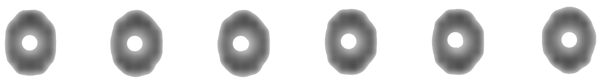
PHYSICS

BOOKS - ARIHANT PHYSICS (HINGLISH)

WAVE PARTICLE DUALITY AND ATOMIC PHYSICS

Others

1. A beam of red light $(\lambda_r = 800 nm)$ is made up of a stream of photons. In the diagram shown the size of dots represent the photon energy and the spacing represents the spatial distribution of photons.



Copy the diagram in your notebook, and just below it draw a similar diagram representing a beam of blue light $(\lambda_b = 400 nm)$ having same intensity.

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2. The brightness of an incandescent light bulb is con- trolled by a regulator. The regulator is a variable resistor connected in series with the bulb. What happens to the colour of the light given off by the bulb as the resistance of the regulator is increased? What happens to the average energy of photons given out by the bulb? Does it increase?

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3. Find the change in energy of a photon of blue light $(\lambda = 400\text{Å})$ when the light enters into a medium of refractive index $\mu = \frac{4}{3}$.

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4. A $0.6 \times 10^{-3} W$ laser is aimed at the Moon. The wavelength of emitted light is 600 nm and the laser beam spreads out of the source at a divergence angle of $\theta = 0.5 \times 10^{-3} rad$. The Earth-Moon distance is nearly $4 \times 108 m$. Calculate the maximum number of photons arriving per second per square meter on the Moon? Neglect any absorption by the atmosphere.

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5. A laser beam of wavelength $\lambda_1 = 5 \times 10^{-7} m$ strikes normally a blackened plate and produces a force of $10^{-5} N$. Mass of the plate is $10 g$ and its specific heat capacity is $400 J kg^{-1} K^{-1}$. At what rate will the temperature of the plate rise? Assume no heat loss to the surrounding.

6. When photons of wavelength $\lambda_1 = 2920\text{Å}$ strike the surface of metal A, the ejected photoelectron have maximum kinetic energy of $k_1 eV$ and the smallest de-Broglie wavelength of λ. When photons of wavelength $\lambda_2 = 2640\text{Å}$ strike the surface of metal B the ejected photoelectrons have kinetic energy ranging from zero to $k_2 = (k_1 - 1.5)eV$. The smallest de-Broglie wavelength of electrons emitted from metal B is 2λ. Find

(a) Work functions of metal A and B.

(b) k_1

Take $hc = 12410 eV \text{Å}$

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7. Work function of metal X is equal to $3.5eV$ and work function of material Y is equal to ionization energy of He+ ion in its first excited state. Light of same wavelength is incident on both X and Y. The maximum kinetic energy of photoelectrons emitted from X is twice that of photoelec- trons emitted from Y. Find the wavelength of incident light. $hc = 12400 eV \text{Å}$.

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8. A particle of mass m is allowed to fall freely under gravity on an elastic horizontal surface. The quantum effect become important if the smallest de-Broglie wavelength of the particle is of the same order as the height from which it was dropped. Write the mechanical energy of the particle if quantum effects become important

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9. A microscope can make you "see" something as small as the wavelength of wave used to make the observation. Calculate the minimum energy of an electron needed in an electron microscope to see a hydrogen atom.

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10. Electrons originally at rest are accelerated through a potential difference of V volts. The applied potential differ- ence is measured using a voltmeter having a least count of DV. The electrons in the beam have a de-Broglie wavelength of $\lambda \pm \Delta\lambda [\Delta\lambda < \ <]$. Find $\left|\frac{\Delta\lambda}{\lambda}\right|$.

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11. Calculate the ratio of de-Broglie wavelength of molecules of hydrogen and oxygen kept in two separate jars at $27^{\circ}C$ and $127^{\circ}C$ respectively.

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12. Calculate de-Broglie wavelength of hydrogen molecules (H_2) present in a container at $400K$. Assume that molecules travel at rms speed. Boltzmann constant

$k = 1.38 \times 10^{-23} JK^{-1}$ Mass of H_2 molecule

$= 2.0 a\mu$

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13. In a nuclear physics experiment, electrons are to be accelerated so as to have de-Broglie wavelength of the order of the diameter of a heavy nucleus $(\sim 10^{-14} m)$. Determine the momentum of the electron needed to make the wavelength of electrons equal to diameter. Use the classical formula for momentum,

$p = m_0 v$ to determine the speed of electrons. Is this speed permissible? Now use the relativistic mass of the electrons in the expression of momentum to find the speed of electrons. Relativistic mass is given by $m = \frac{m_0}{\sqrt{1 - v^2 / c^2}}$.

Where m_0 is rest mass and v is speed of the particle.

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14. A parallel beam of monochromatic light of frequency v is incident on a surface. Intensity of the beam is I and area of the surface is A. Find the force exerted by the light beam on the surface for following cases–

(i) the surface is perfectly absorbing and the light beam is incident normally on it.

(ii) the surface is perfectly reflecting and the light beam is incident normally.

