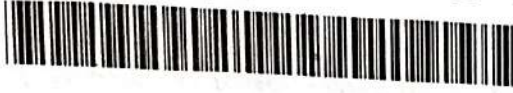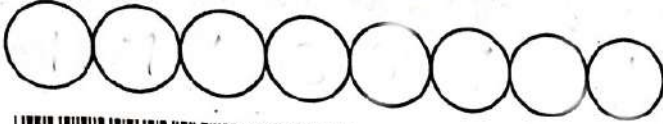रोल नं.
Roll No.

परीक्षार्थी प्रश्न-पत्र कोड को उत्तर-पुस्तिका के मुख-पृष्ठ पर अवश्य लिखें ।
Candidates must write the Q.P. Code on the title page of the answer-book. ✱

भौतिक विज्ञान (सैद्धान्तिक)
PHYSICS (Theory)

निर्धारित समय : 3 घण्टे
Time allowed : 3 hours

अधिकतम अंक : 70
Maximum Marks : 70

नोट / NOTE :

(i) कृपया जाँच कर लें कि इस प्रश्न-पत्र में मुद्रित पृष्ठ **27** हैं ।

Please check that this question paper contains **27** printed pages.

(ii) प्रश्न-पत्र में दाहिने हाथ की ओर दिए गए प्रश्न-पत्र कोड को परीक्षार्थी उत्तर-पुस्तिका के मुख-पृष्ठ पर लिखें ।

Q.P. Code given on the right hand side of the question paper should be written on the title page of the answer-book by the candidate.

(iii) कृपया जाँच कर लें कि इस प्रश्न-पत्र में **35** प्रश्न हैं ।

Please check that this question paper contains **35** questions.

(iv) कृपया प्रश्न का उत्तर लिखना शुरू करने से पहले, उत्तर-पुस्तिका में प्रश्न का क्रमांक अवश्य लिखें ।

Please write down the serial number of the question in the answer-book before attempting it.

(v) इस प्रश्न-पत्र को पढ़ने के लिए 15 मिनट का समय दिया गया है । प्रश्न-पत्र का वितरण पूर्वाह्न में 10.15 बजे किया जाएगा । 10.15 बजे से 10.30 बजे तक छात्र केवल प्रश्न-पत्र को पढ़ेंगे और इस अवधि के दौरान वे उत्तर-पुस्तिका पर कोई उत्तर नहीं लिखेंगे ।

15 minute time has been allotted to read this question paper. The question paper will be distributed at 10.15 a.m. From 10.15 a.m. to 10.30 a.m., the students will read the question paper only and will not write any answer on the answer-book during this period.

Read the following instructions very carefully and strictly follow them :

(i) This question paper contains **35** questions. **All** questions are **compulsory**.

(ii) This question paper is divided into **five** Sections – **A, B, C, D** and **E**.

(iii) In **Section A** – Questions no. **1** to **18** are Multiple Choice (MCQ) type questions, carrying **1** mark each.

(iv) In **Section B** – Questions no. **19** to **25** are Very Short Answer (VSA) type questions, carrying **2** marks each.

(v) In **Section C** – Questions no. **26** to **30** are Short Answer (SA) type questions, carrying **3** marks each.

(vi) In **Section D** – Questions no. **31** to **33** are Long Answer (LA) type questions carrying **5** marks each.

(vii) In **Section E** – Questions no. **34** and **35** are case-based questions carrying **4** marks each.

(viii) There is no overall choice. However, an internal choice has been provided in 2 questions in Section B, 2 questions in Section C, 3 questions in Section D and 2 questions in Section E.

(ix) Use of calculators is **not** allowed.

