures incident optical intensity, a rectifier converts alternating current to direct current, and a repeater boosts weak transmission signals within communications networks.

Step 1: A light-emitting diode (p - n junction) releases photons due to the radiative recombination of injected minority charge carriers when it is operated under a forward bias configuration, matching application (a)–(ii).

Step 2: A photodiode is operated under a reverse bias configuration so that the generation of electron-hole pairs by incident photons produces a measurable reverse current proportional to the light intensity, matching application (b)–(iii).

Step 3: A rectifier circuit utilizes the unidirectional conduction properties of semiconductor diodes to convert an alternating current input into a unidirectional pulsating direct current output, matching application (c)–(i).

Step 4: A repeater is an integrated electronic system consisting of a receiver, an amplifier, and a transmitter that picks up a weakened signal, regenerates it, and retransmits it further, matching application (d)–(iv).

Final Answer: (a)–(ii), (b)–(iii), (c)–(i), (d)–(iv)

Answer: (See above)

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Q29.

Solution

Concept: Wave diffraction is a fundamental wave phenomenon demonstrating that waves do not always propagate exclusively along straight lines. When a wave encounters a sharp edge, physical obstacle, or narrow aperture, it bends around those boundaries and spreads directly into regions that would otherwise be classified as the geometrical shadow.

Step 1: Diffraction is formally defined as the non-rectilinear bending, spreading, and interference of wave crests around the edges of an obstacle or through a narrow opening, deviating from straight paths.

Step 2: The physical extent of this bending behavior becomes highly pronounced and noticeable only when the characteristic physical dimensions of the aperture or obstacle are roughly comparable to the wavelength of the incident wave.

Step 3: A common daily-life illustration of this phenomenon is our ability to hear sound around an open doorway or corner; acoustic waves have relatively long wavelengths and therefore diffract easily through architectural openings.

Final Answer: Diffraction is bending/spreading of waves; it is large when aperture size $\sim \lambda$.

Answer: (See above)

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Q30.

Solution

Concept: The impulse-momentum theorem states that the net impulse delivered to an object is equal to its total resulting change in linear momentum. For a solid body starting from a complete state of rest, this relationship simplifies to $F\Delta t = mv$, assuming that the applied external force remains constant and no frictional forces oppose motion.

Step 1: The mathematical formulation of the impulse-momentum theorem equates the product of the average force and the time interval to the change in momentum: $F\Delta t = \Delta p = m(v - u)$.

Step 2: The problem provides the following parameters: a constant external force $F = 40 \text{ N}$, a time duration $\Delta t = 2 \text{ s}$, an object mass $m = 8 \text{ kg}$, and an initial velocity $u = 0 \text{ m s}^{-1}$.

Step 3: To calculate the total impulse imparted to the object, we compute the product of the force and the time interval: Impulse = $40 \text{ N} \times 2 \text{ s} = 80 \text{ N s}$.

Step 4: Equating this total impulse to the final momentum change gives $80 = 8 \times v$. Isolating the final velocity variable by dividing both sides by the mass yields a final speed of $v = 10 \text{ m s}^{-1}$.

Final Answer: $v = 10 \text{ m s}^{-1}$

Answer: (See above)

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Q31.

Solution

Concept: Gauss’s law relates the net electric flux passing outward through any closed boundary surface to the total net enclosed electric charge divided by the permittivity of free space. For electrical capacitors connected in a series configuration, the charge residing on each plate remains completely identical, and their total equivalent network capacitance is determined by summing the individual reciprocals.

Alternative (i): Step 1: The total electric flux passing through a closed spatial boundary is mathematically defined by the closed surface integral of the electric field vector dot product with the area element, written as $\Phi_E = \oint \vec{E} \cdot d\vec{A}$. **Step 2:** Gauss’s law states that this surface integral evaluates directly to the net enclosed charge divided by the permittivity constant: $\oint \vec{E} \cdot d\vec{A} = q_{\text{enclosed}}/\epsilon_0$. **Step 3:** This law serves as an exceptionally powerful tool for evaluating electric fields when the underlying charge distribution exhibits high spherical, cylindrical, or planar symmetry.

Alternative (ii): Step 1: When two capacitors are connected in a series circuit configuration, the net equivalent capacitance (C_{eq}) is determined via the reciprocal addition formula: $1/C_{eq} = 1/C_1 + 1/C_2$. **Step 2:** Substituting the given capacitance values of $3 \mu\text{F}$ and $6 \mu\text{F}$ into the expression yields the calculation: $1/C_{eq} = 1/3 + 1/6 = (2 + 1)/6 = 3/6 = 1/2 \mu\text{F}^{-1}$. **Step 3:** Taking the reciprocal of this calculated fraction gives a final net equivalent series capacitance value of $C_{eq} = 2 \mu\text{F}$.