(iii) the surface is perfectly absorbing and the light beam is incident at an angle of incidence θ.

(iv) the surface is perfectly reflecting and the light beam is incident at an angle of incidence θ.

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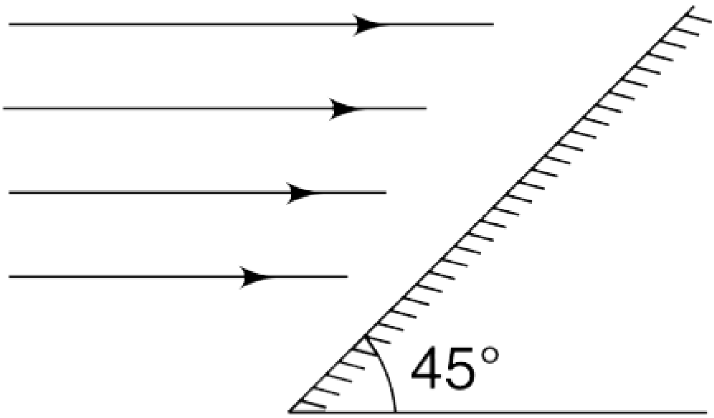
15. A horizontal beam of light in incident on a plane mirror inclined at 45° to the horizontal. The percentage of light energy reflected from the mirror is 80%. Find the direction in which the mirror will experience force due to the incident light.



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16. Intensity of sunlight on the surface of the earth is $I = 1400W/m^2$ (neglecting atmospheric absorption).

(a) Find the Wattage of the Sun.

(b) Assuming that light emitted from the sun is monochromatic having wavelength $l = 6000\text{Å}$, estimate the number of photons emitted from the sun in one second.

(c) According to mass energy equivalence principle, estimate the decrease in mass of the sun in one second.

Given: $h = 6.64 \times 10^{-34} Js, c = 3 \times 10^8 m/s$

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17. A perfectly absorbing solid sphere with a known fixed density, hovers stationary above the sun. This is because the gravitational attraction of the sun is balanced by the pressure due to the sun's light. Assume the sun is far enough away so that it closely approximates a point source of light. Find the radius of the sphere and prove that it is independent of the distance of the sphere from the Sun.

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18. Prove that Bohr's condition for quantization of angular momentum in hydrogen atom can be obtained by requiring an integer number of standing waves around an electron orbit. Use de-Broglie wavelength as the wavelength of wave associated with electron.

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19. The circumference of circular orbit of electron in a He^{+} ion is five times the de-Broglie wavelength associated with the electron. Find the radius of the orbit.

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20. A gas of hydrogen - like atoms can absorb radiations of $698eV$. Consequently , the atoms emit radiation of only three different wavelengths . All the wavelengthsare equal to or smaller than that of the absorbed photon.

a Determine the initial state of the gas atoms.

b Identify the gas atoms

c Find the minimum wavelength of the emitted radiation ,

d Find the ionization energy and the respective wavelength for the gas atoms.

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21. A small particle of mass m moves in such a way that the potential energy $U = ar^2$ where

a is a constant and r is the distance of the particle from the origin. Assuming Bohr's model of quantization of angular momentum and circular orbits, find the radius of n^{th} allowed orbit.

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22. Hydrogen like atoms (atomic number $= Z$) in a sample are in excited state with principal quantum number n. The emission spectrum of the sample has 15 different lines. The second most energetic photon emitted by the sample has energy of $27.2eV$. Find Z.

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23. A μ – meson (charge $= -e$, mass $= 208m_e$) moves in a circular orbit around a heavy nucleus having charge $+3e$. Find the quantum state n for which the radius of the orbit is same as that of first Bohr orbit for hydrogen atom.

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24. A hydrogen like atom (atomic number = Z) is in higher excited state of quantum number n. This excited atom can make a transition to first excited state by successively emitting two photons of energy $22.94eV$ and $5.15eV$. The atom from the same state n can make transition to second excited state by successively emitting two photons of energies $2.4eV$ and $8.7eV$. Find values of n and Z.

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25. A system of positron $\left(+1^{e^0}\right)$ and electron $\left(-1^{e^0}\right)$ is called Positronium atom. The radii of Positronium atom is expanded but energy levels are reduced by a factor of x compared to H – atom.

(a) Find x

(b) Is it true to say that the entire spectrum of Positronium will be shifted towards longer wavelength compared to H – atom.

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26. A negatively charged muon (mass 207 times the mass of an electron) is captured in a Bohr's orbit of high principal quantum number (n). The atom thus formed is called mesic atom. The muon in high energy state cascades down to lower orbits by emitting photons.

(a) The emitted photons are X rays. Why?

(b) Find the atomic number (Z) of a mu-mesic atom in which the orbit with $n = 1$ will just touch the nuclear surface. Assume that the nucleus has equal number of protons and neutrons.

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27. Consider a gas of hydrogen atom filling a cubical box of side length 1 m. Assume that all hydrogen atoms are in their ninth excited state and they fill up the space like footballs filling up a room. Estimate the number of hydrogen atoms in the room.

