PHYSICS

BOOKS - DHANPAT RAI & CO PHYSICS (HINGLISH)

ELECTRONS AND PHOTONS

Example Solution

1. The voltage across the electrodes of a cathode ray gun is 500 V. calculate

(i) the energy gained by the electrons,

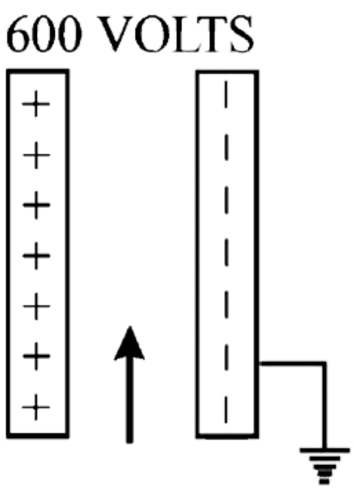
(ii) the speed of the electrons, and

(iii) the momentum of the electrons.

2. (a) Estimate the speed with which electrons emitted from a heated cathode of an evacuated tube impinge on the anode maintained at a potential difference of 500 V with respect to the cathode. Ignore the small initial speeds of the electrons. The specific charge to of the electron, i.e., its e/m is given to $1.76 \times 10^{11} Ckg^{-1}$.

(b) Use the same formula you employ in (a) to obtain electron speed for an anode potential of 10 MV. Do you see what is wrong? In what way is the formula to be modified?

3. A potential difference of $600vo < s$ is applied across the plates of a parallel plate consenser . The separation between the plates is $3mm$. An electron projected vertically, parallel to the plates , with a velocity of $2 \times 10^6 m/\sec$ moves underflected between the plates. Find the magnitude and direction of the magnetic field in the region between the condenser plates. (Neglect the edge effects). (Charge of the electron `= -1.6xx10^(-19) coulomb)



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4. Electrons which have been accelerated by a potential difference of 1000 V enter co-terminus electric and magnetic fields of strengths $20V/cm$ and 1 G respectively as in the Thomson's experiment. Estimate the e/m and the speed fo the electrons if they move undeviated through this system.

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5. In Thomson's experiment for determining e/m the potential different between the cathod and the anod (in accelerating coloumns) is same as that between the deflecting plates (in the regions of crossed field) . If the

$p.d$ is doubled , by what factor should the magnetic field be increased to ensure that the electron beam remains undeflected

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6. (a) A monoenergetic electron beam with electron speed of $5.20 \times 10^6 ms^{-1}$ is subjected to a magnetic field of $1.30 \times 10^{-4} T$, normal to the beam velocity. What is the radius of the circle traced by the beam, given e/m for electron equal $1.76 \times 10^{11} C.kg^{-1}$.

(b) Is the formula you employ in (a) valid for calculating radius of the path of 20 MeV electrons beam? If not, in what way is it modified!

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7. An electron initially at rest, is accelerated through a potential difference of 200 volt, so that it acquires a velocity $8.4 \times 10^6 m / s$. The value of e / m of elctron

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8. An electron moving with a speed of $2.5 \times 10^7 ms^{-1}$ is deflected by an electric field of 1600 Vm^{-1} perpendicular to its circular path. If the radius of the electron trajectory is 2.3 m, calculate the e/m for the electron.

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9. an electron beam passes through a magnetic field of magnetic induction $2 \times 10^{-3} T$ and an electric field of strength $3.4 \times 10^4 V/m$ both acting simultaneously in mutually perpendicular directions. If the path of electrons remains undeviated, calculate the speed of the electrons. If the electric field is removed, what will be the radius of curvature of the trajectory of the electron path after 2s?

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10. An electron entering a magnetic field of $0.01T$ with a velocity of $10^7 ms^{-1}$ describes a circle of radius 0.6 cm. Calculate e/m (specific charge) of the electron.

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11. In an experiment to determine e/m using Thomson's method, electrons from the cathode accelerate through a potential difference of 1.5 kV. The collimated beam of electrons is made to enter a region of crossed electric and magnetic fields, both perpendicular to beam direction. Two parallel plates 2.0 cm apart held at a potential difference of 400 V provide the electric field. while a magnetic field of $8.6 \times 10^{-4} T$ is produced by Helmholtz coils arrangement. The beam hits the fluorescent screen at the end of the tube undeflected. Determine the charge to mass ratio of electron.

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12. An electron gun with its anode at a potential of 100V fires out electrons in a spherical bulb containing hydrogen gas at low pressure $(10^{-2} nmofHg)$. A magnetic field of $2.83 \times 10^{-4} T$ curves the path of the electrons in a circular orbit of radius 12.0 cm. (The path can be viewed because the gas ions in the path focus the beam by attracting electrons and emitting light by electron capture, this method is known as 'fine beam tube' method). Determine e/m from the data.