Final Answer: $\oint \vec{E} \cdot d\vec{A} = q/\epsilon_0; \quad C_{eq} = 2 \mu\text{F}$

Answer: (See above)

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Q32.

Solution

Concept: Optical dispersion represents the physical separation of composite white light into its constituent spectral colors because the refractive index of a medium varies with the wavelength of incident light. Conversely, Huygens’ principle treats every point on a propagation wavefront as an independent source of secondary wavelets that spread out in all directions.

Alternative (i): Step 1: Dispersion is defined as the splitting of a beam of composite white light into its constituent component colors upon undergoing refraction through a dispersive medium such as a triangular glass prism. **Step 2:** Within a standard glass medium, the refractive index encountered by shorter wavelengths like violet light is significantly greater than that encountered by longer wavelengths like red light. **Step 3:** Because the angle of deviation scales directly with the refractive index, the violet component undergoes maximum bending, separating the colors.

Alternative (ii): Step 1: Huygens’ principle states that every single point located along a primary wavefront acts as an active point source generating secondary spherical wavelets that move forward at the speed of light. **Step 2:** The common forward envelope or tangent surface touching these individual secondary wavelets at a subsequent time interval defines the geometry of the newly established wavefront. **Step 3:** A wavefront itself is defined as the continuous locus of all neighboring particles in a medium that are vibrating in the exact same phase.

Final Answer: Dispersion: splitting of white light; wavefront: surface of same phase.

Answer: (See above)

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Q33.

Solution

Concept: A real chemical cell is characterized by an internal electromotive force E and an intrinsic internal resistance r . When this real cell is connected across an external load resistance R , the total circuit current is limited by the combined resistance $I = E/(R + r)$, and the terminal voltage available to the load drops to $V = IR = E - Ir$.

Step 1: The complete circuit loop consists of the external load resistance connected in series with the cell’s internal resistance. Therefore, the total network resistance is calculated as $R + r = 5\ \Omega + 1\ \Omega = 6\ \Omega$.

Step 2: Using Ohm’s law across the entire circuit loop, the steady electrical current drawn from the cell is found by dividing the electromotive force by the total resistance: $I = E/(R + r) = 12\ \text{V}/6\ \Omega = 2\ \text{A}$.

Step 3: The terminal potential difference available across the terminals of the external resistor is determined by calculating the local voltage drop across it: $V = IR = 2\ \text{A} \times 5\ \Omega = 10\ \text{V}$.

Step 4: This result can be cross-verified by subtracting the internal potential drop from the total electromotive force, which yields $E - Ir = 12\ \text{V} - 2\ \text{A} \times 1\ \Omega = 10\ \text{V}$, confirming the calculation.

Final Answer: $I=2\ \text{A}$, $V=10\ \text{V}$

Answer: (See above)

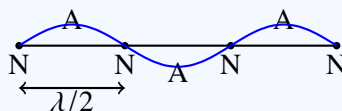
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Q34.

Solution

Concept: A stationary wave established on a flexible string fixed securely at both ends must form displacement nodes at those fixed boundaries due to restricted motion. The spatial separation between any two consecutive nodes is equal to $\lambda/2$, and counting the number of vibrating loops offers a direct method to connect string length to wavelength.



Step 1: Analyzing the vibrational mode shown in the diagram reveals the presence of exactly three independent resonance loops or segments oscillating between the two fixed rigid ends.

Step 2: Since each complete individual loop corresponds to exactly half of a full spatial wavelength, the total length of the string is related to the wavelength by the equation $L = 3(\lambda/2)$.

Step 3: Substituting the provided physical length parameter of $L = 1.2$ m into our geometric loop equation yields the mathematical relationship: $1.2 = 3\lambda/2$.

Step 4: Isolating the wavelength variable by rearranging the terms gives $\lambda = 2 \times 1.2/3 = 0.8$ m. Nodes form at the boundaries and junctions, while antinodes develop at the loop centers.

Final Answer: $\lambda = 0.8$ m; nodes at ends and junctions, antinodes at loop centres.

Answer: (See above)

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Q35.

