NIOS Class 12 Physics Sample Paper-6

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 point charges of $+2\ \mu C$ and $+4\ \mu C$ are placed 3 cm apart in vacuum. What is the electrostatic force between them? (Take $k = 9 \times 10^9$ N m^2 C^{-2}) **(1)**

(A) 40 N

(B) 60 N

(C) 80 N

(D) 100 N

Q2. A body of mass 5 kg is acted upon by a net force of 20 N. What is the acceleration produced in the body? **(1)**

(A) 2 m s^{-2}

(B) 4 m s^{-2}

(C) 5 m s^{-2}

(D) 10 m s^{-2}

Q3. White light splits into its constituent colours after passing through a glass prism. This phenomenon is called: **(1)**

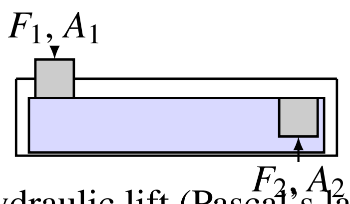
(A) Refraction

(B) Dispersion

(C) Diffraction

(D) Polarisation

Q4. A hydraulic lift has a small piston of area 5 cm^2 and a large piston of area 500 cm^2. What force must be applied on the small piston to support a load of 20000 N placed on the large piston? **(1)**



Hydraulic lift (Pascal's law)

(A) 100 N

(B) 200 N

(C) 400 N

(D) 2000 N

Q5. The electric potential at a distance of 9 cm from a point charge of 3 μC is: (Take $k = 9 \times 10^9$ N m^2 C^{-2}) **(1)**

(A) 3×10^4 V

(B) 3×10^5 V

(C) 3×10^6 V

(D) 3×10^3 V

Q6. According to Bohr's model of the hydrogen atom, the radius of the nth orbit is proportional to: **(1)**

(A) n

(B) n^2

(C) $1/n$

(D) $1/n^2$

Q7. A machine does 6000 J of work in 30 s. Calculate its power output. **(1)**

(A) 100 W

(B) 150 W

(C) 200 W

(D) 300 W

Q8. In an isothermal process carried out on an ideal gas, the internal energy of the gas: **(1)**

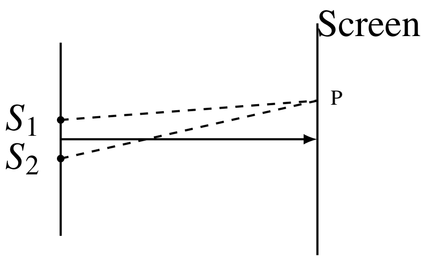
(A) Increases

(B) Decreases

(C) Remains constant

(D) First increases then decreases

Q9. In Young's double slit experiment, the fringe width is found to be 0.4 mm. If the distance between the two slits is doubled, keeping all other factors unchanged, the new fringe width will be: **(1)**



Young's double slit arrangement

(A) 0.2 mm

(B) 0.4 mm

(C) 0.8 mm

(D) 1.6 mm

Q10. In an n-type semiconductor, the majority charge carriers are: **(1)**

(A) Holes

(B) Electrons

(C) Both holes and electrons in equal number

(D) Neither holes nor electrons

Q11. A wire of resistance 10 Ω is stretched uniformly so that its length becomes double, while its volume remains unchanged. Its new resistance becomes: **(1)**

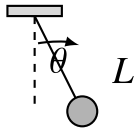
(A) 5 Ω

(B) 10 Ω

(C) 20 Ω

(D) 40 Ω

Q12. The time period of a simple pendulum of length 1 m on the surface of the Earth ($g = 9.8$ m s^{-2}) is approximately: **(1)**



Simple pendulum

(A) 1 s

(B) 1.5 s

(C) 2 s

(D) 3 s

Q13. A rocket accelerates forward by ejecting exhaust gases backward. This working principle is based on the conservation of: **(1)**

(A) Energy

(B) Mass

(C) Linear momentum

(D) Angular momentum

Q14. The half-life of a radioactive substance is 10 days. What fraction of the original sample remains undecayed after 30 days? **(1)**

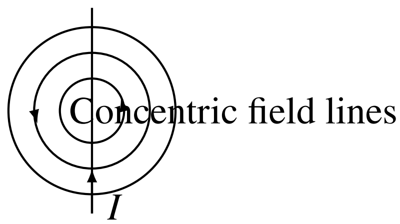
(A) 1/2

(B) 1/4

(C) 1/8

(D) 1/16

Q15. The magnetic field lines around a long straight current-carrying conductor are: **(1)**



(A) Straight lines parallel to the wire

(B) Concentric circles around the wire

(C) Radiating outward from the wire

(D) Randomly oriented near the wire

Q16. The power of a convex lens of focal length 25 cm is: **(1)**

(A) 2 D

(B) 4 D

(C) 5 D

(D) 10 D

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:

A parallel plate capacitor consists of two conducting plates of area A separated by a small distance d, with a dielectric medium of dielectric constant K filling the space between them. When the capacitor is connected to a battery of emf V, the plates acquire equal and opposite charges $Q = CV$, where C is the capacitance. The electric field set up between the plates is uniform and is given by $E = V/d$. Introducing a dielectric medium between the plates reduces the effective electric field for a given free charge and consequently increases the amount of charge the capacitor can store for the same applied voltage. **(2)**

1. Write the formula for the capacitance of a parallel plate capacitor with a dielectric of dielectric constant K between the plates.
2. How does introducing a dielectric medium between the plates affect the capacitance of a parallel plate capacitor?

Q18. Complete the following by using the options given below:
(real, virtual, converging, diverging, erect) **(2)**

1. A concave mirror forms a and inverted image of an object placed beyond its centre of curvature.
2. A convex mirror always forms a , diminished image of the object placed in front of it.

Q19. Read the passage given below and answer the following questions:

Newton's three laws of motion form the foundation of classical mechanics. The first law states that a body continues in its state of rest or of uniform motion in a straight line unless an external unbalanced force acts on it; this law is also known as the law of inertia. The second law relates the net force acting on a body to the rate of change of its linear momentum, and for a body of constant mass this reduces to $F = ma$. The third law states that for every action there is an equal and opposite reaction, and that these two forces always act on two different bodies. **(2)**

1. State Newton's first law of motion and explain what is meant by the term inertia.
2. Two bodies A and B interact through a mutual contact force. If body A exerts a force of 15 N on body B, what force does body B exert on body A, according to Newton's third law of motion?

Q20. Complete the following by using the options given below:
(ground state, excited state, ionisation energy, quantised, continuous) **(2)**

1. The energy of an electron in a hydrogen atom is , meaning that it can take only certain discrete values.
2. The minimum energy required to remove an electron completely from an atom, taking it to infinity, is called its . . . .

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

Column I	Column II
(a) *p*-*n* junction diode	(i) Allows current to flow in one direction only
(b) Zener diode	(ii) Used as a voltage regulator
(c) Light Emitting Diode (LED)	(iii) Converts electrical energy into light energy
(d) Photodiode	(iv) Converts light energy into an electrical signal

Q22. Complete the following by using the options given below:
(Pascal's law, Bernoulli's theorem, Archimedes' principle, viscosity, surface tension) **(2)**

1. The principle that a body immersed partially or wholly in a fluid experiences an upward buoyant force equal to the weight of the fluid it displaces is called .
2. The property of a fluid due to which it opposes the relative motion between its adjacent layers is called . . . .

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

1. The resistance of most metallic conductors increases with an increase in temperature.
2. Kirchhoff's current law at a junction is based on the principle of conservation of energy.

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

Column I	**Column II**
(a) Isothermal process	(i) $\Delta T = 0$
(b) Adiabatic process	(ii) $\Delta Q = 0$
(c) Isochoric process	(iii) $\Delta V = 0$
(d) Isobaric process	(iv) $\Delta P = 0$

Q25. Complete the following by using the options given below:
(amplitude, frequency, time period, wavelength, phase) **(2)**

1. The maximum displacement of a particle from its mean position during simple harmonic motion is called its . . . .
2. The distance travelled by a progressive wave in one complete time period is called its . . . .

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

Column I	**Column II**
(a) Convex lens	(i) Converging
(b) Concave lens	(ii) Diverging
(c) Concave mirror	(iii) Converging
(d) Convex mirror	(iv) Diverging

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

1. The work done by the centripetal force on a body moving with uniform speed along a circular path is always zero.
2. Kinetic energy is a vector quantity because velocity is a vector quantity.