Use the following values of physical constants, if required :

$$c = 3 \times 10^8 \text{ m/s}$$

$$h = 6 \cdot 63 \times 10^{-34} \text{ Js}$$

$$e = 1 \cdot 6 \times 10^{-19} \text{ C}$$

$$\mu_0 = 4\pi \times 10^{-7} \text{ T m A}^{-1}$$

$$\varepsilon_0 = 8 \cdot 854 \times 10^{-12} \text{ C}^2 \text{ N}^{-1} \text{ m}^{-2}$$

$$\frac{1}{4\pi\varepsilon_0} = 9 \times 10^9 \text{ N m}^2 \text{ C}^{-2}$$

Mass of electron $(m_e) = 9 \cdot 1 \times 10^{-31}$ kg

Mass of neutron $= 1 \cdot 675 \times 10^{-27}$ kg

Mass of proton $= 1 \cdot 673 \times 10^{-27}$ kg

Avogadro's number $= 6 \cdot 023 \times 10^{23}$ per gram mole

Boltzmann constant $= 1 \cdot 38 \times 10^{-23}$ JK^{-1}

SECTION A

1. Two charges q_1 and q_2 are placed at the centres of two spherical conducting shells of radius r_1 and r_2 respectively. The shells are arranged such that their centres are d $[> (r_1 + r_2)]$ distance apart. The force on q_2 due to q_1 is :

   (a) $\dfrac{1}{4\pi \varepsilon_0} \dfrac{q_1 q_2}{d^2}$

   (b) $\dfrac{1}{4\pi \varepsilon_0} \dfrac{q_1 q_2}{(d - r_1)^2}$

   (c) Zero

   (d) $\dfrac{1}{4\pi \varepsilon_0} \dfrac{q_1 q_2}{[d - (r_1 + r_2)]^2}$

2. An electron enters a uniform magnetic field with speed v. It describes a semicircular path and comes out of the field. The final speed of the electron is :
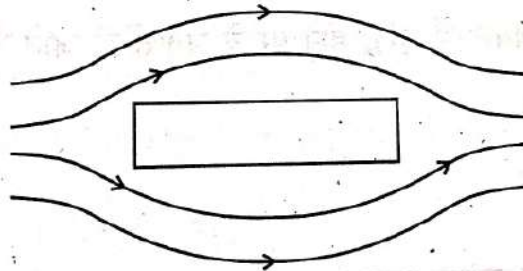
   (a) Zero
   (b) v
   (c) $\dfrac{v}{2}$
   (d) 2v

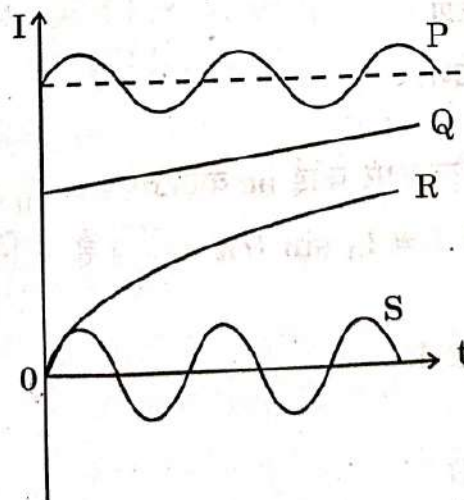3. The magnetic field lines near a substance are as shown in the figure. The substance is :

   (a) Copper
   (b) Iron
   (c) Sodium
   (d) Aluminium

4. The figure shows variation of current (I) with time (t) in four devices P, Q, R and S. The device in which an alternating current flows is :


   (a) P
   (b) Q
   (c) R
   (d) S

5. The electromagnetic waves used in radar systems are :
   (a) Infrared waves
   (b) Ultraviolet rays
   (c) Microwaves
   (d) X-rays

6. In a Young's double-slit experiment, the fringe width is found to be β. If the entire apparatus is immersed in a liquid of refractive index μ, the new fringe width will be :
   (a) β
   (b) $\mu\beta$
   (c) $\dfrac{\beta}{\mu}$
   (d) $\dfrac{\beta}{\mu^2}$

7. Photons of energy 3·2 eV are incident on a photosensitive surface. If the stopping potential for the emitted electrons is 1·5 V, the work function for the surface is :
   (a) 1·5 eV
   (b) 1·7 eV
   (c) 3·2 eV
   (d) 4·7 eV

8. Which of the following statements is *not* true for nuclear forces ?
   (a) They are stronger than Coulomb forces.
   (b) They have about the same magnitude for different pairs of nucleons.
   (c) They are always attractive.
   (d) They saturate as the separation between two nucleons increases.