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28. Hydrogen atoms in ground state are bombarded by electrons accelerated through a potential difference of V volts. For what range of values of V, will we get only one spectral line in the spectrum of hydrogen atoms excited by impacts of electrons? Take ground state energy of hydrogen atom to be $-13.6eV$.

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29. A glass tube has Be^{+++} ions excited to their second excited state. The radiation coming out of this tube is incident on a metal plate having work function $f = 5eV$. Find the minimum de-Broglie wavelength of emitted photoelectrons.

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30. An electron in an excited hydrogen atom makes transition from a state of quantum number n to a state of quantum number $(n-1)$.

(a) Show that the frequency of emitted radiation is intermediate between the frequencies of orbital revolution in initial and final states.

(b) What is the relationship between frequency of emitted photon and the orbital frequency of the electron when n is large?

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31. Hydrogen atoms in very high quantum state have been observed in radio astronomy. The wavelength of radiation emitted when hydrogen atom makes transition from $n = 110$ state to $n = 109$ state is $\lambda = 5.8 cm$. Imagine a He atom in which one of the electrons has been excited to $n = 110$ state. What will be wavelength of emitted radiation if the electron makes transition to $n = 109$?

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32. A moving hydrogen atom absorbs a photon and comes to rest. What is the maximum possible wavelength of photon? $[hc = 12420 eV \text{Å}]$

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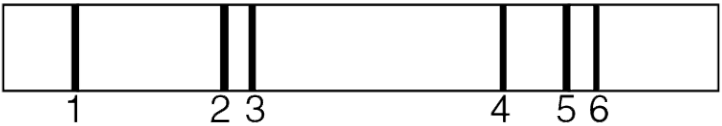
33. A tube contains a sample of hydrogen atoms which are all in their third excited state. The atoms de-excite and a spectrum of the radiation emitted is obtained. The spectrum is shown in the given figure.



(a) Which of the lines $(1, 2, 3, 4, 5$ or $6)$ represent a transition from quantum state $n = 3$ to $n = 2$.

(b) Which of the lines represent the one with second smallest wavelength?

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34. The biding energy of an electron in the ground state of He atom is 25 eV. Find the energy required to remove both the electrons.

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35. Which of the followings can excite a hydrogen atom in ground state?

(i) A photon having 11 eV energy

(ii) A neutron having $11eV$ kinetic energy

(iii) An electron having $11eV$ kinetic energy

Give reasons for your answer.

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36. Absorption spectrum is obtained for a sample of gas having atomic hydrogen in ground state. Which lines of the spectrum will be in the range $94nm$ to $122nm$.

Take Rydberg's constant $R = 1.1 \times 107m^{-1}$

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37. Radiation from hydrogen gas excited to first excited state is used for illuminating certain photoelectric plate . When the radiation from same unknown hydrogen-like gas excited to the same level is used to expose the same plate , it is found that the de Broglie wavelength of the fastest photoelectron has decreased $2.3 time$gt It is given that the energy corresponding to the longest wavelength of the Lyman series of the known gas is 3 times the ionization energy of the hydrogen gas $(13.6 eV)$. Find the work function of photoelectric plate in eV.

$\left[Take(2.3)^2 = 5.25\right]$

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38. An X ray tube with Copper target is found to emit characteristic X rays other than only due to Copper. The ka lie of Copper has a wavelength of 1.5405Å. The other Ka line observed is having a wavelength of 1.6578Å. Identify the impurity.

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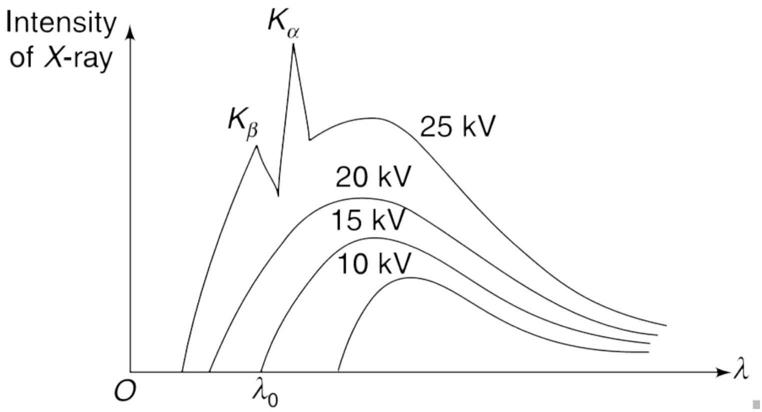
39. X-ray spectrum obtained from a metallic target has been shown in the figure. The spectrum has been obtained for four different accelerating voltages in the X-ray tube: $25kV$, $20kV, 15kV$ and $10kV$.



(a) Find the value of λ_0 shown in the graph.

(b) What can you say about the energy of a K-shell electron in the target atom?

