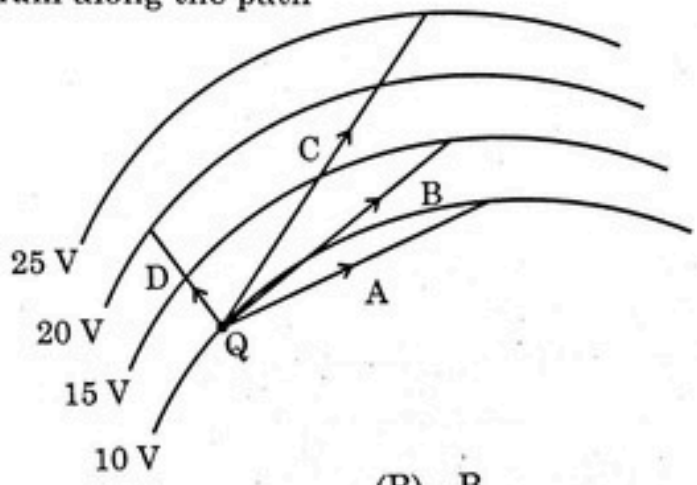
SECTION – A

1. In the figure curved lines represent equipotential surfaces. A charge Q is moved along different paths A, B, C and D. The work done on the charge will be maximum along the path 1



(A) A (B) B
(C) C (D) D

2. The resistance of a wire of length L and radius r is R. Which one of the following would provide a wire of the same material of resistance $\frac{R}{2}$? 1

(A) Using a wire of same radius and twice the length
(B) Using a wire of same radius and half length
(C) Using a wire of same length and twice the radius
(D) Using a wire of same length and half the radius

3. A 1 cm segment of a wire lying along x-axis carries current of 0.5 A along +x direction. A magnetic field $\vec{B} = (0.4\ mT)\,\hat{j} + (0.6\ mT)\,\hat{k}$ is switched on, in the region. The force acting on the segment is 1

(A) $(2\hat{j} + 3\hat{k})$ mN (B) $(-3\hat{j} + 2\hat{k})$ μN
(C) $(6\hat{j} + 4\hat{k})$ mN (D) $(-4\hat{j} + 6\hat{k})$ μN

4. A circular coil of diameter 15 mm having 300 turns is placed in a magnetic field of 30 mT such that the plane of the coil is perpendicular to the direction of magnetic field. The magnetic field is reduced uniformly to zero in 20 ms and again increased uniformly to 30 mT in 40 ms. If the emfs induced in the two time intervals are e_1 and e_2 respectively, then the value of e_1/e_2 is 1

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

5. You are required to design an air-filled solenoid of inductance 0.016 H having a length 0.81 m and radius 0.02 m. The number of turns in the solenoid should be 1

(A) 2592
(B) 2866
(C) 2976
(D) 3140

6. A voltage $v = v_0 \sin \omega t$ applied to a circuit drives a current $i = i_0 \sin (\omega t + \phi)$ in the circuit. The average power consumed in the circuit over a cycle is 1

(A) Zero
(B) $i_0 v_0 \cos \phi$
(C) $\frac{i_0 v_0}{2}$
(D) $\frac{i_0 v_0}{2} \cos \phi$

7. Which one of the following correctly represents the change in wave characteristics (all in vacuum) from microwaves to X-rays in electromagnetic spectrum ? 1

	Speed	Wavelength	Frequency
(A)	Remains same	Decreases	Remains same
(B)	Remains same	Decreases	Increases
(C)	Increases	Increases	Decreases
(D)	Remains same	Increases	Remains same

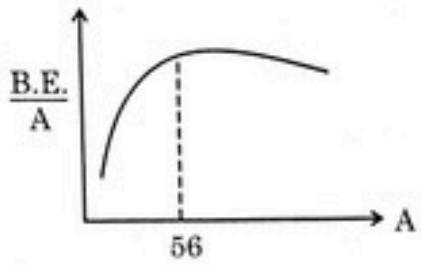
8. The speed of light in two media '1' and '2' are v_1 and v_2 ($> v_1$) respectively. For a ray of light to undergo total internal reflection at the interface of these two media, it must be incident from 1