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13. An electron moving in a horizontal direction with a speed of $5.0 \times 10^{7} ms^{-1}$ enters a region where there is an electric field of 2000 V m^{-1} directed upwards in its plane of motion. Find the electron coordinates referred to the point of entry and its direction of motion 4×10^{-8}s later.

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14. Calculate the voltage needed to balance on all drop carrying 10 electrons when located between the plates of a capacitor which are 5 mm apart. Mass of oil drop is $3 \times 10^{-16} kg$(take $g = 10m / s^2$)

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15. An oil drop of radius $10^{-6} m$ carries a charge equal to that on an electron. If the density of the oil is $2 \times 10^3 kgm^3$

, find the electric field required to keep it stationary. Take $e = 1.6 \times 10^{-19} C$ and $g = 9.8 m s^{-2}$.

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16. In Millikan's experiment, a drop of diameter $10^{-4} cm$ with a density of $0.9 g / cm^3$ is observed. The condenser plates are 2 cm apart. A potential of 72 V applied across the plates keeps the drop just in balance. How many electronic charges are there in the oil drop ?

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17. Calculate the energy and momentum of a photon of wavelength $6600 Å$

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18. Calculate the frequency associated with a photon of energy $3.3 \times 10^{20} J$.

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19. Frequency of photon having energy 66 eV is

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20. The wavelength of a spectral line is 4000Å. Calculate its frequency and energy.

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21. (a) An X-ray tube produces a continuous spectrum of radiation with its shorts wavelength end ate0.45Å. What is the maximum energy of the photon in the radiation? (b) From your answer to (a) , guess what order of accelerating voltage (for electrons) is required in such a tube?

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22. In an accelerator experiment on high energy collision of electrons with positrons, a certain events is interpreted as annihilation of an electron-positron pair of total energy 10.2 BeV into two γ-rays of equal energy. What is the wavelength associated with each γ-rays?

$(1BeV = 10^9 eV)$

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23. Find the number of photons emitted per second by a MW transmitter of $10kW$ power emitting radiowaves of wavelength $500m$.

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24. Find the number of photons entering the pupil of our eye per second corresponding to the minimum internsity of white light that we humans can perceive $(-10^{-10} Wm^{-2})$. Take the area of the pupil to be about

$0.4 cm^2$, and the average frequency of white light to be about $6 \times 10^{14} Hz$.

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25. Find the number of photons emitted per second by a 25 watt source of monochromatic light of wavelength 6000Å.

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26. If 5% of the energy supplied to a bulb is irradiated as visible light, how many quanta are emitted per second by a 100 W lamp? Assume wavelength of visible light as 5.6×10^{-5} cm.

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27. Energy from the sun is recived on earth at the rate of 2 cal per cm^2 per min. If avergae wavelength of solar light be taken at $5500A$ then how many photons are recived on the earth per cm^2 per min ?

$(h = 6.6 \times 10^{-34} J - s, 1cal = 4.2J)$

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28. If a photoemissive surface has a threshold frequency of $.6 \times 10^{14} Hz$, calculate the energy of the photons in eV. Given $h = 6.6 \times 10^{-34} Js$.

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29. Work function of sodium is 2.3 eV. Does sodium show photoelectric emission for orange light $(\lambda = 6800\text{Å})$?

Given $h = 6.63 \times 10^{-34} Js$

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30. The threshold frequency of a certain metal is $3.3 \times 10^{14} Hz$. If light of frequency $8.2 \times 10^{14} Hz$ is incident on the metal, predict the cut off voltage for photoelectric emission. Given Planck's constant, $h = 6.62 \times 10^{-34} Js$.

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31. Light of wavelength 5000Å falls on a metal surface of work function 1.9eV. Find (i) the energy of photons in eV (ii) the kinetic energy of photoelectrons and (iii) the stopping potential. Use $h = 6.63 \times 10^{-34} Js$,

$c = 3 \times 10^{8} ms^{-1}, e = 1.6 \times 10^{-9} C$.

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32. Calculate the threshold frequency of photon for photoelectric emission from a metal of work function 0.1 eV.

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33. The work function of a metal is 3.45 eV. Calculate what should be the maximum wavelength of a photon that can eject photoelectrons from the metal ?

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34. Light of wavelength 3500Å is incident on two metals A and B. Which metal will yield photoelectrons if their work functions are 4.2 eV and 1.9 eV respectivley ?