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40. When the voltage applied to an X-ray tube increases from 10 to $20kV$ the wavelength difference between the ka line and the short wave cut-off of continuous X-ray spectrum increases by a factor of 3.0. Identify the target element. Take $\frac{4}{3}R = 1200 Å$ where R is Rydberg's contant and $hc = 12.4keV Å$

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41. An X-ray tube has nickel as target. The wavelength difference between the ka X-ray and the cut-off wavelength of continuous X-ray spectrum is 84 pm. Find the accelerating voltage applied in the X-ray tube.

[Take $hc = 12400 eV Å$]

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42. How many elements have ka lines between 241 pm and 180 pm?

Take Rydberg's constant $R = 1.09 \times 107 m^{-1}$

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43. In an electron capture process, a nucleus captures an electron from K shell of the atom. The electron is having a binding energy of B_0. Followed by this capture of electron, several photons are emitted due to electronic transitions. What will be Sum of energy of all such photons emitted?

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44. A normal human eye can detect yellow light if more than 10 photons enter into it per second. A star is generating as much power as the Sun and is emitting predominantly yellow light $(\lambda = 6000 \text{Å})$. How far is the star if our eye isbarely able to see it? It is given that intensity of solar light on surface of the earth is $I = 1400 W m^{-2}$ and the distance of the Sun from the Earth is $r = 1.5 \times 10^{11} m$. The diameter of pupil of our eye is $d = 6 mm$.

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45. A microwave oven operates at 2.5 GHz. Assume that 5% of microwave photons are absorbed by 200 ml of water kept inside the oven. The time needed to warm the water from $20^{\circ}C$to $70^{\circ}C$ is 2 minute. Specific heat capacity of water is $4.2Jg^{-1}.^{\circ}C^{-1}$. Neglect any heat loss by water to the surrounding. Calculate the number of photons emitted per second per kilowatt of power consumed by the microwave. Efficiency of the oven to convent electrical energy into microwave energy is 70%

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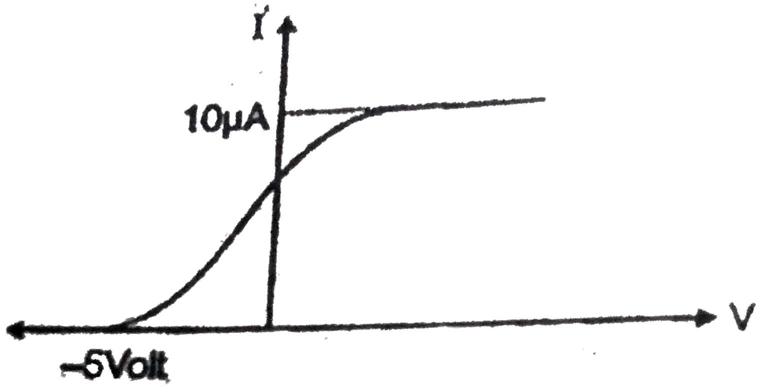
46. In the photoelectric experiment, if we use a monochromatic light, the I-V curve is as shown. If work function of the metal is 2eV, estimate the power of light used. (Assume efficiency of photo emission $= 10^{-3}\%$, i.e. number of photoelectrones emitted are $10^{-3}\%$ of number of photons incident on

metal.)



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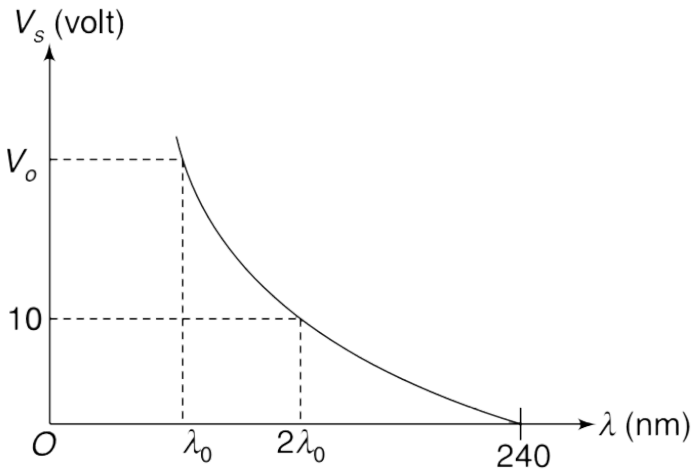
47. In a photoelectric experiment light of different wavelengths are used on a metal surface. For each wavelength the stopping potential difference is recorded. The given graph shows the variation of stopping potential difference (V_s) versus the wavelength (l) of light used. Find the value of V_0 shown in the graph. Given $h = 4 \times 10^{-15} eVs$ and $c = 3 \times 108 ms^{-1}$.