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

Column I	**Column II**
(a) Faraday's law of induction	(i) $\varepsilon = -\frac{d\Phi_B}{dt}$
(b) Lenz's law	(ii) Induced current opposes the change in flux
(c) Ampere's circuital law	(iii) Relates magnetic field to enclosed current
(d) Fleming's right-hand rule	(iv) Gives direction of induced current in a moving conductor

Section: B

Q29. State the law of conservation of linear momentum. A gun of mass 4 kg fires a bullet of mass 20 g with a velocity of 300 m s^{-1}. Calculate the recoil velocity of the gun. **(2)**

Q30. State the lens maker's formula for a thin convex lens and use it to find the focal length of a convex lens made of glass of refractive index 1.5, whose surfaces have radii of curvature 20 cm and −20 cm. **(2)**

Q31. (i) Calculate the amount of heat required to raise the temperature of 2 kg of water from 20°C to 80°C. (Specific heat of water = 4200 J kg^{-1} $°C^{-1}$)

OR

(ii) State the first law of thermodynamics. A gas absorbs 500 J of heat and does 200 J of work on its surroundings. Calculate the change in its internal energy. **(2)**

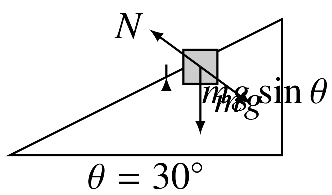
Q32. (i) State Ohm's law. Three resistors of 2 Ω, 3 Ω and 5 Ω are connected in series across a 20 V battery. Calculate the current flowing through the circuit.

OR

(ii) Define electric flux and state Gauss's law for electrostatics. **(2)**

Q33. A block of wood of density 600 kg m^{-3} floats in water of density 1000 kg m^{-3}. If the total volume of the block is 0.05 m^3, calculate the volume of the block that remains submerged in water. **(2)**

Q34. A block of mass 10 kg is placed on a frictionless inclined plane making an angle of 30° with the horizontal. Draw the free body diagram of the block and calculate its acceleration down the incline. (Take $g = 10$ m s^{-2}) **(2)**



Q35. (i) Distinguish between an intrinsic semiconductor and an extrinsic semiconductor.

OR

(ii) Draw the circuit symbol of a p-n junction diode and state one application each of forward biasing and reverse biasing. **(2)**

Q36. Write the equation of a progressive wave travelling along the positive x-direction having amplitude 0.02 m, frequency 50 Hz and wavelength 2 m. Also calculate the speed of the wave. **(2)**

Q37. State the law of radioactive decay. A radioactive sample has a decay constant of 0.0231 per year. Calculate its half-life. **(2)**

Q38. Define the following terms with one example/formula each:
A. Specific heat capacity
B. Latent heat
C. Efficiency of a Carnot engine **(3)**

Q39. (i) A convex lens of focal length 15 cm forms an image of an object placed 30 cm in front of it. Using the lens formula, calculate the image distance and the magnification produced.

OR

(ii) Explain the phenomenon of total internal reflection, stating the necessary conditions. Calculate the critical angle for a glass-air interface if the refractive index of glass is 1.5. **(3)**

Q40. State Bernoulli's theorem and write its mathematical expression for a fluid in streamline flow. Explain briefly, using this theorem, why the velocity of a fluid increases at the narrower section of a horizontal pipe. **(3)**

Q41. (i) Derive an expression for the equivalent resistance of three resistors R_1, R_2 and R_3 connected in series, and use it to calculate the equivalent resistance for $R_1 = 4\ \Omega$, $R_2 = 6\ \Omega$, $R_3 = 10\ \Omega$.

OR

(ii) Explain the working principle of a simple AC generator with the help of a labelled diagram, and write the expression for the instantaneous emf induced.
(3)

Q42. (i) (a) State and prove the work-energy theorem for a body moving under a constant force.
(b) A car of mass 1000 kg moving with a velocity of 20 m s^{-1} is brought to rest by applying brakes over a distance of 50 m. Calculate the average braking force.
(c) State the law of conservation of mechanical energy.

OR

(ii) (a) Derive an expression for the kinetic energy of a body of mass m moving with velocity v, using the work-energy theorem.
(b) A ball of mass 0.5 kg is dropped from a height of 20 m. Calculate its kinetic energy just before it hits the ground, neglecting air resistance. (Take $g = 10$ m s^{-2})
(c) State the law of conservation of energy. **(5)**

Q43. (i) (a) Draw the circuit diagram of a half-wave rectifier using a p-n junction diode and explain its working.
(b) State one advantage of a full-wave rectifier over a half-wave rectifier.
(c) Define ripple factor.

OR

(ii) (a) Explain the basic elements of a communication system with the help of a block diagram (transmitter, channel, receiver).

(b) Distinguish between amplitude modulation and frequency modulation.

(c) State one application of satellite communication. **(5)**

Detailed Solutions

Q1.

Solution

Concept: Coulomb's law describes the electrostatic force of attraction or repulsion between two stationary point charges. It states that the force is directly proportional to the product of the two charges and inversely proportional to the square of the distance separating them. Mathematically, this is written as $F = \frac{kq_1q_2}{r^2}$, where k is the electrostatic constant (9×10^9 N m^2 C^{-2} in vacuum), q_1 and q_2 are the magnitudes of the charges, and r is the separation between them. Care must always be taken to convert all given quantities into SI units before substitution.

Step 1 — Convert the given quantities into SI units. The charges are $q_1 = 2\ \mu\text{C} = 2 \times 10^{-6}$ C and $q_2 = 4\ \mu\text{C} = 4 \times 10^{-6}$ C, and the separation is $r = 3$ cm $= 0.03$ m.
Step 2 — Substitute the values into Coulomb's law:

$$F = \frac{(9 \times 10^9)(2 \times 10^{-6})(4 \times 10^{-6})}{(0.03)^2} = \frac{9 \times 10^9 \times 8 \times 10^{-12}}{9 \times 10^{-4}} = \frac{0.072}{9 \times 10^{-4}} = 80 \text{ N}$$

Step 3 — Verify against the options. The computed force of 80 N matches option C exactly; the other options would correspond to an incorrect placement of the decimal point or an error in squaring the distance.

Final Answer: 80 N (Option C)

Answer: (C)

Go Back to Question 1

Q2.

Solution

Concept: Newton's second law of motion states that the net external force acting on a body is directly proportional to the rate of change of its momentum, and for a body of constant mass this simplifies to $F = ma$, where F is the net force, m is the mass, and a is the acceleration produced. This is one of the most frequently applied relations in mechanics, and rearranging it gives $a = F/m$.

Step 1 — Identify the given quantities: net force $F = 20$ N and mass $m = 5$ kg.
Step 2 — Substitute into the rearranged form of Newton's second law:

$$a = \frac{F}{m} = \frac{20}{5} = 4 \text{ m s}^{-2}$$

Step 3 — Check the result against the options. The value 4 m s^{-2} matches option B.

Final Answer: 4 m s^{-2} (Option B)

Answer: (B)

Go Back to Question 2

Q3.

Solution

Concept: When a beam of white light passes through a triangular glass prism, each constituent colour of light bends by a different amount because the refractive index of glass is slightly different for each wavelength (violet bends the most, red the least). As a result, the emergent beam separates into its constituent colours, forming a coloured band called a spectrum. This splitting of white light into its component colours is a distinct optical phenomenon and should not be confused with refraction, diffraction, or polarisation, which describe different optical behaviours.

Step 1 — Recall the definitions of the four listed phenomena. Refraction is simply the bending of light at an interface between two media; diffraction is the bending of light around obstacles or through narrow openings; polarisation restricts the vibration of light waves to a single plane.
Step 2 — Match the description in the question, "splitting of white light into its constituent colours," with the correct term. This process is specifically termed dispersion, matching option B.

Final Answer: Dispersion (Option B)

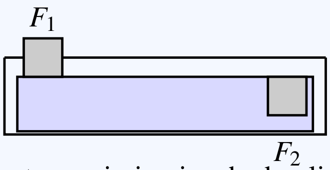
Answer: (B)

Go Back to Question 3

Q4.

Solution

Concept: Pascal's law states that pressure applied at any point in an enclosed, incompressible fluid is transmitted equally and undiminished to every point of the fluid and to the walls of the container. A hydraulic lift uses this principle: a small force applied on a piston of small area creates a pressure that is transmitted through the fluid to a piston of larger area, producing a much larger force on the second piston. Mathematically, since pressure is the same throughout, $P = \frac{F_1}{A_1} = \frac{F_2}{A_2}$.