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35. The work function for a metal is 1.8eV. Light of 5000Å is incident on it. Calculate (a) threshold frequency and threshold wavelength, (b) maximum kinetic energy of the emitted electrons, (c) maximum velocity of the emitted electrons, (d) if the intensity of the incident light be doubled, then what will be the maximum kinetic energy of the emitted electrons? given, $h = 6.63 \times 10^{-34} Js, m_e = 9 \times 10^{-31} kg, c = 3 \times 10^8 ms^{-1}$.

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36. Ultraviolet light of wavelength 2271Å from a 100W mercury source irradiates a photocell made of molybdenum metal. If the stopping potential is 1.3V, estimate the work function of the metal. How would the photocell respond to a high intensity $(\sim 10^5 Wm^{-2})$ red light of wave length 6328Å produced by a He-Ne laser?

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37. Monochromatic radiation of wave length 640.2 nm $(1nm = 10^{-9}m)$ from a neon lamp irradiates a photosensitive material made of calcium or tungsten. The stopping voltage is measured to be 0.54V. The source is replaced by an iron source and its 427.2 nm line irradiates the same photocell. Predict the new stopping voltage.

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38. Find the frequency of light which ejects electrons from a metal surface. Fully stopped by a retarding potential of $3V$, the photoelectric effect begins in this metal at a frequency of $6 \times 10^{14} Hz$. Find the work function for this metal. (Given $h = 6.63 \times 10^{-34} Js$).

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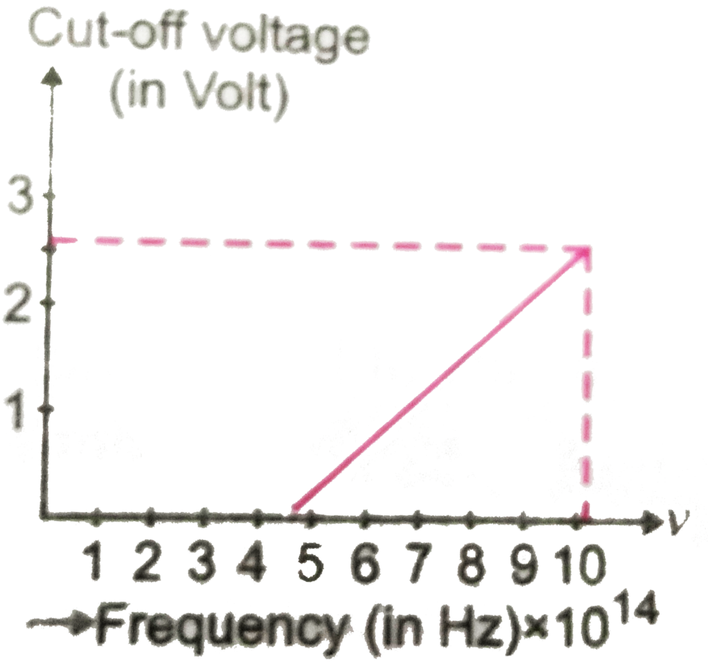
39. For photoelectric effect in sodium, fig. shows the plot of cut-off voltage versus frequency of the incident radiation. Caclculate:



(i) the threshold frequency

(ii) the work function for sodium. (Use $h = 6.6 \times 10^{-34} Js$)

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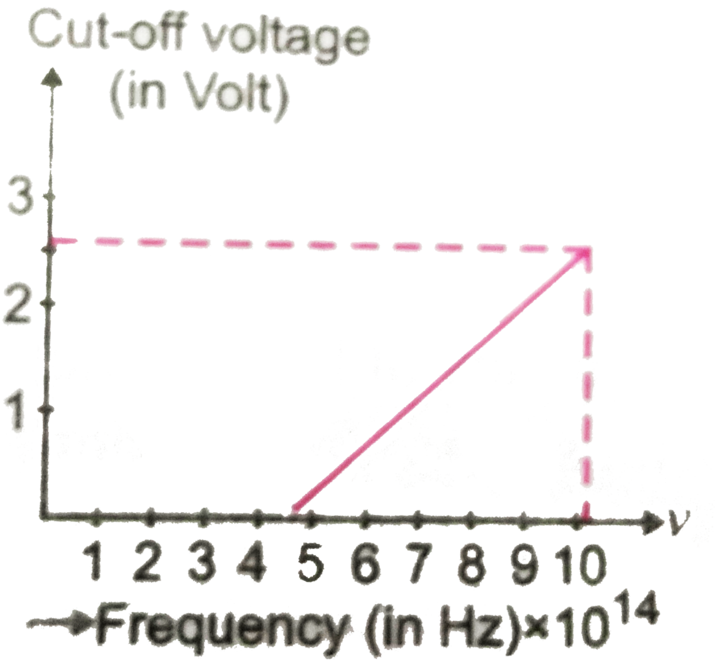
40. For photoelectric effect in sodium, fig. shows the plot of cut-off voltage versus frequency of the incident radiation. Caclculate:



(i) the threshold frequency

(ii) the work function for sodium. (Use $h = 6.6 \times 10^{-34} Js$)

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41. In an experiment on photoelectric effect, the slope of the cut off voltage versus frequency of incident light is found to be $4.12 \times 10^{-15} Vs$. Given $e = 1.6 \times 10^{-19} C$, estimate the value of Planck's constant.