Solution

Concept: Bohr’s atomic model explains the discrete hydrogen emission spectrum by postulating the existence of non-radiating stationary orbits governed by quantized angular momentum. Conversely, nuclear binding energy arises directly from a net mass defect, serving as a quantitative measure of the overall stability of a nucleus.

Alternative (i): Step 1: Bohr’s first postulate states that bound electrons revolve around the central nucleus only in specific, non-radiating paths called stationary orbits, where they do not emit electromagnetic energy. **Step 2:** The orbital angular momentum of an electron within these allowed orbits is restricted to integral multiples of Planck’s constant divided by 2π , expressed as $mvr = nh/2\pi$, where $n = 1, 2, 3, \dots$

Alternative (ii): Step 1: The mass defect (Δm) is defined as the difference between the total combined mass of the constituent protons and neutrons when separated and the actual measured mass of the bound nucleus. **Step 2:** The nuclear binding energy is the energy equivalent of this mass defect according to Einstein’s mass-energy equivalence principle, given by the relation $E_b = \Delta mc^2$.

Final Answer: Bohr: stationary orbits and $mvr = nh/2\pi$; $E_b = \Delta mc^2$.

Answer: (See above)

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Q36.

Solution

Concept: The equation of continuity is derived from the law of conservation of mass applied to the steady, streamline flow of an ideal incompressible fluid. It states that the total volume flow rate, given by the product of the cross-sectional area A and the fluid velocity v , must remain constant throughout a tube of flow.

Step 1: The mathematical statement of mass conservation for fluid passing through a channel of varying thickness is given by the equation of continuity: $A_1v_1 = A_2v_2$.

Step 2: The problem provides the following parameters: an initial area $A_1 = 8 \text{ cm}^2$, a constricted secondary area $A_2 = 2 \text{ cm}^2$, and an initial entry fluid flow velocity $v_1 = 0.5 \text{ m s}^{-1}$.

Step 3: Substituting these parameters directly into the continuous flow equation yields the numerical relationship: $8 \text{ cm}^2 \times 0.5 \text{ m s}^{-1} = 2 \text{ cm}^2 \times v_2$.

Step 4: Simplifying the left-hand side of the equation gives $4 = 2v_2$. Isolating the unknown final velocity parameter by dividing both sides by 2 results in a final velocity of $v_2 = 2 \text{ m s}^{-1}$.

Final Answer: $v_2 = 2 \text{ m s}^{-1}$

Answer: (See above)

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Q37.

Solution

Concept: The thermodynamic work performed by an expanding gas during an isobaric expansion process is calculated using the formula $W = P\Delta V = P(V_2 - V_1)$. This mechanical work is given a positive value because the expanding gas system exerts a force over a distance to do work on its surroundings.

Step 1: The initial volume of the gas system is recorded as $V_1 = 2 \times 10^{-3} \text{ m}^3$, and the final volume after the expansion phase is recorded as $V_2 = 5 \times 10^{-3} \text{ m}^3$.

Step 2: To find the net change in the system's volume, we subtract the initial volume from the final volume: $\Delta V = V_2 - V_1 = (5 \times 10^{-3} - 2 \times 10^{-3}) \text{ m}^3 = 3 \times 10^{-3} \text{ m}^3$.

Step 3: The constant pressure maintained throughout this expansion process is $P = 2 \times 10^5 \text{ N m}^{-2}$. Substituting the pressure and volume change into the work formula yields: $W = (2 \times 10^5) \times (3 \times 10^{-3})$.

Step 4: Evaluating the product of these values simplifies to $W = 6 \times 10^2 \text{ J} = 600 \text{ J}$. This positive value confirms that the expanding gas performed work on the external environment.

Final Answer: 600 J

Answer: (See above)

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Q38.

Solution

Concept: Solid-state semiconductor devices operate based on the precise control of electrical conductivity. Pure semiconductors rely on thermally generated charge carriers, doped semiconductors utilize introduced impurities to establish a majority carrier type, and rectifiers exploit the unidirectional conduction properties of p - n junctions.

Step 1: An intrinsic semiconductor is an chemically pure semiconductor crystal containing no intentional doping impurities. In these materials, the concentrations of free electrons and holes are equal, generated solely by thermal energy (e.g., pure silicon).

Step 2: A p -type semiconductor is fabricated by doping an intrinsic crystal with trivalent impurity atoms like boron. This substitution introduces vacant electronic states or holes into the valence band, making holes the majority charge carriers.