Force transmission in a hydraulic lift

Step 1 — List the given quantities: small piston area $A_1 = 5\ \text{cm}^2$, large piston area $A_2 = 500\ \text{cm}^2$, and load on the large piston $F_2 = 20000$ N.
Step 2 — Apply Pascal's law in the form $\frac{F_1}{A_1} = \frac{F_2}{A_2}$ and solve for F_1:

$$F_1 = F_2 \times \frac{A_1}{A_2} = 20000 \times \frac{5}{500} = 20000 \times 0.01 = 200\ \text{N}$$

Step 3 — Note that because the areas are used only as a ratio, they need not be converted to m^2; the ratio A_1/A_2 is dimensionless and unaffected by the choice of area unit, as long as both are expressed in the same unit. The computed force of 200 N matches option B.

Final Answer: 200 N (Option B)

Answer: (B)

Go Back to Question 4

Q5.

Solution

Concept: The electric potential due to a point charge q at a distance r from it is defined as the work done per unit positive charge in bringing a small test charge from infinity to that point, and is given by $V = \frac{kq}{r}$, where k is the electrostatic constant. Unlike electric field, potential is a scalar quantity, and its value depends only on the magnitude of the source charge and the distance from it, not on direction.

Step 1 — Convert the given quantities to SI units: $q = 3\ \mu\text{C} = 3 \times 10^{-6}$ C and $r = 9$ cm $= 0.09$ m.
Step 2 — Substitute into the formula for electric potential:

$$V = \frac{kq}{r} = \frac{(9 \times 10^9)(3 \times 10^{-6})}{0.09} = \frac{2.7 \times 10^4}{9 \times 10^{-2}} = 3 \times 10^5 \text{ V}$$

Step 3 — Verify the power of ten carefully, since this is a common source of error in such calculations. The computed potential of 3×10^5 V matches option B.

Final Answer: 3×10^5 V (Option B)

Answer: (B)
Go Back to Question 5

Q6.

Solution

Concept: Bohr's model of the hydrogen atom assumes that electrons revolve around the nucleus only in certain allowed circular orbits, in which the angular momentum of the electron is quantised as $mvr = \frac{nh}{2\pi}$, where n is a positive integer called the principal quantum number. Combining this quantisation condition with the requirement that the electrostatic force of attraction provides the necessary centripetal force leads to an expression for the radius of the nth orbit, which is found to depend on n in a specific way.

Step 1 — Recall the standard result derived from Bohr's postulates for the radius of the nth orbit of the hydrogen atom:

$$r_n = \frac{n^2 h^2 \varepsilon_0}{\pi m e^2}$$

where h, ε_0, m, and e are all constants for a given atom.
Step 2 — Observe that, apart from the constants, r_n depends only on n^2. This means that as the principal quantum number increases, the orbit radius grows in proportion to the square of n, not n itself.
Step 3 — Match this dependence with the given options. The correct proportionality $r_n \propto n^2$ corresponds to option B.

Final Answer: n^2 (Option B)

Answer: (B)
Go Back to Question 6

Q7.

Solution

Concept: Power is defined as the rate at which work is done, or equivalently, the rate at which energy is transferred or converted from one form to another. It is mathematically expressed as $P = \frac{W}{t}$, where W is the work done and t is the time taken to do that work. The SI unit of power is the watt (W), where 1 W = 1 J s^{-1}.

Step 1 — Identify the given quantities: work done $W = 6000$ J and time taken $t = 30$ s.
Step 2 — Substitute these values into the power formula:

$$P = \frac{W}{t} = \frac{6000}{30} = 200 \text{ W}$$

Step 3 — Compare with the given options. The computed power of 200 W matches option C.

Final Answer: 200 W (Option C)

Answer: (C)

Go Back to Question 7

Q8.

Solution

Concept: According to the first law of thermodynamics, the internal energy of an ideal gas depends only on its absolute temperature and is independent of its pressure or volume. In an isothermal process, the temperature of the gas is deliberately kept constant throughout the process by allowing heat to enter or leave the system slowly. Since internal energy is purely a function of temperature for an ideal gas, if the temperature does not change, the internal energy also cannot change.

Step 1 — Recall that for an ideal gas, internal energy U depends only on temperature T, so that $\Delta U = 0$ whenever $\Delta T = 0$.
Step 2 — Apply this directly to an isothermal process, in which by definition T is constant throughout, so $\Delta T = 0$ and hence $\Delta U = 0$ as well.
Step 3 — Match this conclusion with the given options. Since the internal energy remains unchanged, option C is correct, while options A, B, and D would only apply to non-isothermal processes.

Final Answer: Remains constant (Option C)

Answer: (C)

Go Back to Question 8

Q9.

Solution

Concept: In Young's double slit experiment, two coherent light sources separated by a small distance d produce an interference pattern of alternating bright and dark fringes on a screen placed at a distance D from the slits. The width of each fringe, called the fringe width β, is given by $\beta = \frac{\lambda D}{d}$, where λ is the wavelength of light used. This formula shows that fringe width is directly proportional to the wavelength and the slit-to-screen distance, but inversely proportional to the slit separation d.

Step 1 — Write the fringe width formula and note its dependence on the slit separation: $\beta \propto \frac{1}{d}$, with λ and D held fixed.
Step 2 — Apply this inverse proportionality to the given situation. If the slit separation d is doubled while λ and D remain unchanged, the new fringe width becomes:

$$\beta' = \frac{\beta}{2} = \frac{0.4}{2} = 0.2 \text{ mm}$$

Step 3 — Verify against the options. The computed value of 0.2 mm matches option A; doubling d must halve β, ruling out options C and D, which would incorrectly suggest an increase.

Final Answer: 0.2 mm (Option A)

Answer: (A)

Go Back to Question 9

Q10.

Solution

Concept: When a pure semiconductor such as silicon is doped with a pentavalent impurity (having five valence electrons, such as phosphorus or arsenic), four of the five valence electrons form covalent bonds with the neighbouring silicon atoms, while the fifth electron remains loosely bound and becomes free to conduct electricity at ordinary temperatures. Such doping creates an n-type semiconductor, in which the impurity atoms are called donor atoms because they donate free electrons.

Step 1 — Recall that in an n-type semiconductor, the doping process contributes a very large number of free electrons compared to the small number of holes created thermally in the intrinsic material.
Step 2 — Compare the number of electrons and holes present in such a material. Since electrons vastly outnumber holes, electrons are termed the majority charge carriers, while holes are the minority charge carriers.
Step 3 — Match this conclusion with the options given. This confirms that option B is correct.

Final Answer: Electrons (Option B)

Answer: (B)

Go Back to Question 10

Q11.

Solution

Concept: The resistance of a conductor of length L, cross-sectional area A, and resistivity ρ is given by $R = \frac{\rho L}{A}$. When a wire is stretched, its volume $V = AL$ remains constant (since no material is added or removed), so if the length increases, the cross-sectional area must decrease proportionately. Using this constraint, it is possible to express the new resistance purely in terms of the change in length.

Step 1 — Let the original length be L and the original area be A, so that $R = \frac{\rho L}{A} = 10\ \Omega$. Since the wire is stretched to double its length, the new length is $L' = 2L$.
Step 2 — Apply the constant-volume condition $AL = A'L'$ to find the new area:

$$A' = \frac{AL}{L'} = \frac{AL}{2L} = \frac{A}{2}$$

Step 3 — Substitute the new length and new area into the resistance formula to find the new resistance R':

$$R' = \frac{\rho L'}{A'} = \frac{\rho(2L)}{(A/2)} = 4 \times \frac{\rho L}{A} = 4R = 4 \times 10 = 40\ \Omega$$

Step 4 — Compare with the options. The computed value of 40 Ω matches option D; this result also shows the general rule that resistance is proportional to the square of the length when volume is kept constant.

Final Answer: 40 Ω (Option D)

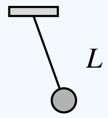
Answer: (D)

Go Back to Question 11

Q12.

Solution

Concept: A simple pendulum consists of a small heavy bob suspended by a light, inextensible string from a rigid support. For small angular displacements, the motion of the bob is simple harmonic, and its time period is given by $T = 2\pi\sqrt{\frac{L}{g}}$, where L is the length of the pendulum and g is the acceleration due to gravity. This formula shows that the time period depends only on the length of the pendulum and the local value of g, and not on the mass of the bob or the amplitude of oscillation (for small angles).