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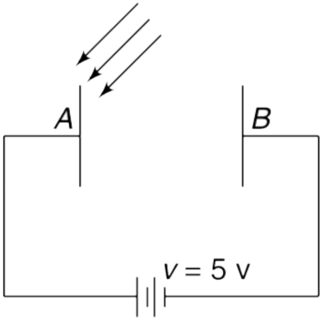
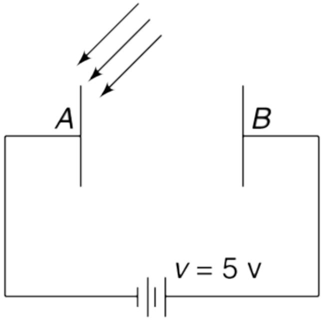
48. In a photoelectric experiment, a monochromatic light is incident on the metal plate A. It was observed that with $V = 5\text{volt}$, the maximum kinetic energy of photoelectrons striking plate B was $1eV$. The polarity of the applied potential difference was as shown in figure (a). With polarity of the applied potential difference reversed (as shown in figure (b)) and frequency of incident light doubled, it was observed that in saturation state, the kinetic energy of electrons striking plate B ranged between 5 eV to 20 eV. Find the work function of metal used in plate A.



(a)



(b)

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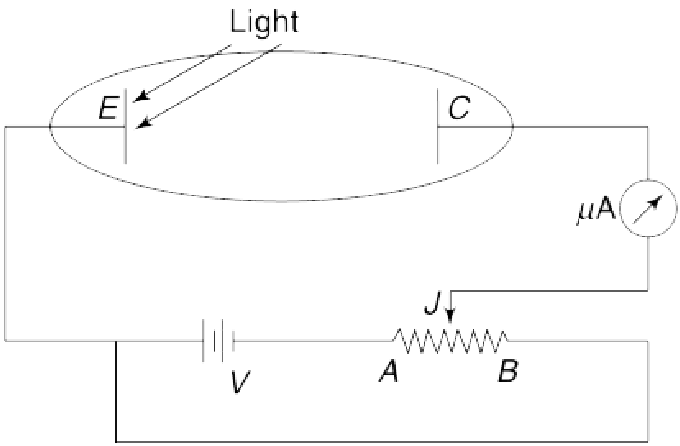
49. In a photoelectric experimental set-up ultraviolet light of wavelength 350 nm is incident on emitter plate (E). The work function of the emitter plate is $\phi = 2.2$ eV. AB is a uniform wire resistor having length $L = 100cm$. Resistance of the wire AB is 10 W and the emf of the battery is $V = 10$ volt. The sliding contact J can be moved along the wire AB. When the sliding contact is placed at end B of the wire resistor the micro-ammeter shows a reading of $i = 6\mu A$. For answering the following questions assume that photoelectric current is very small compared to the current through the cell.

(a) Find the reading of the ammeter when the slider is moved to end A of the wire.

(b) The slider is moved gradually away from A.

Plot the variation of ammeter reading versus distance of the slider measured from A.

(c) Find the maximum speed with which an electron will hit the collector plate (C) if slider J is placed at a distance of $95 cm$ from A



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50. A point source is emitting 0.2 W of ultravio- let radiation at a wavelength of $\lambda = 2537 \text{Å}$. This source is placed at a distance of $1.0 m$ from the cathode of a photoelectric cell. The cathode is made of potassium (Work function $= 2.22 eV$) and has a surface area of $4 cm^2$.

(a) According to classical theory, what time of exposure to the radiation shall be required for a potassium atom to accumulate sufficient energy to eject a photoelectron. Assume that radius of each potassium atom is 2 Å and it absorbs all energy incident on it.

(b) Photon flux is defined as number of light photons reaching the cathode in unit time. Calculate the photon flux.

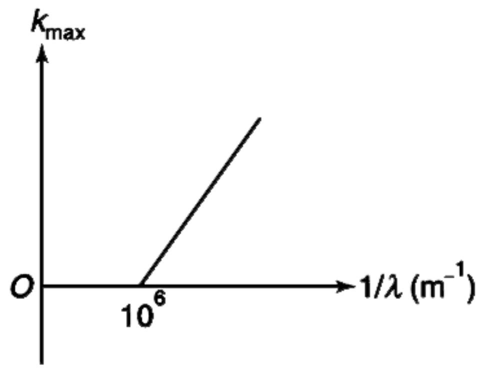
(c) Photo efficiency is defined as probability of a photon being successful in knocking out an electron from the metal surface. Calculate the saturation photocurrent in the cell assuming a photo efficiency of 0.1.

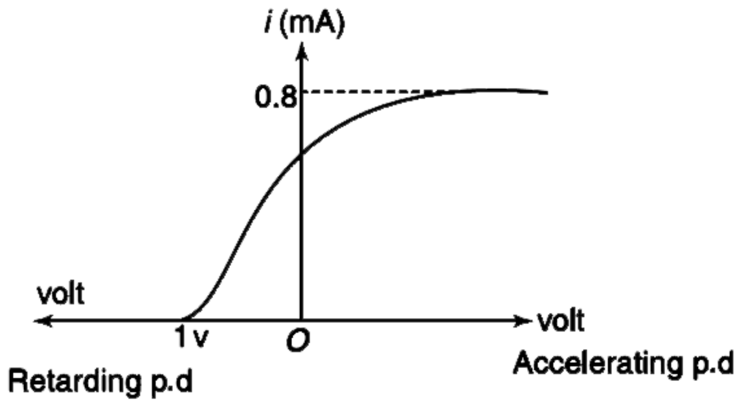
(d) Find the cut – off potential difference for the cell.