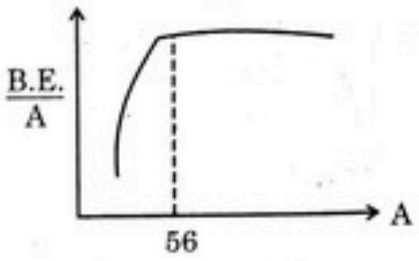
(A) medium '1' and at an angle greater than $\sin^{-1}\left(\frac{v_1}{v_2}\right)$
(B) medium '1' and at an angle greater than $\cos^{-1}\left(\frac{v_1}{v_2}\right)$
(C) medium '2' and at an angle greater than $\sin^{-1}\left(\frac{v_1}{v_2}\right)$
(D) medium '2' and at an angle greater than $\cos^{-1}\left(\frac{v_1}{v_2}\right)$

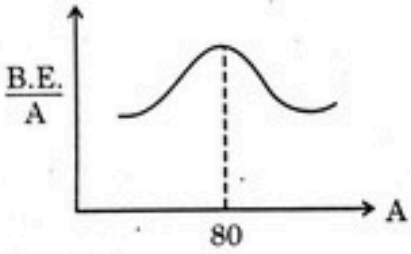
9. A source produces monochromatic light of frequency 5.0×10^{14} Hz and the power emitted is 3.31 mW. The number of photons emitted per second by the source, on an average is 1

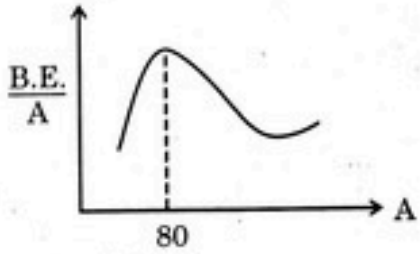
(A) 10^{16}
(B) 10^{24}
(C) 10^{10}
(D) 10^{20}

10. Which of the following figures correctly represent the shape of curve of binding energy per nucleon as a function of mass number ? 1

(A) 

(B) 

(C) 

(D) 

11. When a p-n junction diode is forward biased 1
(A) the barrier height and the depletion layer width both increase.
(B) the barrier height increases and the depletion layer width decreases.
(C) the barrier height and the depletion layer width both decrease.
(D) the barrier height decreases and the depletion layer width increases.

12. Let λ_e, λ_p and λ_d be the wavelengths associated with an electron, a proton and a deuteron, all moving with the same speed. Then the correct relation between them is 1
(A) $\lambda_d > \lambda_p > \lambda_e$
(B) $\lambda_e > \lambda_p > \lambda_d$
(C) $\lambda_p > \lambda_e > \lambda_d$
(D) $\lambda_e = \lambda_p = \lambda_d$

Note : Question numbers **13** to **16** are Assertion (A) and Reason (R) type questions. Two statements are given – one labelled Assertion (A) and the other labelled Reason (R). Select the correct answer from the codes (A), (B), (C) and (D) as given below.
(A) Both Assertion (A) and Reason (R) are true and Reason (R) is the correct explanation of Assertion (A).
(B) Both Assertion (A) and Reason (R) are true, but Reason (R) is not the correct explanation of Assertion (A).
(C) Assertion (A) is true, but Reason (R) is false.
(D) Assertion (A) is false and Reason (R) is also false.

13. **Assertion (A) :** The potential energy of an electron revolving in any stationary orbit in a hydrogen atom is positive. 1
Reason (R) : The total energy of a charged particle is always positive.

14. **Assertion (A)** : We cannot form a p-n junction diode by taking a slab of a p-type semiconductor and physically joining it to another slab of a n-type semiconductor. 1

Reason (R) : In a p-type semiconductor $\eta_e >> \eta_h$ while in a n-type semiconductor $\eta_h >> \eta_e$.

15. **Assertion (A)** : The deflection in a galvanometer is directly proportional to the current passing through it. 1

Reason (R) : The coil of a galvanometer is suspended in a uniform radial magnetic field.

16. **Assertion (A)** : It is difficult to move a magnet into a coil of large number of turns when the circuit of the coil is closed. 1

Reason (R) : The direction of induced current in a coil with its circuit closed, due to motion of a magnet, is such that it opposes the cause.

SECTION – B

17. Show that $\vec{E} = \rho \vec{j}$ leads to Ohm's law. Write a condition in which the Ohm's law is not valid for a material. 2

18. (a) In a diffraction experiment, the slit is illuminated by light of wavelength 600 nm. The first minimum of the pattern falls at $\theta = 30°$. Calculate the width of the slit. 2

OR

(b) In a Young's double-slit experiment, two light waves, each of intensity I_o, interfere at a point, having a path difference $\frac{\lambda}{8}$ on the screen. Find the intensity at this point.