Bob at mean position

Step 1 — Identify the given quantities: length $L = 1$ m and $g = 9.8$ m s^{-2}.

Step 2 — Substitute into the time period formula:

$$T = 2\pi\sqrt{\frac{L}{g}} = 2\pi\sqrt{\frac{1}{9.8}} = 2\pi \times 0.3194 \approx 2.01 \text{ s}$$

Step 3 — Round this value to compare with the given options. The computed time period of approximately 2.0 s matches option C most closely.

Final Answer: 2 s (Option C)

Answer: (C)

Go Back to Question 12

Q13.

Solution

Concept: The law of conservation of linear momentum states that in the absence of an external force, the total linear momentum of an isolated system remains constant. A rocket (or a gun firing a bullet) initially at rest has zero total momentum. When the exhaust gases (or the bullet) are ejected in one direction with some momentum, an equal and opposite momentum must be generated in the remaining body (the rocket or the gun) to keep the total momentum of the system unchanged, in accordance with Newton's third law working together with momentum conservation.

Step 1 — Recognise that the system is initially at rest, so the exhaust gases (or bullet) gain momentum only in one direction, and the rocket (or gun) must gain an equal and opposite momentum to conserve the total momentum of the system.
Step 2 — Compare this description with the options given. The underlying principle is the conservation of linear momentum, matching option C; energy conservation, mass conservation, and angular momentum conservation do not directly explain this forward thrust mechanism.

Final Answer: Linear momentum (Option C)

Answer: (C)
Go Back to Question 13

Q14.

Solution

Concept: Radioactive decay follows an exponential law in which the number of undecayed nuclei decreases continuously with time. A useful way to describe this decay is through the half-life $t_{1/2}$, which is the time taken for exactly half of the radioactive nuclei present at any instant to decay. After every successive half-life, the remaining fraction of the original sample is repeatedly halved, so after n half-lives, the fraction remaining is $\left(\frac{1}{2}\right)^n$.

Step 1 — Determine the number of half-lives that have elapsed. Since the half-life is 10 days and the total elapsed time is 30 days, the number of half-lives is:

$$n = \frac{30}{10} = 3$$

Step 2 — Apply the formula for the fraction of the sample remaining after n half-lives:

$$\text{Fraction remaining} = \left(\frac{1}{2}\right)^n = \left(\frac{1}{2}\right)^3 = \frac{1}{8}$$

Step 3 — Verify against the given options. The computed fraction of $1/8$ matches option C.

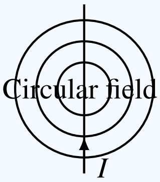
Final Answer: $1/8$ (Option C)

Answer: (C)
Go Back to Question 14

Q15.

Solution

Concept: According to Oersted's discovery, a current-carrying conductor produces a magnetic field around it. For a long straight wire, the direction of this magnetic field at any point can be found using the right-hand thumb rule: if the thumb points in the direction of the current, the curled fingers indicate the direction of the magnetic field lines. Because of the cylindrical symmetry of a straight wire, the field lines form closed loops that are perfectly circular and centred on the wire, lying in planes perpendicular to it.



Circular field lines around the wire

Step 1 — Recall the geometry of the magnetic field around a long straight current-carrying wire: since the wire has cylindrical symmetry, the magnitude of the field is the same at every point equidistant from the wire.
Step 2 — Apply the right-hand thumb rule to determine the shape and orientation of the field lines. This shows that the field lines form concentric circles lying in a plane perpendicular to the wire, centred on the wire itself.
Step 3 — Compare this description with the options given. The field lines being concentric circles around the wire matches option B; they are neither straight nor radiating outward like electric field lines of a point charge.

Final Answer: Concentric circles around the wire (Option B)

Answer: (B)

Go Back to Question 15

Q16.

Solution

Concept: The power of a lens is a measure of its ability to converge or diverge a beam of light, and is defined as the reciprocal of its focal length when the focal length is expressed in metres: $P = \frac{1}{f\,(\text{in metres})}$. The SI unit of power of a lens is the dioptre (D). A converging (convex) lens has a positive power, while a diverging (concave) lens has a negative power.

Step 1 — Convert the given focal length into metres: $f = 25$ cm $= 0.25$ m.
Step 2 — Substitute into the power formula:

$$P = \frac{1}{f} = \frac{1}{0.25} = 4\text{ D}$$

Step 3 — Compare with the options. The computed power of 4 D matches option B; since the lens is convex (converging), the power is correctly positive.

Final Answer: 4 D (Option B)

Answer: (B)

Go Back to Question 16

Q17.

Solution

Concept: A parallel plate capacitor's capacitance depends on the geometry of the plates and the medium between them. With vacuum (or air) between the plates, the capacitance is $C_0 = \frac{\varepsilon_0 A}{d}$. Filling the gap with a dielectric medium of dielectric constant K reduces the net electric field for the same free charge, since the dielectric becomes polarised and produces an opposing induced field. This allows the capacitor to store more charge for the same potential difference, thereby increasing its capacitance by a factor of K.

Step 1 — Write the capacitance of a parallel plate capacitor with a dielectric of dielectric constant K completely filling the gap between the plates:

$$C = \frac{K\varepsilon_0 A}{d}$$

Step 2 — Explain the effect of the dielectric. Since $K > 1$ for all dielectric materials, introducing a dielectric always increases the capacitance compared to the vacuum value $C_0 = \varepsilon_0 A/d$, by a factor equal to the dielectric constant K.

Final Answer: (i) $C = K\varepsilon_0 A/d$. (ii) The capacitance increases by a factor of K when a dielectric is introduced.

Answer: (See above)

Go Back to Question 17

Q18.

Solution

Concept: Spherical mirrors form images whose nature (real or virtual) depends on the position of the object relative to the pole, focus, and centre of curvature. A concave mirror is a converging mirror that can form both real and virtual images depending on object position, while a convex mirror is a diverging mirror that always forms a virtual, erect, and diminished image regardless of where the object is placed, because the reflected rays always appear to diverge from a point behind the mirror.

Step 1 — Analyse the image formed by a concave mirror when the object lies beyond the centre of curvature. In this case the reflected rays actually converge in front of the mirror, forming a real, inverted, and diminished image between the focus and the centre of curvature.
Step 2 — Analyse the image formed by a convex mirror. Since a convex mirror always diverges the incident rays further, the reflected rays never actually meet in front of the mirror; they only appear to meet behind it, producing a virtual, erect, and diminished image for any object position.

Final Answer: (i) real (ii) virtual

Answer: (See above)

Go Back to Question 18

Q19.

Solution

Concept: Newton's first law of motion, also called the law of inertia, states that every body continues in its state of rest or of uniform motion in a straight line unless it is acted upon by an unbalanced external force. Inertia is the inherent property of a body by virtue of which it resists any change in its state of rest or of uniform motion; the mass of a body is a direct quantitative measure of its inertia. Newton's third law states that whenever one body exerts a force on a second body, the second body simultaneously exerts a force of equal magnitude but opposite direction on the first body, and these two forces always act on different bodies.

Step 1 — State Newton's first law precisely: a body remains at rest or continues moving with constant velocity in a straight line unless a net external force acts on it. Inertia is the tendency of the body to oppose any change in this state, and it depends directly on the mass of the body — greater the mass, greater the inertia.
Step 2 — Apply Newton's third law to the given interaction. If body A exerts a force of 15 N on body B, then body B must exert an equal and oppositely directed force of 15 N on body A (i.e., the reaction force is 15 N, directed opposite to the force exerted by A on B).

Final Answer: (i) A body remains at rest or in uniform motion unless acted upon by a net force; inertia is the resistance to a change in this state, proportional to mass. (ii) 15 N, in the opposite direction.

Answer: (See above)

Go Back to Question 19

Q20.

Solution

Concept: In Bohr's model of the atom, an electron bound to the nucleus can occupy only certain fixed, discrete energy levels rather than any arbitrary value of energy; such a restricted set of allowed values is said to be quantised. When an electron occupies the lowest available energy level, the atom is said to be in its ground state; if it occupies any higher energy level, the atom is in an excited state. The ionisation energy is the specific minimum energy that must be supplied to completely free an electron from the atom, taking it from its ground state to just outside the atom (effectively to infinity, where the electron experiences no further attraction).