51. In photoelectric experiment set up, the maximum kinetic energy (k_{max}) of emitted photoelectrons was measured for different wavelength (λ) of light used. The graph of k_{max} vs $\frac{1}{\lambda}$ was obtained as shown in first figure. In the same setup, keeping the wavelength of incident light fixed at l, the applied potential difference was varied and the photoelectric current was recorded. The result has been shown in graph in second figure.

(a) Find λ is Å

(b) Taking the photo efficiency to be 2% (i.e. percentage of incident photons which produce photoelectrons) find the power of light incident on the emitter plate in the experiment. [Take $hc = 12400 eV \text{Å}$]





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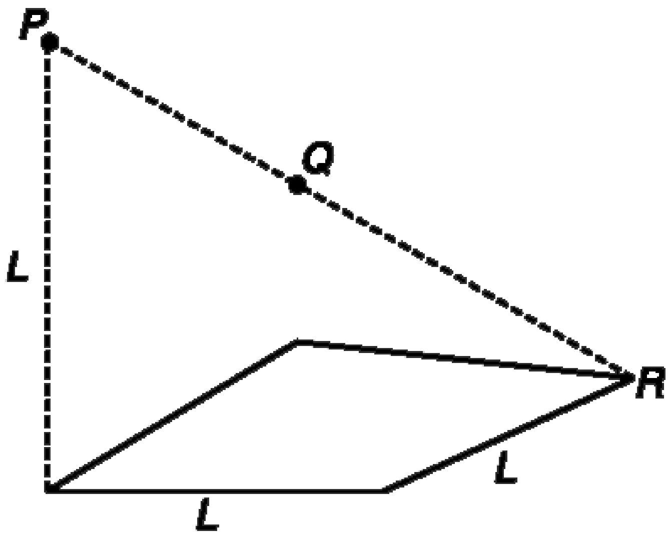
52. A square plate of side length L absorbs all radiation incident on it. A point source of light is placed at a point P which is directly above a corner of the plate at a height L. The incident light on the plate produces a force of magnitude F_0 on the plate. Calculate the magnitude of force on the plate if the source is moved to a point Q (Q is midpoint of the

line PR).



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53. A light photon of wavelength λ_0 is absorbed by an atom of mass m at rest in ground state. The atom is free to move. The atom after absorbing the incident photon, emits another photon in direction opposite to that of the incident photon and returns back to its ground state. In the process the atom acquires a kinetic energy k. Find λ_0 in terms of k and m.

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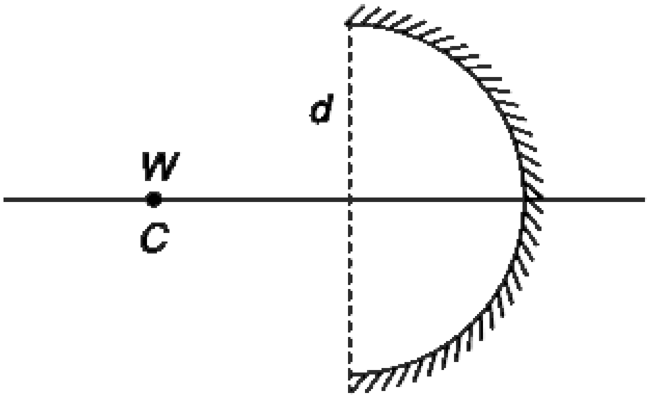
54. A spherical concave mirror has aperture diameter d and radius of curvature R. A point source of light is placed at its centre of curvature. Source emits power W and the mirror surface is completely reflecting. Find force on the mirror due to light incident on it.



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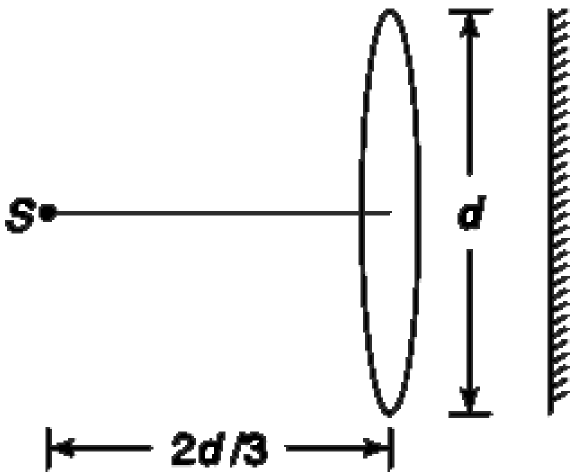
55. A point source (S) of light having power 500 W is kept at the focus of a lens of aperture diameter d. The focal length of the lens is $2\frac{d}{3}$. Assume that 40% of the incident light energy is transmitted through the lens and the complete transmitted light is incident normally on a perfectly reflecting surface placed behind the lens. Calculate the force on the reflecting surface.