Step 3: A rectifier is an electronic circuit that converts an alternating current input into a unidirectional direct current output by leveraging the property of a p - n junction diode to conduct current easily in only one direction.

Final Answer: Intrinsic: pure Si; p -type: B-doped Si; rectifier: AC to DC converter.

Answer: (See above)

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Q39.

Solution

Concept: In Young’s double-slit interference experiment, the linear spatial width of a fringe is given by $\beta = \lambda D/d$. For an optical thin lens, the image formation behavior is governed by the standard lens formula $1/f = 1/v - 1/u$, evaluated using the Cartesian sign convention.

Alternative (i): Step 1: Convert all parameters into standard SI units: wavelength $\lambda = 600 \text{ nm} = 6 \times 10^{-7} \text{ m}$, slit-to-screen distance $D = 1.5 \text{ m}$, and slit separation distance $d = 0.5 \text{ mm} = 5 \times 10^{-4} \text{ m}$.

Step 2: Substitute these values into the fringe width formula: $\beta = \lambda D/d = (6 \times 10^{-7} \times 1.5)/(5 \times 10^{-4})$. **Step 3:** Simplifying the expression yields $\beta = 9 \times 10^{-7}/5 \times 10^{-4} = 1.8 \times 10^{-3} \text{ m} = 1.8 \text{ mm}$.

Alternative (ii): Step 1: Using the sign convention for a real object placed before a convex lens, the object distance is $u = -20 \text{ cm}$ and the focal length is $f = +10 \text{ cm}$. **Step 2:** Substitute into the lens formula: $1/10 = 1/v - 1/(-20)$, which simplifies to $1/10 = 1/v + 1/20$. **Step 3:** Isolating the term gives $1/v = 1/10 - 1/20 = 1/20$, so $v = 20 \text{ cm}$. The linear magnification is $m = v/u = 20/(-20) = -1$.

Final Answer: $\beta = 1.8 \text{ mm}$; $v = 20 \text{ cm}$, $m = -1$

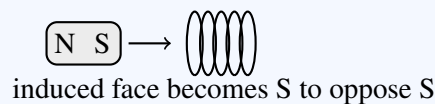
Answer: (See above)

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Q40.

Solution

Concept: Faraday’s law of induction establishes that a changing magnetic flux induces an electromotive force proportional to its rate of change. Lenz’s law dictates the direction of this effect, stating that the induced current flows such that its own magnetic field opposes the original flux change.



Step 1: Faraday’s law is written mathematically as $\mathcal{E} = -d\Phi_B/dt$. The negative sign in this derivative equation represents the mathematical manifestation of Lenz’s law.

Step 2: As the south pole of a permanent bar magnet approaches the face of the stationary conducting coil, the total magnetic flux lines linking the loop increase over time.

Step 3: According to Lenz’s law, the coil creates an opposing magnetic field to resist this increase. Therefore, the near face of the coil develops a south magnetic pole to repel the approaching magnet.

Step 4: This induced magnetic polarity requires an induced current to flow through the loop, establishing a magnetic macroscopic mechanical opposition that acts to slow down the approaching magnet.

Final Answer: $\mathcal{E} = -d\Phi_B/dt$; induced current opposes the approaching magnet.

Answer: (See above)

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Q41.

Solution

Concept: The work-energy theorem states that the net mechanical work performed by external forces on a body is equal to its total resulting change in kinetic energy. In contrast, the conservation of mechanical energy states that in the absence of non-conservative forces, the total energy ($K + U$) remains constant.

Alternative (i): Step 1: For a constant external force acting parallel to a displacement vector, the mechanical work performed is given by the simple scalar product $W = Fs$. **Step 2:** From kinematics $v^2 - u^2 = 2as$, substituting $a = F/m$ gives $v^2 - u^2 = 2(F/m)s$. Rearranging this expression yields the work-energy relation: $Fs = \frac{1}{2}m(v^2 - u^2)$. **Step 3:** Thus, $W = \Delta K$. Substituting $m = 2 \text{ kg}$, $u = 3 \text{ m s}^{-1}$, and $v = 5 \text{ m s}^{-1}$ gives $W = \frac{1}{2}(2)(25 - 9) = 16 \text{ J}$.

Alternative (ii): Step 1: A freely falling body under the influence of gravity continuously loses gravitational potential energy and converts it into kinetic energy, provided that atmospheric air resistance is neglected. **Step 2:** Just before hitting the ground after falling from a height of $h = 10 \text{ m}$, the gained kinetic energy is equal to the initial potential energy: $K = mgh$. **Step 3:** Substituting the parameters yields the final kinetic energy value: $K = 0.5 \text{ kg} \times 10 \text{ m s}^{-2} \times 10 \text{ m} = 50 \text{ J}$.