Step 1 — Recognise that the electron in a hydrogen atom cannot possess any arbitrary energy value; it is restricted to a discrete set of allowed energies corresponding to $n = 1, 2, 3, \ldots$, so its energy is quantised.
Step 2 — Identify the term for the energy needed to completely remove the electron from the atom. This minimum energy is called the ionisation energy of the atom.

Final Answer: (i) quantised (ii) ionisation energy

Answer: (See above)
Go Back to Question 20

Q21.

Solution

Concept: Semiconductor devices are built using the special electrical properties of a *p*-*n* junction, which conducts current more easily in one direction than the other. Depending on the exact construction and the type of biasing used, junction diodes can perform different specialised functions: simple rectification, voltage regulation using controlled reverse breakdown, light emission, or light detection. Recognising the defining characteristic of each device is essential to correctly match its function.

Step 1 — Analyse the ordinary *p*-*n* junction diode. Because of the depletion region formed at the junction, it conducts significant current only when forward biased and blocks current when reverse biased, so it allows current to flow in essentially one direction only; this matches item (i).
Step 2 — Analyse the remaining three devices. A Zener diode is specially designed to operate in reverse breakdown at a fixed voltage and is used to maintain a constant output voltage, so it acts as a voltage regulator, matching item (ii). An LED emits visible (or infrared) light when forward biased due to recombination of electrons and holes at the junction, matching item (iii). A photodiode, in contrast, is operated in reverse bias and generates a current proportional to the intensity of light falling on it, converting light into an electrical signal, matching item (iv).

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

Answer: (See above)
Go Back to Question 21

Q22.

Solution

Concept: Fluids exhibit several distinct physical properties governed by different principles. Archimedes' principle deals with the upward buoyant force experienced by a body immersed in a fluid, stating that this force equals the weight of the fluid displaced by the immersed part of the body. Viscosity, on the other hand, is a property related to internal friction within a fluid: it measures the resistance offered by a fluid to relative motion between its adjacent layers, and is responsible for the gradual damping of fluid flow.

Step 1 — Identify the principle describing buoyant force. The statement that an immersed body experiences an upward force equal to the weight of the fluid it displaces is precisely Archimedes' principle.

Step 2 — Identify the property describing internal fluid friction. The property responsible for a fluid opposing relative motion between its layers, analogous to friction between solid surfaces, is called viscosity.

Final Answer: (i) Archimedes' principle (ii) viscosity

Answer: (See above)

Go Back to Question 22

Q23.

Solution

Concept: The resistance of a metallic conductor arises due to collisions between free electrons and the vibrating positive ions of the metal lattice. As temperature rises, the lattice ions vibrate more vigorously, increasing the frequency of collisions and hence the resistance. Kirchhoff's current law (junction rule), on the other hand, is a direct statement of the conservation of electric charge at a junction, not of energy; it states that the algebraic sum of currents entering and leaving any junction in an electrical circuit is zero because charge cannot accumulate at a junction.

Step 1 — Evaluate the first statement. Since increased temperature raises the frequency of electron collisions with lattice ions, the resistance of most metallic conductors indeed increases with rising temperature. Statement 1 is therefore true.

Step 2 — Evaluate the second statement. Kirchhoff's current law is based on the conservation of electric charge at a junction (it is Kirchhoff's voltage law that is based on the conservation of energy). Since the statement incorrectly attributes the current law to energy conservation, Statement 2 is false.

Final Answer: T; F

Answer: (See above)

Go Back to Question 23

Q24.

Solution

Concept: Thermodynamic processes are classified according to which state variable is deliberately held constant during the process. An isothermal process keeps temperature constant, so $\Delta T = 0$; an adiabatic process is one in which no heat is exchanged with the surroundings, so $\Delta Q = 0$; an isochoric (constant-volume) process keeps volume fixed, so $\Delta V = 0$; and an isobaric (constant-pressure) process keeps pressure fixed, so $\Delta P = 0$. Recognising which quantity remains unchanged is the key to identifying each process correctly.

Step 1 — Match the isothermal process, in which temperature is held fixed by allowing slow heat exchange, with the condition $\Delta T = 0$, corresponding to item (i).
Step 2 — Match the adiabatic process, which occurs rapidly enough (or in a perfectly insulated system) that no heat enters or leaves, with the condition $\Delta Q = 0$, corresponding to item (ii).
Step 3 — Match the remaining two processes: an isochoric process occurs in a rigid, fixed-volume container, so $\Delta V = 0$ (item iii); an isobaric process occurs under constant external pressure, so $\Delta P = 0$ (item iv).

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

Answer: (See above)

Go Back to Question 24

Q25.

Solution

Concept: Simple harmonic motion and wave motion are described using a common set of characteristic quantities. The amplitude of an oscillation is the maximum magnitude of displacement of the oscillating particle from its equilibrium (mean) position. For a progressive wave, the wavelength is the distance between two consecutive points that are in the same phase of oscillation (such as two successive crests), and it is also equal to the distance the wave travels in exactly one time period, since the wave pattern repeats itself after this distance.

Step 1 — Identify the term for the maximum displacement from the mean position in SHM. This maximum displacement is, by definition, the amplitude of the motion.
Step 2 — Identify the term for the distance travelled by a wave in one complete time period. Since the wave advances by exactly one repeating pattern in a time equal to one time period, this distance is the wavelength.

Final Answer: (i) amplitude (ii) wavelength

Answer: (See above)

Go Back to Question 25

Q26.

Solution

Concept: Optical elements are broadly classified as converging or diverging based on how they alter the path of an incident parallel beam of light. A convex lens and a concave mirror both act as converging elements, bringing parallel rays of light together at a real focus. A concave lens and a convex mirror both act as diverging elements, spreading parallel rays apart so that they appear to originate from a virtual focus behind the element.

Step 1 — Classify the two lenses. A convex lens is thicker at the centre than at the edges and converges an incident parallel beam to a real focal point, so it is converging (item i). A concave lens is thinner at the centre and diverges an incident parallel beam, so it is diverging (item ii).
Step 2 — Classify the two mirrors. A concave mirror, being a converging mirror, reflects parallel rays to a real focus in front of it (item iii). A convex mirror, being a diverging mirror, reflects parallel rays such that they appear to diverge from a virtual focus behind it (item iv).

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

Answer: (See above)

Go Back to Question 26

Q27.

Solution

Concept: Work done by a force is defined as the product of the force and the displacement of the point of application in the direction of the force, or more precisely, $W = \vec{F} \cdot \vec{d} = Fd\cos\theta$. For a body moving in a circle at uniform speed, the centripetal force is always directed radially inward, that is, perpendicular to the instantaneous velocity (and hence to the displacement) of the body at every instant. Kinetic energy, by contrast, is defined as $\frac{1}{2}mv^2$, and since it depends only on the square of the speed (a scalar), it does not carry any directional information and is therefore a scalar quantity, not a vector.

Step 1 — Evaluate the first statement. Since the centripetal force is always perpendicular to the velocity (and displacement) of the body in uniform circular motion, $\theta = 90^\circ$ and $\cos 90^\circ = 0$, so the work done by this force is indeed always zero. Statement 1 is true.
Step 2 — Evaluate the second statement. Kinetic energy $\frac{1}{2}mv^2$ involves only the square of the magnitude of velocity and has no associated direction, so it is a scalar quantity, not a vector quantity. Statement 2 is false.

Final Answer: T; F

Answer: (See above)

Go Back to Question 27

Q28.

Solution

Concept: Electromagnetic induction and magnetostatics are governed by a set of interlinked laws. Faraday's law of electromagnetic induction quantifies the induced emf produced by a changing magnetic flux, while Lenz's law provides the direction of the induced current by invoking energy conservation. Ampere's circuital law relates a steady magnetic field to the current that produces it, and Fleming's right-hand rule gives a convenient way to find the direction of induced current in a straight conductor moving through a magnetic field.

Step 1 — Match Faraday's law with its mathematical form. It states that the induced emf equals the negative rate of change of magnetic flux linked with the circuit, $\varepsilon = -\frac{d\Phi_B}{dt}$, matching item (i).
Step 2 — Match Lenz's law with its physical statement. It specifies that the direction of the induced current is always such as to oppose the very change in flux that produces it, matching item (ii).
Step 3 — Match the remaining two laws. Ampere's circuital law relates the line integral of the magnetic field around a closed loop to the current enclosed by that loop, matching item (iii). Fleming's right-hand rule gives the direction of the induced current in a conductor moving through a magnetic field, matching item (iv).