19. A spherical convex surface of radius of curvature R separates glass (refractive index 1.5) from air. Light from a point source placed in air at distance R/2 from the surface falls on it. Find the position and nature of the image formed. 2

20. The energy of an electron in an orbit of Bohr hydrogen atom is –3.4 eV. Find its angular momentum. 2

21. A p-type Si semiconductor is made by doping an average of one dopant atom per 5×10^7 silicon atoms. If the number density of silicon atoms in the specimen is 5×10^{28} atoms m^{-3}, find the number of holes created per cubic centimetre in the specimen due to doping. Also give one example of such dopants. 2

SECTION – C

22. (a) Two batteries of emf's 3V & 6V and internal resistances 0.2 Ω & 0.4 Ω are connected in parallel. This combination is connected to a 4 Ω resistor. Find : 3

(i) the equivalent emf of the combination

(ii) the equivalent internal resistance of the combination

(iii) the current drawn from the combination

OR

(b) (i) A conductor of length l is connected across an ideal cell of emf E. Keeping the cell connected, the length of the conductor is increased to $2l$ by gradually stretching it. If R and R′ are initial and final values of resistance and v_d and v_d' are initial and final values of drift velocity, find the relation between (i) R′ and R and (ii) v_d' and v_d.

(ii) When electrons drift in a conductor from lower to higher potential, does it mean that all the 'free electrons' of the conductor are moving in the same direction ?

23. (a) Define magnetic moment of a current-carrying coil. Write its SI unit.

(b) A coil of 60 turns and area 1.5×10^{-3} m^3 carrying 2A current lies in a vertical plane. It experiences a torque of 0.12 Nm when placed in a uniform horizontal magnetic field. The torque acting on the coil changes to 0.05 Nm after the coil is rotated about its diameter by 90°, in the magnetic field. Find the magnitude of the magnetic field. 3

24. Consider two long co-axial solenoids S_1 and S_2, each of length l ($>> r_2$) and of radius r_1 and r_2 ($r_2 > r_1$). The number of turns per unit length are n_1 and n_2 respectively. Derive an expression for mutual inductance M_{12} of solenoid S_1 with respect to solenoid S_2. Show that $M_{21} = M_{12}$. 3

25. (a) A parallel plate capacitor is charged by an ac source. Show that the sum of conduction current (I_c) and the displacement current (I_d) has the same value at all points of the circuit. 3

(b) In case (a) above, is Kirchhoff's first rule (junction rule) valid at each plate of the capacitor ? Explain.

26. (a) Draw a plot of frequency ν of incident radiations as a function of stopping potential V_0 for a given photo emissive material. What information can be obtained from the value of the intercept on the stopping potential axis ? 3

(b) Calculate : (i) the momentum and (ii) de Broglie wavelength, of an electron with kinetic energy of 80 eV.

27. (a) Draw circuit arrangement for studying V-I characteristics of a p-n junction diode. 3

(b) Show the shape of the characteristics of a diode.

(c) Mention two information that you can get from these characteristics.

28. (a) Define 'Mass defect' and 'Binding energy' of a nucleus. Describe 'Fission process' on the basis of binding energy per nucleon. 3

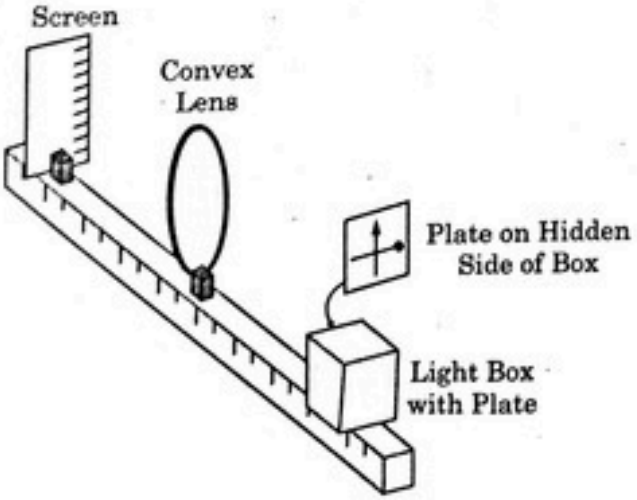
(b) A deuteron contains a proton and a neutron and has a mass of 2.013553 u. Calculate the mass defect for it in u and its energy equivalence in MeV. (m_p = 1.007277 u, m_n = 1.008665 u, 1u = 931.5 MeV/c^2)

SECTION – D

Question numbers **29** and **30** are case study based questions. Read the following paragraphs and answer the questions that follow.