9. The direction of induced current in the loop abc is :
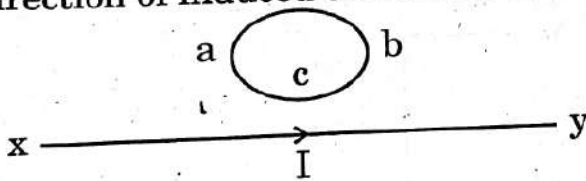
   (a) along abc if I decreases
   (b) along acb if I increases
   (c) along abc if I is constant
   (d) along abc if I increases

10. An ac voltage $v = v_0 \sin \omega t$ is applied to a series combination of a resistor R and an element X. The instantaneous current in the circuit is $I = I_0 \sin \left(\omega t + \dfrac{\pi}{4}\right)$. Then which of the following is correct ?
   (a) X is a capacitor and $X_C = \sqrt{2}\ R$
   (b) X is an inductor and $X_L = R$
   (c) X is an inductor and $X_L = \sqrt{2}\ R$
   (d) X is a capacitor and $X_C = R$

P.T.

11. A plane wavefront is incident on a concave mirror of radius of curvature R. The radius of the refracted wavefront will be :

(a) 2R   (b) R   (c) $\dfrac{R}{2}$ (d) $\dfrac{R}{4}$

12. A proton and an alpha particle have the same kinetic energy. The ratio of de Broglie wavelengths associated with the proton to that with the alpha particle is :

(a) 1   (b) 2   (c) $2\sqrt{2}$ (d) $\dfrac{1}{2}$

13. The potential energy of an electron in the second excited state in hydrogen atom is :

(a) $-3\cdot4$ eV   (b) $-3\cdot02$ eV   (c) $-1\cdot51$ eV   (d) $-6\cdot8$ eV

14. The difference in mass of ^{7}X nucleus and total mass of its constituent nucleons is $21\cdot00$ u. The binding energy per nucleon for this nucleus is equal to the energy equivalent of :

(a) 3 u   (b) $3\cdot5$ u   (c) 7 u   (d) 21 u

15. The threshold voltage for a p-n junction diode used in the circuit is 0·7 V. The type of biasing and current in the circuit are :
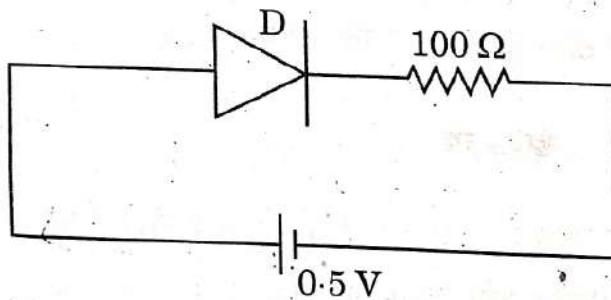
(a) Forward biasing, 0 A   (b) Reverse biasing, 0 A

(c) Forward biasing, 5 mA   (d) Reverse biasing, 2 mA

Questions number 16 to 18 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 the Assertion (A).

(b) Both Assertion (A) and Reason (R) are true, but Reason (R) is *not* the correct explanation of the Assertion (A).

(c) Assertion (A) is true, but Reason (R) is false.

(d) Assertion (A) is false and Reason (R) is also false.

16. *Assertion (A) :* When three electric bulbs of power 200 W, 100 W and 50 W are connected in series to a source, the power consumed by the 50 W bulb is maximum.