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

Answer: (See above)

Go Back to Question 28

Q29.

Solution

Concept: The law of conservation of linear momentum states that if no external force acts on a system, the total linear momentum of the system remains constant, both in magnitude and direction. For a gun-bullet system initially at rest, the total momentum before firing is zero. When the bullet is fired forward with some momentum, the gun must recoil backward with an equal and opposite momentum so that the total momentum of the system remains zero after firing, exactly as before.

Step 1 — State the law of conservation of momentum: the total momentum of an isolated system remains constant in the absence of an external force, that is, $m_1v_1 + m_2v_2 = \text{constant}$.

Step 2 — Set up the momentum equation for the gun-bullet system. Before firing, both the gun (mass $M = 4$ kg) and the bullet (mass $m = 20$ g $= 0.02$ kg) are at rest, so the total initial momentum is zero. After firing, the bullet moves forward with velocity $v = 300$ m s^{-1} and the gun recoils with velocity V (taken as negative, i.e., in the opposite direction):

$$0 = MV + mv \implies MV = -mv$$

Step 3 — Solve for the recoil velocity V:

$$V = -\frac{mv}{M} = -\frac{0.02 \times 300}{4} = -\frac{6}{4} = -1.5 \text{ m s}^{-1}$$

The negative sign indicates that the gun recoils in the direction opposite to that of the bullet.

Final Answer: Recoil velocity of the gun = 1.5 m s^{-1}, directed opposite to the bullet.

$\boxed{1.5 \text{ m s}^{-1}}$

Answer: (See above)

Go Back to Question 29

Q30.

Solution

Concept: The lens maker's formula relates the focal length of a thin lens to the refractive index of its material and the radii of curvature of its two surfaces. For a thin lens of refractive index n placed in air, with radii of curvature R_1 and R_2 (measured according to the standard sign convention), the formula is:

$$\frac{1}{f} = (n-1)\left(\frac{1}{R_1} - \frac{1}{R_2}\right)$$

For a convex lens, the first surface is convex towards the incident light (so R_1 is positive) and the second surface is concave towards the incident light (so R_2 is negative), which together make the lens converging.

Step 1 — Identify the given values: refractive index $n = 1.5$, $R_1 = +20$ cm, and $R_2 = -20$ cm (using the Cartesian sign convention with light travelling from left to right).

Step 2 — Substitute these values into the lens maker's formula:

$$\frac{1}{f} = (1.5-1)\left(\frac{1}{20} - \frac{1}{-20}\right) = 0.5\left(\frac{1}{20} + \frac{1}{20}\right) = 0.5 \times \frac{2}{20} = 0.5 \times 0.1 = 0.05\ \text{cm}^{-1}$$

Step 3 — Take the reciprocal to find the focal length:

$$f = \frac{1}{0.05} = 20\ \text{cm}$$

Final Answer: $f = 20$ cm (a converging/convex lens, as expected, since the result is positive)

$\boxed{f = 20\ \text{cm}}$

Answer: (See above)

Go Back to Question 30

Q31.

Solution

Concept: The heat required to change the temperature of a substance without changing its state is given by $Q = mc\Delta T$, where m is the mass, c is the specific heat capacity of the substance, and ΔT is the change in temperature. The first law of thermodynamics is a statement of the conservation of energy applied to thermodynamic systems, and states that the heat supplied to a system equals the sum of the increase in its internal energy and the work done by the system on its surroundings: $Q = \Delta U + W$.

Alternative (i): Identify the given quantities: mass of water $m = 2$ kg, specific heat of water $c = 4200$ J kg^{-1} °C^{-1}, and temperature change $\Delta T = 80 - 20 = 60$°C. Substituting into the heat formula:

$$Q = mc\Delta T = 2 \times 4200 \times 60 = 504000 \text{ J} = 5.04 \times 10^5 \text{ J}$$

Alternative (ii): State the first law of thermodynamics: $Q = \Delta U + W$, where Q is the heat supplied to the system, ΔU is the change in internal energy, and W is the work done by the system. Given $Q = 500$ J and $W = 200$ J (work done by the gas on the surroundings), rearrange to find ΔU:

$$\Delta U = Q - W = 500 - 200 = 300 \text{ J}$$

Final Answer: (i) $Q = 5.04 \times 10^5$ J. (ii) $\Delta U = 300$ J.

Answer: (See above)

Go Back to Question 31

Q32.

Solution

Concept: Ohm's law states that, at constant temperature, the current flowing through a conductor is directly proportional to the potential difference applied across its ends, so that $V = IR$, where R is the resistance of the conductor. When several resistors are joined end to end (in series), the same current flows through each one, and the total resistance of the combination is simply the sum of the individual resistances: $R_{eq} = R_1 + R_2 + R_3$. Electric flux, on the other hand, is a measure of the total number of electric field lines passing through a given surface, and Gauss's law relates this flux to the charge enclosed by the surface.

Alternative (i): State Ohm's law: $V = IR$, provided physical conditions such as temperature remain constant. For three resistors in series, the equivalent resistance is:

$$R_{eq} = R_1 + R_2 + R_3 = 2 + 3 + 5 = 10\,\Omega$$

Using Ohm's law with the applied voltage $V = 20$ V, the current through the circuit is:

$$I = \frac{V}{R_{eq}} = \frac{20}{10} = 2\text{ A}$$

Alternative (ii): Define electric flux as the total number of electric field lines passing normally through a given area, mathematically $\Phi_E = \vec{E} \cdot \vec{A}$ for a uniform field. Gauss's law states that the total electric flux through any closed surface is equal to $\frac{1}{\varepsilon_0}$ times the net charge q enclosed by that surface: $\Phi_E = \frac{q}{\varepsilon_0}$.

Final Answer: (i) $I = 2$ A. (ii) $\Phi_E = q/\varepsilon_0$ (Gauss's law).

Answer: (See above)

Go Back to Question 32

Q33.

Solution

Concept: When a solid body floats in equilibrium on the surface of a liquid, the upward buoyant force acting on the submerged part of the body exactly balances the total weight of the body (the law of floatation). By Archimedes' principle, the buoyant force equals the weight of the liquid displaced by the submerged volume of the body. Equating the weight of the body to the weight of the displaced liquid gives a simple relation between the densities of the body and the liquid and the fraction of the body that is submerged.

Step 1 — Apply the law of floatation: the weight of the block equals the weight of the water displaced by its submerged part.

$$\rho_{\text{block}}\, V_{\text{block}}\, g = \rho_{\text{water}}\, V_{\text{sub}}\, g$$

Step 2 — Cancel g from both sides and solve for the submerged volume V_{sub}:

$$V_{\text{sub}} = V_{\text{block}} \times \frac{\rho_{\text{block}}}{\rho_{\text{water}}} = 0.05 \times \frac{600}{1000} = 0.05 \times 0.6 = 0.03 \text{ m}^3$$

Step 3 — Check that the answer is physically reasonable: since the block is less dense than water, only a fraction (here, 60%) of its volume should be submerged, and 0.03 m^3 is indeed 60% of 0.05 m^3, confirming the result.

Final Answer: $V_{\text{sub}} = 0.03 \text{ m}^3$

$\boxed{0.03 \text{ m}^3}$

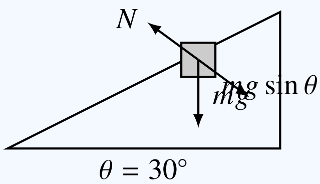
Answer: (See above)

Go Back to Question 33

Q34.

Solution

Concept: When a block rests on a frictionless inclined plane, only two forces act on it: its weight mg, acting vertically downward, and the normal reaction N, acting perpendicular to the inclined surface. It is convenient to resolve the weight into two mutually perpendicular components: one along the incline, $mg \sin\theta$, which causes the block to slide down, and one perpendicular to the incline, $mg \cos\theta$, which is balanced exactly by the normal reaction N (since there is no acceleration perpendicular to the incline).



Free body diagram of the block

Step 1 — Resolve the weight of the block along and perpendicular to the incline. The component along the incline, which is the net unbalanced force (since the surface is frictionless and N balances only the perpendicular component), is $mg \sin\theta$.