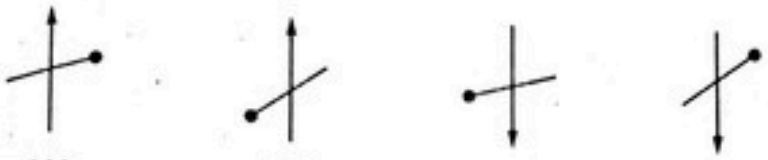
29. A thin lens is a transparent optical medium bounded by two surfaces, at least one of which should be spherical. Applying the formula for image formation by a single spherical surface successively at the two surfaces of a lens, one can obtain the 'lens maker formula' and then the 'lens formula'. A lens has two foci – called 'first focal point' and 'second focal point' of the lens, one on each side. **4 × 1 = 4**

(i)



Consider the arrangement shown in figure. A black vertical arrow and a horizontal thick line with a ball are painted on a glass plate. It serves as the object. When the plate is illuminated, its real image is formed on the screen.

Which of the following correctly represents the image formed on the screen ?



(A) (B) (C) (D)

(ii) Which of the following statements is incorrect ?

(A) For a convex mirror magnification is always negative.

(B) For all virtual images formed by a mirror magnification is positive.

(C) For a concave lens magnification is always positive.

(D) For real and inverted images, magnification is always negative.

(iii) A convex lens of focal length 'f' is cut into two equal parts perpendicular to the principal axis. The focal length of each part will be :

(A) f (B) 2 f

(C) $\frac{f}{2}$ (D) $\frac{f}{4}$

OR

(iii) If an object in case (i) above is 20 cm from the lens and the screen is 50 cm away from the object, the focal length of the lens used is

(A) 10 cm (B) 12 cm

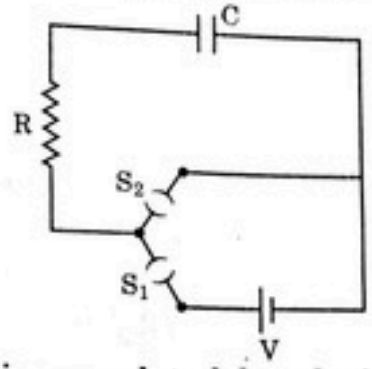
(C) 16 cm (D) 20 cm

(iv) The distance of an object from first focal point of a biconvex lens is X_1 and distance of the image from second focal point is X_2. The focal length of the lens is

(A) $X_1 X_2$ (B) $\sqrt{X_1 + X_2}$

(C) $\sqrt{X_1 X_2}$ (D) $\sqrt{\frac{X_2}{X_1}}$

30. A circuit consisting of a capacitor C, a resistor of resistance R and an ideal battery of emf V, as shown in figure is known as RC series circuit. $4 \times 1 = 4$



As soon as the circuit is completed by closing key S_1 (keeping S_2 open) charges begin to flow between the capacitor plates and the battery terminals. The charge on the capacitor increases and consequently the potential difference V_c (= q/C) across the capacitor also increases with time. When this potential difference equals the potential difference across the battery, the capacitor is fully charged (Q = VC). During this process of charging, the charge q on the capacitor changes with time t as $q = Q[1 - e^{-t/RC}]$

The charging current can be obtained by differentiating it and using $\frac{d}{dx}(e^{mx}) = me^{mx}$.

Consider the case when R = 20 kΩ, C = 500 μF and V = 10 V.

(i) The final charge on the capacitor, when key S_1 is closed and S_2 is open, is

(A) 5 μC (B) 5 mC
(C) 25 mC (D) 0.1 C

(ii) For sufficient time the key S_1 is closed and S_2 is open. Now key S_2 is closed and S_1 is open. What is the final charge on the capacitor ?