Reason (R) : In a series circuit, current is the same through each bulb, but the potential difference across each bulb is different.

17. *Assertion (A) :* A current carrying square loop made of a wire of length L is placed in a magnetic field. It experiences a torque which is greater than the torque on a circular loop made of the same wire carrying the same current in the same magnetic field.

Reason (R) : A square loop occupies more area than a circular loop, both made of wire of the same length.

18. *Assertion (A) :* In 'n' type semiconductor, number density of electrons is greater than the number density of holes but the crystal maintains an overall charge neutrality.
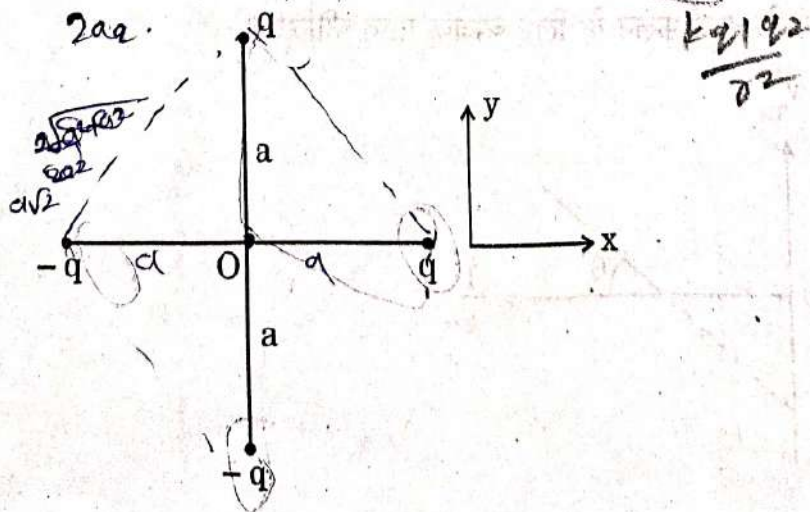
Reason (R) : The charge of electrons donated by donor atoms is just equal and opposite to that of the ionised donor.

SECTION B

19. Two identical dipoles are arranged in x-y plane as shown in the figure. Find the magnitude and the direction of net electric field at the origin O.   2

20. Write two differences between the emf and terminal potential difference of a cell. What is the most important precaution that one should take while drawing current from a cell ? **2**

21. A small magnetised needle P is placed at the origin of x-y plane with its magnetic moment pointing along the y-axis. Another identical magnetised needle Q is placed in two positions, one by one.

Case 1 : at (a, 0) with its magnetic moment pointing along x-axis.

Case 2 : at (0, a) with its magnetic moment pointing along y-axis.

(a) In which case is the potential energy of P and Q minimum ?

(b) In which case is P and Q not in equilibrium ?

Justify your answers. **2**

22. (a) What is a displacement current ? How is it different from a conduction current ? **2**

OR

(b) Write any two characteristics of an electromagnetic wave. Why are microwaves used in radar systems ? **2**

23. The figure shows v_m^2 versus $\frac{1}{\lambda}$ graph for photoelectrons emitted from a surface where v_m is the maximum speed of electrons and λ is the wavelength of incident radiation. Using this graph and Einstein's photoelectric equation, obtain the expression for Planck's constant and work function of the surface. **2**
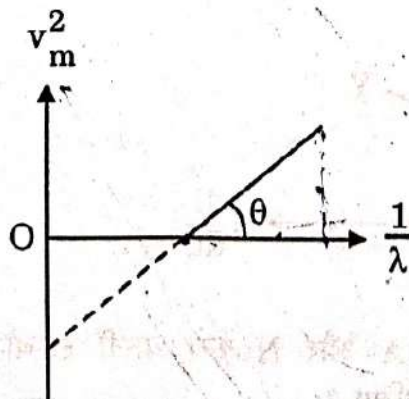
24. Draw the graph showing the variation of binding energy per nucleon with mass number A of nuclei ($2 < A < 170$). Use this graph to explain the release of energy in nuclear fission. 2