Step 2 — Apply Newton's second law along the incline. Since the net force along the incline is $mg \sin\theta$ and this is the only unbalanced force, the acceleration of the block down the incline is:

$$a = \frac{mg \sin\theta}{m} = g \sin\theta$$

Step 3 — Substitute the given values $g = 10\ \text{m s}^{-2}$ and $\theta = 30°$ (so $\sin 30° = 0.5$):

$$a = 10 \times 0.5 = 5\ \text{m s}^{-2}$$

Notice that the mass of the block cancels out entirely, confirming that on a frictionless incline all objects, regardless of mass, slide down with the same acceleration for a given angle.

Final Answer: $a = 5\ \text{m s}^{-2}$, directed down the incline.

$\boxed{5\ \text{m s}^{-2}}$

Answer: (See above)

Go Back to Question 34

Q35.

Solution

Concept: An intrinsic semiconductor is a pure semiconducting material (such as pure silicon or germanium) in which conduction takes place due to thermally generated electron-hole pairs, and the number of free electrons always equals the number of holes. An extrinsic semiconductor is formed by deliberately adding a small, controlled amount of impurity atoms (doping) to an intrinsic semiconductor, which drastically increases either the electron concentration (n-type, using pentavalent dopants) or the hole concentration (p-type, using trivalent dopants), making the material's conductivity far higher and easily controllable.

Alternative (i): Distinguish the two: an intrinsic semiconductor is undoped and has equal numbers of electrons and holes, with relatively low and strongly temperature-dependent conductivity, whereas an extrinsic semiconductor is doped with a specific impurity, has unequal numbers of majority and minority carriers, and possesses a much higher, more controllable conductivity at room temperature.

Alternative (ii): The circuit symbol of a p-n junction diode consists of a triangle (representing the p-side, the anode) pointing towards a bar (representing the n-side, the cathode), with the arrow indicating the conventional direction of current flow when forward biased. Forward biasing is used in rectifier circuits to allow current to pass and convert AC to DC, while reverse biasing (particularly using a Zener diode) is used in voltage regulator circuits to maintain a constant output voltage.

Final Answer: (i) Intrinsic: pure, equal electrons and holes; Extrinsic: doped, majority/minority carrier imbalance, higher conductivity. (ii) Forward bias – rectification; Reverse bias (Zener) – voltage regulation.

Answer: (See above)

Go Back to Question 35

Q36.

Solution

Concept: A progressive (travelling) wave moving along the positive x-direction can be represented mathematically as $y(x,t) = A\sin(\omega t - kx)$, where A is the amplitude, $\omega = 2\pi f$ is the angular frequency, and $k = \frac{2\pi}{\lambda}$ is the wave number (or propagation constant). The speed of the wave is related to its frequency and wavelength by the fundamental relation $v = f\lambda$, since the wave advances a distance of one wavelength in a time equal to one time period.

Step 1 — Identify the given quantities: amplitude $A = 0.02$ m, frequency $f = 50$ Hz, and wavelength $\lambda = 2$ m.

Step 2 — Calculate the angular frequency and wave number:

$$\omega = 2\pi f = 2\pi \times 50 = 100\pi \text{ rad s}^{-1}, \qquad k = \frac{2\pi}{\lambda} = \frac{2\pi}{2} = \pi \text{ rad m}^{-1}$$

Step 3 — Substitute these into the general wave equation for a wave travelling in the positive x-direction:

$$y(x,t) = 0.02\sin(100\pi t - \pi x) \text{ m}$$

Step 4 — Calculate the speed of the wave using $v = f\lambda$:

$$v = f\lambda = 50 \times 2 = 100 \text{ m s}^{-1}$$

Final Answer: $y(x,t) = 0.02\sin(100\pi t - \pi x)$ m; speed $v = 100$ m s^{-1}

Answer: (See above)

Go Back to Question 36

Q37.

Solution

Concept: Radioactive decay is a spontaneous, random process in which unstable nuclei transform into more stable ones by emitting particles or radiation. The law of radioactive decay states that the rate of decay of a radioactive sample at any instant is directly proportional to the number of undecayed nuclei present at that instant, and is expressed mathematically as $N = N_0 e^{-\lambda t}$, where N_0 is the initial number of nuclei, N is the number remaining after time t, and λ is the decay constant of the substance. The half-life $t_{1/2}$ is related to the decay constant by $t_{1/2} = \frac{0.693}{\lambda}$, obtained by setting $N = N_0/2$ in the decay law.

Step 1 — State the law of radioactive decay: $\frac{dN}{dt} = -\lambda N$, which upon integration gives $N = N_0 e^{-\lambda t}$, showing that the number of undecayed nuclei decreases exponentially with time.
Step 2 — Derive the relation between half-life and decay constant by setting $N = N_0/2$ at $t = t_{1/2}$: $\frac{1}{2} = e^{-\lambda t_{1/2}}$, which on taking natural logarithms gives $t_{1/2} = \frac{\ln 2}{\lambda} = \frac{0.693}{\lambda}$.
Step 3 — Substitute the given decay constant $\lambda = 0.0231$ year^{-1}:

$$t_{1/2} = \frac{0.693}{0.0231} \approx 30 \text{ years}$$

Final Answer: $t_{1/2} \approx 30$ years

30 years

Answer: (See above)

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Q38.

Solution

Concept: Calorimetry and heat engines rely on precisely defined quantities that describe how substances absorb, store, or convert thermal energy. Specific heat capacity characterises how much heat a unit mass of a substance can absorb for a given temperature rise. Latent heat characterises the heat absorbed or released during a change of state at constant temperature. The efficiency of a Carnot engine characterises what fraction of the heat absorbed from a hot reservoir is converted into useful mechanical work, based on the temperatures of the hot and cold reservoirs alone.

Step 1 — Define specific heat capacity: it is the amount of heat required to raise the temperature of a unit mass of a substance by one degree Celsius (or one Kelvin), given by $c = \dfrac{Q}{m\Delta T}$. For example, the specific heat capacity of water is 4200 J kg^{-1} °C^{-1}.
Step 2 — Define latent heat: it is the amount of heat absorbed or released by a unit mass of a substance during a change of state (such as melting or vaporisation) at constant temperature, given by $L = \dfrac{Q}{m}$. For example, the latent heat of fusion of ice is approximately 336000 J kg^{-1}.
Step 3 — Define the efficiency of a Carnot engine: it is the ratio of the useful work output to the heat input from the hot reservoir, and for an ideal (Carnot) engine operating between temperatures T_1 (hot) and T_2 (cold), it is given by $\eta = 1 - \dfrac{T_2}{T_1}$, where both temperatures are measured in Kelvin.

Final Answer: A. $c = Q/(m\Delta T)$, e.g., water = 4200 J kg^{-1} °C^{-1}. B. $L = Q/m$, e.g., latent heat of fusion of ice ≈ 336000 J kg^{-1}. C. $\eta = 1 - T_2/T_1$.

Answer: (See above)

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Q39.

Solution

Concept: The lens formula relates the object distance u, image distance v, and focal length f of a thin lens through $\frac{1}{v} - \frac{1}{u} = \frac{1}{f}$, using the Cartesian sign convention in which distances are measured from the optical centre, with distances in the direction of incident light taken as positive. The magnification produced by a lens is given by $m = \frac{v}{u}$, and its sign indicates whether the image is erect (+) or inverted (−) relative to the object. Total internal reflection occurs when light travelling from a denser to a rarer medium strikes the boundary at an angle greater than the critical angle, at which point all the light is reflected back into the denser medium instead of being refracted out. The critical angle C is related to the refractive index n of the denser medium by $\sin C = \frac{1}{n}$.

Alternative (i): Apply the sign convention: since the object is placed in front of the lens, $u = -30$ cm, and for a convex lens $f = +15$ cm. Substitute into the lens formula:

$$\frac{1}{v} = \frac{1}{f} + \frac{1}{u} = \frac{1}{15} + \frac{1}{-30} = \frac{2}{30} - \frac{1}{30} = \frac{1}{30} \implies v = 30 \text{ cm}$$

The magnification is:

$$m = \frac{v}{u} = \frac{30}{-30} = -1$$

The negative sign shows that the image is real and inverted, and its magnitude of 1 shows that the image is the same size as the object.

Alternative (ii): Total internal reflection requires two conditions: (a) light must travel from a denser medium to a rarer medium (e.g., glass to air), and (b) the angle of incidence in the denser medium must exceed the critical angle for that pair of media. Using $\sin C = \frac{1}{n}$ with $n = 1.5$ for glass:

$$\sin C = \frac{1}{1.5} = 0.667 \implies C = \sin^{-1}(0.667) \approx 41.8^\circ$$

Final Answer: (i) $v = 30$ cm, $m = -1$ (real, inverted, same size). (ii) $C \approx 41.8^\circ$.