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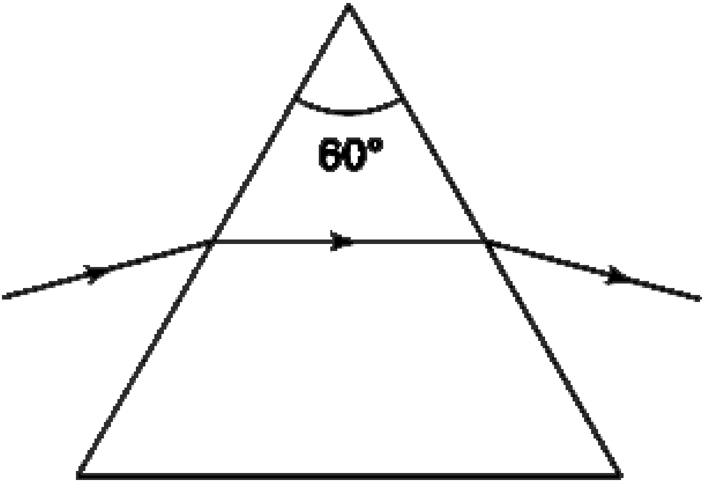
56. An equilateral glass prism kept on a table has refractive index of $\mu = \sqrt{2}$. It is illuminated by a narrow laser beam having power P_0 and wavelength l. The path of the laser beam inside the prism is parallel to the base of the prism. Calculate change in weight of the prism due to the incident laser beam.



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57. A proton X is projected in a region of uniform electric field E with speed u. Another proton Y is projected simultaneously with same speed u in a separate region having a

uniform magnetic field ‘B’. It was found that both X and Y had same de-Broglie wavelength after time T. Specific charge on a proton is $\sigma(C / kg)$.

(a) Find the angle a at which the proton X was projected with respect to the direction of electric field.

(b) Find the displacement of the proton X in time T.

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58. It is possible for a photon to materialize into an electron and a position. The process is called pair production.

(a) Using conservation of energy and momentum prove that pair production cannot occur in empty space.

(b) Argue qualitatively that such pair production is possible near a nucleus.

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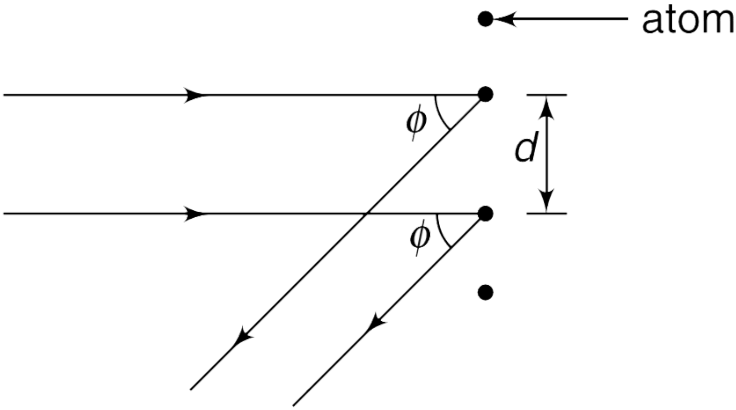
59. The figure shows the reflection of a plane wave by two neighbouring atoms on the surface of a crystal. The depicted waves are actually de-Broglie wave of electrons accelerated from rest by a potential difference of V volt. Neglect relativistic effects and take mass and charge of an electron to be m and e respectively. Calculate ϕ for the case of a constructive interference.



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60. A particle of mass m is trapped between two perfectly rigid parallel walls. The particle bounces back and forth between the walls without losing any energy. From a wave point of view, the particle trapped between the walls is like a standing wave in a stretched string between the walls. Distance between the two walls is L.

(a) Calculate the energy difference between third energy state and the ground state (lowest energy state) of the particle.

(b) Calculate the ground state energy if the mass of the particle is $m = 1mg$ and separation between the walls is $L = 1cm$.

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61. A moving H-atom makes a head on perfectly inelastic collision with a stationary Li^{++} ion. Just before collision, both $-H$ and Li^{++} are in their first excited state. Immediately after collision H was found to be in ground state and Li^{++} was in its second excited state. Find the kinetic energy of H – atom before collision. No photon is emitted in the process. Assume that mass of Li^{++} is nearly 7 times the mass of H.

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62. In a Lithium atom there is one electron in second orbit. The interaction of this electron with the two inner electrons can be accounted for by assuming that this electron (the electron in second orbit) sees a nuclear attraction of Z' protons (where $Z' < Z = 3$). Experimentally, it is known that $5.39 eV$ of energy is needed to remove the outermost electron from the atom.

(a) Find Z'

(b) Find the longest wavelength of photon that can be absorbed by the electron in $n = 2$ state.

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63. In a hypothetical hydrogen-like atom the wavelength in A° for the spectral lines for transitions from $n = P$ to $n = 1$ are given by $\lambda = \frac{1500p^2}{p^2 - 1}$ where p is an integer larger than is the ionization potential of this atom ?

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64. Assume that structure of hydrogen atom is gov- erned by classical mechanics. An electron is circulating around a proton and it is radiating energy at a rate given $\frac{dE}{dt} = \frac{e^2 a^2}{6\pi c^3 \in_0}$ where a is the acceleration of the electron.