Final Answer: $W=16 \text{ J}$; $K=50 \text{ J}$

Answer: (See above)

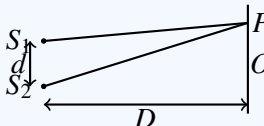
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Q42.

Solution

Concept: Spatial interference fringes develop due to a stable path difference between overlapping coherent light waves. The photoelectric effect is governed by the conservation of energy during a single photon-electron collision. Dispersion in a prism arises from wavelength-dependent refraction, and radioactive decay follows half-life intervals.



Alternative (i): Step 1: For bright interference fringes, the path difference must equal an integer multiple of the wavelength, $\Delta = n\lambda$. In a standard YDSE setup, the fringe positions are given by $y_n = n\lambda D/d$. **Step 2:** For the second bright fringe, we set $n = 2$. Substituting the parameters gives $y_2 = 2(500 \times 10^{-9} \text{ m})(2 \text{ m})/(0.8 \times 10^{-3} \text{ m}) = 2.5 \times 10^{-3} \text{ m} = 2.5 \text{ mm}$. **Step 3:** Einstein's photoelectric equation is written as $h\nu = \phi + K_{\text{max}}$. The material work function ϕ represents the minimum energy required to liberate a bound electron from the surface.

Alternative (ii): Step 1: Angular dispersion measures the angular separation between constituent emergent colors. The dispersive power is defined as the ratio of this angular dispersion to the mean deviation. **Step 2:** A glass prism splits composite white light because its refractive index varies inversely with wavelength, causing shorter wavelengths like violet to bend more than longer red wavelengths. **Step 3:** For a half-life of 10 h over a total time of 30 h, the number of half-lives is $n = 3$. The remaining fraction is calculated as $(1/2)^3 = 1/8$.

Final Answer: $y_2 = 2.5 \text{ mm}$, $h\nu = \phi + K_{\text{max}}$; remaining fraction = $1/8$

Answer: (See above)

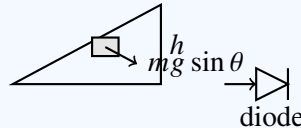
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Q43.

Solution

Concept: The laws of conservation of mechanical energy, the work-energy theorem, cyclic thermodynamic processes, acoustic beats, and semiconductor logic gates represent foundational physics principles. Each part can be addressed by applying its core governing law to a direct system application.



Alternative (i): Step 1: On a smooth inclined plane, total mechanical energy is conserved. Equating the potential energy at the top to the kinetic energy at the base gives $mgh = \frac{1}{2}mv^2$, which simplifies to $v = \sqrt{2gh}$. **Step 2:** For a complete thermodynamic cycle, the net change in internal energy is zero ($\Delta U = 0$). Applying the first law simplifies the energy balance to $Q_{\text{net}} = W_{\text{net}}$. **Step 3:** Acoustic beats are periodic intensity variations resulting from the superposition of two sound waves with slightly different frequencies, which is useful for tuning instruments. **Step 4:** A *p-n* junction diode allows current to flow in only one direction, enabling its use in rectifier circuits.

Alternative (ii): Step 1: The work done by a net force is $W = Fs = mas$. Applying the work-energy theorem gives $mas = \frac{1}{2}m(v^2 - u^2)$, which simplifies to the kinematic formula $v^2 = u^2 + 2as$. **Step 2:** The zeroth law of thermodynamics states that if two separate systems are each in thermal equilibrium with a third system, they must be in thermal equilibrium with each other. **Step 3:** Acoustic resonance occurs when a periodic driving force matches a system's natural frequency, causing large-amplitude oscillations, such as a child's swing pushed in sync with its motion. **Step 4:** A digital NOT gate acts as a logical inverter, producing a high output (1) for a low input (0) and a low output (0) for a high input (1).

Final Answer: $v = \sqrt{2gh}$; $Q_{\text{cycle}} = W_{\text{cycle}}$; beats aid tuning; diode rectifies; NOT gate inverts.

Answer: (See above)

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Answer Key

Q	Ans	Q	Ans	Q	Ans	Q	Ans	Q	Ans
1	B	2	C	3	D	4	A	5	B
6	C	7	C	8	B	9	A	10	C
11	B	12	C	13	D	14	C	15	C
16	B								