25. (a) Obtain an expression for electrostatic potential energy of a system of three charges q, $2q$ and $-3q$ placed at the vertices of an equilateral triangle of side a. 2

OR

(b) Two small conducting balls A and B of radius r_1 and r_2 have charges q_1 and q_2 respectively. They are connected by a wire. Obtain the expression for charges on A and B, in equilibrium. 2

SECTION C

26. Two circular loops A and B, each of radius 3 m, are placed coaxially at a distance of 4 m. They carry currents of 3 A and 2 A in opposite directions respectively. Find the net magnetic field at the centre of loop A. 3

27. (a) The figure shows the variation of induced emf as a function of rate of change of current for two identical solenoids X and Y. One is air cored and the other is iron cored. Which one of them is iron cored ? Why ?
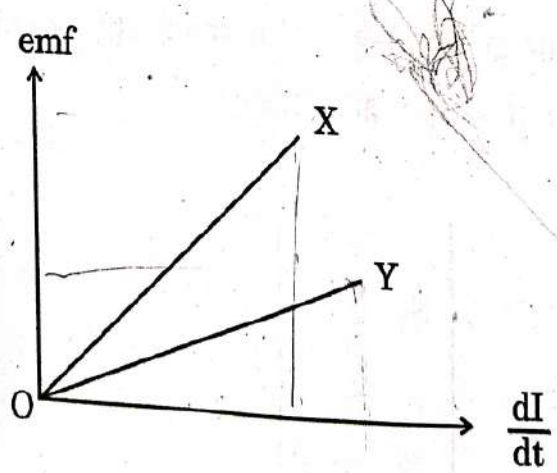
(b) Obtain an expression for self-inductance of a long solenoid of length L and cross-sectional area A having N turns. 3

28. **(a)** A resistor of 30 Ω and a capacitor of $\frac{250}{\pi}$ μF are connected in series to a 200 V, 50 Hz ac source. Calculate (i) the current in the circuit, and (ii) voltage drops across the resistor and the capacitor. (iii) Is the algebraic sum of these voltages more than the source voltage ? If yes, solve the paradox. 3

OR

(b) A series LCR circuit with R = 20 Ω, L = 2 H and C = 50 μF is connected to a 200 volts ac source of variable frequency. What is (i) the amplitude of the current, and (ii) the average power transferred to the circuit in one complete cycle, at resonance ? (iii) Calculate the potential drop across the capacitor. 3

29. **(a)** **(i)** In diffraction due to a single slit, the phase difference between light waves reaching a point on the screen is 5π. Explain whether a bright or a dark fringe will be formed at the point.

(ii) What should the width (a) of each slit be to obtain eight maxima of two double-slit patterns (slit separation d) within the central maximum of the single slit pattern ?

(iii) Draw the plot of intensity distribution in a diffraction pattern due to a single slit. 3

OR

(b) **(i)** In a Young's double-slit experiment $SS_2 - SS_1 = \frac{\lambda}{4}$, where S_1 and S_2 are the two slits as shown in the figure. Find the path difference $(S_2P - S_1P)$ for constructive and destructive interference at P.
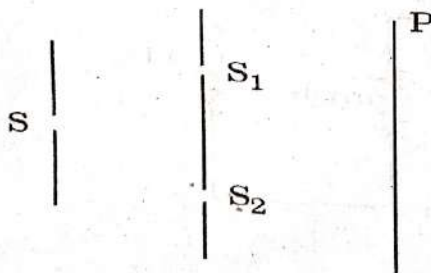
(ii) What is the effect on the interference fringes in a Young's double-slit experiment, if the monochromatic source S is replaced by a source of white light? 3