Answer: (See above)

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Q40.

Solution

Concept: Bernoulli's theorem is a statement of the conservation of energy applied to an ideal fluid (incompressible and non-viscous) in streamline flow. It states that the sum of the pressure energy, kinetic energy, and potential energy per unit volume of the fluid remains constant along any streamline. Mathematically, this is written as:

$$P + \frac{1}{2}\rho v^2 + \rho g h = \text{constant}$$

where P is the pressure, ρ is the density of the fluid, v is its flow speed, and h is its height above a reference level.

Step 1 — State Bernoulli's theorem and its equation as above, noting that it follows directly from the work-energy theorem applied to a small element of moving fluid.

Step 2 — Apply the equation of continuity for an incompressible fluid flowing through a pipe of varying cross-section: $A_1 v_1 = A_2 v_2$, which shows that the flow speed increases as the cross-sectional area decreases (since the volume of fluid passing any cross-section per second must remain the same).

Step 3 — Explain the pressure change using Bernoulli's equation. For a horizontal pipe (h constant), the theorem reduces to $P + \frac{1}{2}\rho v^2 = \text{constant}$. Since the flow speed v increases at the narrower section (from Step 2), the kinetic energy term $\frac{1}{2}\rho v^2$ increases; to keep the total sum constant, the pressure P at the narrower section must correspondingly decrease. This explains both why the fluid speeds up in the narrow section and why its pressure drops there.

Final Answer: By the equation of continuity, a smaller cross-sectional area requires a higher flow speed to maintain the same volume flow rate; Bernoulli's theorem then shows that this increase in speed is accompanied by a decrease in pressure at the narrow section.

Answer: (See above)

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Q41.

Solution

Concept: When resistors are connected in series, the same current flows through each resistor, but the total potential difference across the combination is the sum of the potential differences across each individual resistor. This property allows the derivation of a single equivalent resistance that could replace the entire series combination without changing the current drawn from the source. Electromagnetic induction, the basis of an AC generator, relies on Faraday's law: whenever the magnetic flux linked with a coil changes (for example, by rotating the coil in a uniform magnetic field), an emf is induced in the coil.

Alternative (i): Let a current I flow through three resistors R_1, R_2, R_3 connected in series across a battery of voltage V. Since the same current I flows through each resistor, the voltage drops across them are $V_1 = IR_1$, $V_2 = IR_2$, $V_3 = IR_3$. By Kirchhoff's voltage law, the total voltage equals the sum of the individual drops:

$$V = V_1 + V_2 + V_3 = I(R_1 + R_2 + R_3)$$

Comparing this with $V = IR_{\text{eq}}$ for a single equivalent resistor gives $R_{\text{eq}} = R_1 + R_2 + R_3$. Substituting the given values:

$$R_{\text{eq}} = 4 + 6 + 10 = 20\ \Omega$$

Alternative (ii): An AC generator consists of a rectangular coil of many turns rotated at a constant angular speed ω within a uniform magnetic field B, using slip rings and brushes to connect the rotating coil to the external circuit. As the coil rotates, the flux linked with it varies as $\Phi = BA\cos(\omega t)$, and by Faraday's law the induced emf is:

$$\varepsilon = -\frac{d\Phi}{dt} = BA\omega\sin(\omega t) = \varepsilon_0\sin(\omega t)$$

where $\varepsilon_0 = BA\omega$ is the peak value of the emf, and A is the area of the coil.

Final Answer: (i) $R_{\text{eq}} = R_1 + R_2 + R_3 = 20\ \Omega$. (ii) $\varepsilon = \varepsilon_0\sin(\omega t)$, with $\varepsilon_0 = BA\omega$.

Answer: (See above)

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Q42.

Solution

Concept: The work-energy theorem states that the net work done by all the forces acting on a body is equal to the change in its kinetic energy. This provides a powerful shortcut for solving mechanics problems in which forces vary or the path is complicated, since it connects the work done directly to the change in speed without requiring detailed information about acceleration at every instant. The law of conservation of mechanical energy states that in the absence of non-conservative forces (like friction or air resistance), the total mechanical energy (kinetic plus potential energy) of a system remains constant.

Alternative (i): (a) Consider a body of mass m acted upon by a constant net force F, causing a displacement s and acceleration $a = F/m$. Using the kinematic relation $v^2 = u^2 + 2as$, we can write $\frac{v^2 - u^2}{2} = as$, so that $ma \cdot s = \frac{1}{2}mv^2 - \frac{1}{2}mu^2$. Since $F = ma$, the left-hand side is exactly the work done, $W = Fs$, giving $W = \frac{1}{2}mv^2 - \frac{1}{2}mu^2 = \Delta KE$, which proves the work-energy theorem for a constant force.
(b) For the car, use $v^2 = u^2 + 2as$ with $u = 20$ m s^{-1}, $v = 0$, and $s = 50$ m to find the deceleration:

$$0 = (20)^2 + 2a(50) \implies a = -\frac{400}{100} = -4 \text{ m s}^{-2}$$

The magnitude of the average braking force is then $F = ma = 1000 \times 4 = 4000$ N.
(c) The law of conservation of mechanical energy states that for a system acted upon only by conservative forces, the sum of kinetic energy and potential energy remains constant: $KE + PE =$ constant.

Alternative (ii): (a) Consider a body of mass m starting from rest and accelerated uniformly by a constant force F to a final velocity v over a displacement s. By the work-energy theorem, the work done by the force equals the kinetic energy gained: $W = Fs = mas$. Using $v^2 = 0 + 2as$, we get $as = \frac{v^2}{2}$, so $W = m \times \frac{v^2}{2} = \frac{1}{2}mv^2$. This is precisely the kinetic energy of the body, so $KE = \frac{1}{2}mv^2$.
(b) As the ball falls, all its loss in potential energy is converted into kinetic energy (neglecting air resistance), so the kinetic energy just before impact equals the initial potential energy: $KE = mgh = 0.5 \times 10 \times 20 = 100$ J.
(c) The law of conservation of energy states that energy can neither be created nor destroyed; it can only be transformed from one form to another, and the total energy of an isolated system always remains constant.

Final Answer: (i) (a) $W = \Delta KE$ (proved). (b) $F = 4000$ N. (c) $KE + PE =$ constant. (ii) (a) $KE = \frac{1}{2}mv^2$ (derived). (b) $KE = 100$ J. (c) Energy is conserved, only transformed between forms.

Answer: (See above)

Go Back to Question 42

Q43.

Solution

Concept: A p-n junction diode conducts only when forward biased, enabling rectification. A half-wave rectifier uses one diode to pass one half-cycle of AC, while a full-wave rectifier utilizes both half-cycles for a smoother, more efficient DC output. A basic communication system consists of a transmitter, a channel, and a receiver.

Alternative (i): (a) In a half-wave rectifier, a single diode conducts during the positive half-cycle (forward biased) and blocks during the negative half-cycle (reverse biased), producing a pulsating, unidirectional DC output.
(b) A full-wave rectifier utilizes both halves of the AC cycle (via center-tapped or bridge configurations), yielding higher average DC voltage, superior efficiency, and lower ripple than a half-wave rectifier.
(c) The ripple factor (r) measures the remaining AC fluctuation in the DC output: $r = \frac{V_{\text{rms(AC)}}}{V_{\text{DC}}}$.

Alternative (ii): (a) A communication system consists of three elements: a **transmitter** (modulates the message onto a carrier wave), a **channel** (transmission medium), and a **receiver** (demodulates and recovers the original signal).
(b) In **Amplitude Modulation (AM)**, the carrier's amplitude varies with the message signal. In **Frequency Modulation (FM)**, its frequency varies; FM is inherently more noise-resistant.
(c) Satellite communication is widely used for direct-to-home (DTH) television broadcasting because a geostationary satellite can cover massive surface areas without ground relay chains.

Final Answer: (i) (a) Half-wave rectifier blocks one half-cycle, yielding pulsating DC. (b) Full-wave rectifier offers higher efficiency and lower ripple. (c) $r = V_{\text{rms(AC)}}/V_{\text{DC}}$. (ii) (a) Transmitter $\rightarrow$ Channel $\rightarrow$ Receiver. (b) AM varies amplitude; FM varies frequency (noise-resistant). (c) DTH television broadcasting.

Answer: (See above) Go Back to Question 43

Answer Key

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