Assume that speed of the electron is $v(> > c)$.

(a) Estimate the fraction of kinetic energy lost by the electron per revolution in terms of v. Make suitable assumptions.

(b) Is the energy loss per revolution large? Is it safe to assume that orbit is circular during a small time interval?

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65. In a hypothetical hydrogen atom the electrostatic potential energy of interaction of proton and electron is given by $U = U_0 \ln\left(\frac{r}{r_0}\right)$ where U_0 and r_0 are constants and r is radius of circular orbit of electron. For such hydrogen atom the energy difference between n^{th} and m^{th} state is represented by ΔE_{nm}. Calculate the ratio $\Delta E_{12} : \Delta E_{24}$ Assume Bohr's assumption of angular momentum quantization to hold.

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66. When radiations of wavelength $\lambda_1, \lambda_2 (= 0.6\lambda_1), \lambda_3 (= 4\lambda_2)$ and λ_4 are incident on a metal plate, photoelectrons with maximum kinetic energy of – 5.2 eV are emitted for $\lambda_1, 12\ eV$ are emitted for $\lambda_2, 0.95 eV$ are emitted for λ_4 and no electron is emitted for l3. It is known that a hydrogen like atom (atomic number Z) in a higher excited state of quantum number n can make a transition to first excited state by successively emitting two photons of wavelength $\lambda 1$ and λ_2 respectively. Alternatively, the atom from same excited state can make a transition to the second excited state by successively emitting two photons of wavelength λ_3 and λ_4 respectively.

(a) Find the work function of the metal.

(b) Find the values of n and Z for the atom.

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67. An electron approaches a fixed proton from a large distance with a kinetic energy of 12.2 eV. The electron gets captured by the proton to form a hydrogen atom in an excited state and a photon of wavelength $\lambda_1 = 796\text{Å}$ is emitted. Later, the hydrogen atom de-excites by emitting a single photon of wavelength λ_2. Find λ_2. [Take $h = 6.62 \times 10^{-34} Js, c = 3 \times 108 m/s$]

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68. A free hydrogen atom in its ground state is at rest. A neutron having kinetic energy k_0 collides head one with the atom. Assume that mass of both neutron and the atom is same.

(a) Find minimum value of k_0 so that this collision can be inelastic.

(b) If $k_0 = 25eV$, find the kinetic energy of neutron after collision if its excites the hydrogen atom to its second excited state.

Take ionization energy of hydrogen atom in ground state to be $13.6eV$.

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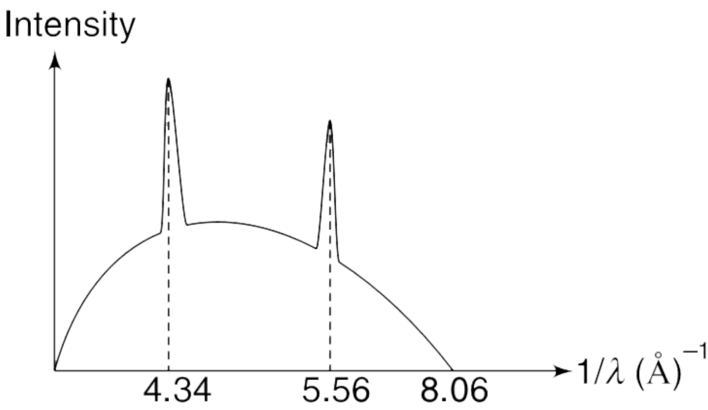
69. The X-ray spectrum of a metallic target has been shown in figure

(a) What is the accelerating potential difference for bombarding electrons?

(b) Two characteristic X-rays have been shown in the figure one of them is k_{α} X-ray and the other one is k_{β} X-ray. What is wavelength of k_{α} X-ray?

(c) Find the atomic number of the target atom.



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70. In a X-ray tube, after an electron has been removed from an inner shell of a target atom, an electron from outer shell falls into the vacancy and the excess energy is usually released in form of a photon. Many a times an atom chooses to release this excess energy by ejecting another electron. The ejected electron is called Auger electron. In one such event, the bombarding electron removed an electron from K shell of a target atom. An electron from L shell falls to occupy the vacant K shell position, and the excess energy is used by the atom to eject an Auger electron from L shell. What will be kinetic energy of such an Auger electron if the ionization energies for K and L shell of the atom is E_k and E_L respectively.

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71. A hydrogen atom in ground state is moving with a kinetic energy of 30 eV. It collides with a deuterium atom in ground state at rest. The hydrogen atom is scattered at right angle to its original line of motion. Assume that energy of n^{th} state in both the atoms is given by $E_n = -\frac{13.6}{n^2} eV$ and the mass of deuterium is twice that of hydrogen. Write the maximum and minimum possible kinetic energy of deuterium after collision.

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72. A hydrogen atom at rest de-excites from n = 2 state to n = 1 state. Calculate the percentage error in calculation of momentum of photon if recoil of atom is not taken into account. The energy equivalent of rest mass of hydrogen atom is 940 MeV.

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