30. Briefly explain Geiger-Marsden experiment. Show the variation of the number of particles scattered (N) with scattering angle (θ) in this experiment. What is the main conclusion that can be inferred from this plot? 3
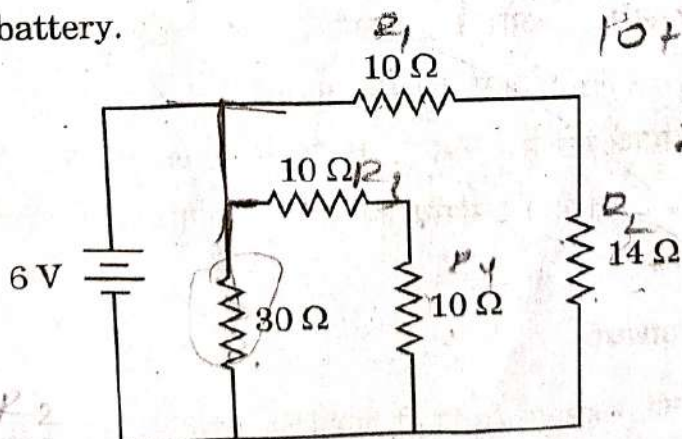
SECTION D

31. (a) (i) Define mobility of electrons. Give its SI units.

(ii) A steady current flows through a wire AB, as shown in the figure. What happens to the electric field and the drift velocity along the wire? Justify your answer.
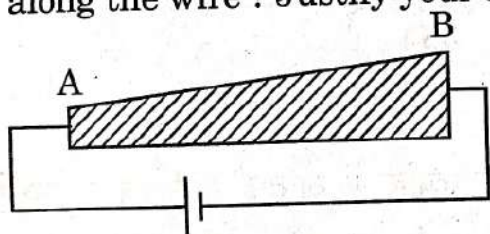
(iii) Consider the circuit shown in the figure. Find the effective resistance of the circuit and the current drawn from the battery. 5
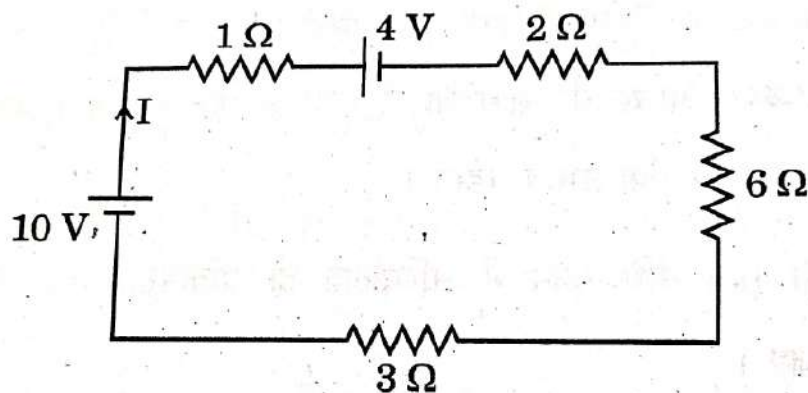

OR

(b) (i) Define electrical conductivity of a wire. Give its SI unit.

(ii) High current is to be drawn safely from (1) a low-voltage battery, and (2) a high-voltage battery. What can you say about the internal resistance of the two batteries ?

(iii) Calculate the total energy supplied by the batteries to the circuit shown in the figure, in one minute.

32. (a) (i) Draw a ray diagram to show how the final image is formed at infinity in an astronomical refracting telescope. Obtain an expression for its magnifying power.

(ii) Two thin lenses L_1 and L_2, L_1 being a convex lens of focal length 24 cm and L_2 a concave lens of focal length 18 cm are placed coaxially at a separation of 45 cm. A 1 cm tall object is placed in front of the lens L_1 at a distance of 36 cm. Find the location and height of the image formed by the combination. 5

OR

(b) (i) Explain the working principle of an optical fibre with the help of a diagram. Mention one use of a light pipe.