(A) Zero (B) 5 mC
(C) 2.5 mC (D) 5 μC

(iii) The dimensional formula for RC is

(A) $[M L^2 T^{-3} A^{-2}]$ (B) $[M^0 L^0 T^{-1} A^0]$
(C) $[M^{-1} L^{-2} T^4 A^2]$ (D) $[M^0 L^0 T A^0]$

(iv) The key S_1 is closed and S_2 is open. The value of current in the resistor after 5 seconds, is

(A) $\frac{1}{2\sqrt{e}}$ mA (B) $\sqrt{e}$ mA (C) $\frac{1}{\sqrt{e}}$ mA (D) $\frac{1}{2e}$ mA

OR

(iv) The key S_1 is closed and S_2 is open. The initial value of charging current in the resistor, is

(A) 5 mA (B) 0.5 mA (C) 2 mA (D) 1 mA

SECTION – E

31. (a) (i) (1) What are coherent sources ? Why are they necessary for observing a sustained interference pattern ? 5

(2) Lights from two independent sources are not coherent. Explain.

(ii) Two slits 0.1 mm apart are arranged 1.20 m from a screen. Light of wavelength 600 nm from a distant source is incident on the slits.

(1) How far apart will adjacent bright interference fringes be on the screen ?

(2) Find the angular width (in degree) of the first bright fringe.

OR

(b) (i) Define a wavefront. An incident plane wave falls on a convex lens and gets refracted through it. Draw a diagram to show the incident and refracted wavefront.

(ii) A beam of light coming from a distant source is refracted by a spherical glass ball (refractive index 1.5) of radius 15 cm. Draw the ray diagram and obtain the position of the final image formed.

32. (a) (i) Two point charges 5 μC and –1 μC are placed at points (–3 cm, 0, 0) and (3 cm, 0, 0) respectively. An external electric field $\vec{E} = \frac{A}{r^2}\hat{r}$ where $A = 3 \times 10^5$ Vm is switched on in the region. Calculate the change in electrostatic energy of the system due to the electric field. 5

(ii) A system of two conductors is placed in air and they have net charge of +80μC and –80μC which causes a potential difference of 16 V between them.

(1) Find the capacitance of the system.

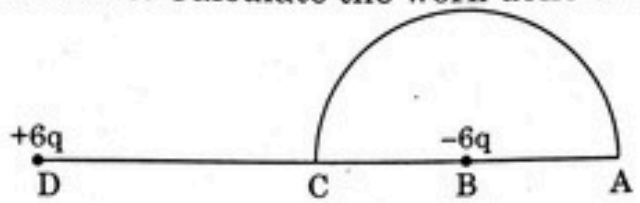
(2) If the air between the capacitor is replaced by a dielectric medium of dielectric constant 3, what will be the potential difference between the two conductors ?

(3) If the charges on two conductors are changed to +160 μC and –160 μC, will the capacitance of the system change ? Give reason for your answer.

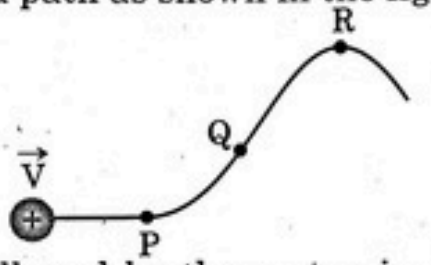
OR

(b) (i) Consider three metal spherical shells A, B and C, each of radius R. Each shell is having a concentric metal ball of radius R/10. The spherical shells A, B and C are given charges +6q, −4q, and 14q respectively. Their inner metal balls are also given charges −2q, +8q and −10q respectively. Compare the magnitude of the electric fields due to shells A, B and C at a distance 3R from their centres.

(ii) A charge −6 μC is placed at the centre B of a semicircle of radius 5 cm, as shown in the figure. An equal and opposite charge is placed at point D at a distance of 10 cm from B. A charge +5 μC is moved from point 'C' to point 'A' along the circumference. Calculate the work done on the charge.



33. (a) (i) A proton moving with velocity $\vec{V}$ in a non-uniform magnetic field traces a path as shown in the figure. 5



The path followed by the proton is always in the plane of the paper. What is the direction of the magnetic field in the region near points P, Q and R ? What can you say about relative magnitude of magnetic fields at these points ?

(ii) A current carrying circular loop of area A produces a magnetic field B at its centre. Show that the magnetic moment of the loop is $\frac{2\,BA}{\mu_0}\sqrt{\frac{A}{\pi}}$.

OR

(b) (i) Derive an expression for the torque acting on a rectangular current loop suspended in a uniform magnetic field.

(ii) A charged particle is moving in a circular path with velocity $\vec{V}$ in a uniform magnetic field $\vec{B}$. It is made to pass through a sheet of lead and as a consequence, it looses one half of its kinetic energy without change in its direction. How will (1) the radius of its path (2) its time period of revolution change ?