(ii) A ray of light is incident at an angle of 60° on one face of a prism with the prism angle A = 60°. The ray passes symmetrically through the prism. Find the angle of minimum deviation (δ_m) and refractive index of the material of the prism. If the prism is immersed in water, how will δ_m be affected ? Justify your answer.   5

33. (a) (i) A germanium crystal is doped with antimony. With the help of energy-band diagram, explain how the conductivity of the doped crystal is affected.

(ii) Briefly explain the two processes involved in the formation of a p-n junction.

(iii) What will the effect of (1) forward biasing, and (2) reverse biasing be on the width of depletion layer in a p-n junction diode ?   5

OR

(b) (i) With the help of a circuit diagram, briefly explain the working of a full-wave rectifier using p-n junction diodes.

(ii) Draw V – I characteristics of a p-n junction diode. Explain how these characteristics make a diode suitable for rectification.

(iii) Carbon and silicon have the same lattice structure. Then why is carbon an insulator but silicon a semiconductor ?   5

34. Electrostatics deals with the study of forces, fields and potentials arising from static charges. Force and electric field, due to a point charge is basically determined by Coulomb's law. For symmetric charge configurations, Gauss's law, which is also based on Coulomb's law, helps us to find the electric field. A charge/a system of charges like a dipole experience a force/torque in an electric field. Work is required to be done to provide a specific orientation to a dipole with respect to an electric field.

Answer the following questions based on the above :

(a) Consider a uniformly charged thin conducting shell of radius R. Plot a graph showing the variation of $|\vec{E}|$ with distance r from the centre, for points $0 \leq r \leq 3R$. 1

(b) The figure shows the variation of potential V with $\frac{1}{r}$ for two point charges Q_1 and Q_2, where V is the potential at a distance r due to a point charge. Find $\frac{Q_1}{Q_2}$. 1
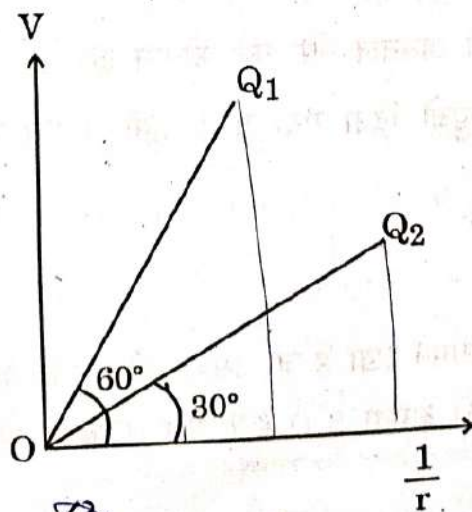
(c) An electric dipole of dipole moment of 6×10^{-7} C-m is kept in a uniform electric field of 10^4 N/C such that the dipole moment and the electric field are parallel. Calculate the potential energy of the dipole.　　2

OR

(c) An electric dipole of dipole moment $\vec{p}$ is initially kept in a uniform electric field $\vec{E}$ such that $\vec{p}$ is perpendicular to $\vec{E}$. Find the amount of work done in rotating the dipole to a position at which $\vec{p}$ becomes antiparallel to $\vec{E}$.　　2

35. The lens maker's formula is useful to design lenses of desired focal lengths using surfaces of suitable radii of curvature. The focal length also depends on the refractive index of the material of the lens and the surrounding medium. The refractive index depends on the wavelength of the light used. The power of a lens is related to its focal length.

Answer the following questions based on the above :

(a) How will the power of a lens be affected with an increase of wavelength of light ?　　1

(b) The radius of curvature of two surfaces of a convex lens is R each. For what value of μ of its material will its focal length become equal to R ?　　1

(c) The focal length of a concave lens of $\mu = 1.5$ is 20 cm in air. It is completely immersed in water of $\mu = \dfrac{4}{3}$. Calculate its focal length in water.　　2

OR

(c) An object is placed in front of a lens which forms its erect image of magnification 3. The power of the lens is 5 D. Calculate the distance of the object and the image from the lens.　　2