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42. If photoelectrons are to be emitted from a potassium surface with a speed of $6 \times 10^{6} ms^{-1}$, what frequency of radiation must be used ? (Threshold frequency for potassium is $4.22 \times 10^{14} Hz, h = 6.6 \times 10^{-34} Js$ and $m_e = 9.1 \times 10^{-31} kg$)

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43. A sheet of silver is illuminated by monochromatic ultraviolet light of wavelength = 1810Å. What is the maximum energy of the emitted electron ? Threshold wavelength of silver is 2640Å.

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44. If the speed of photoelectrons is $10^6 ms^{-1}$, what should be the frequency of the incident radiation on the potassium metal ? (Work function of potassium = 2.3 eV).

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45. Determine the Planck's constant h if photoelectrons emitted from a surface of a certain metal by light of frequency 2.2×10^{15}Hz are fully retarted by a reverse potential of 6.6 V and those ejected by light of frequency 4.6×10^{15} Hz by a reverse potential of $16.5eV$.

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46. The photoelectric threshold wavelength for a metal is 10,000 Å. When light of wavelength 5461Å is incident on it, the retarding potential in Millikan's experiment is 1.02 V. Calculate the value of Planck's constant.

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47. A photon of wavelength 3310Å falls on a photocathode and an electron of energy $3 \times 10^{-19} J$ is ejected. If the wavelength of the incident photon is changed to 5000Å, the energy of the ejected electron is $9.72 \times 10^{-20} J$. Calculate the value of Planck's constant and threshold wavelength of the photon.

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48. The work function for the following metals is given Na: 2.75 eV, K:2.30 eV , Mo: 4.17 eV , Ni: 515 eV.

Which of these metals will not give photoelectric emission for a radiation of wavelength 3300 A from a $He - Cd$ laser placed 1m away from the photocell? What happens if the laser is brought nearer and placed 50 cm away?

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49. Light of intensity $10^{-5} Wm^{-2}$ falls on a sodium photocell of surface area $2cm^2$. Assuming that the top 5 layers of sodium absorb the incident energy, estimate the time required for photoelectric emission in the wave picture of radiation. The work function of the metal is given to be about 2eV. What is the implication of your answer? effective atomic area $= 10^{-20} m^2$.

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50. (i) Show that a free electron at rest cannot absorb a photon and thereby acquire kinetic energy equal to the energy of the photon. Would the conclusion change if the free electron was moving with a constant velocity ?

(ii) If the absorption of a photon by a free electron is ruled out as proved in (i) above, how does photoelectric emission take place at all ?

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51. In an experiment on photoelectric emission of γ-rays on platinum, the energy distribution of photoelectron exhibits peaks at a number of descrete energies : 270keV, 339keV and 354keV. The binding energy of K,L and M shell in platinum are known to be 77keV, 13keV and 3.5keV approx., what is the wavelength of γ-rays with which the data are consistent.

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52. Calculate the de Broglie wavelength of a proton of momentum $2.55 \times 10^{-22} kgms^{-1}$.

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53. What is the de-Broglie wavelength of a 3 kg object moving with a speed of $2ms^{-1}$?

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54. Determine the de Broglie wavelength of a proton, whose kinetice energy is equal to the rest of the mass energy of an electron. Given that the mass of an electron is 9×10^{-31} kg and the mass of a proton is 1837 times as that of the electron.

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55. Crystal diffraction experiments can be performed using X-rays, or electrons accelerated through appropriate voltage. Which probe has greater energy? An X-ray photon or the electron? (For quantitative comparison, take the wavelength of the probe equal to 1Å, which is of the order of interatomic spacing in the lattice), $m_e = 9.11 \times 10^{-31} kg$.

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56. Calculate the de-Broglie wavelength of an electron beam accelerated through a potential difference of 60 V.

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57. What voltage must be applied to an electron microscope to produce electrons of wavelength $0.4A$?

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58. Find the de-Broglie wavelength associated with an electron moving with a velocity 0.5 c and rest mass = $9.1 \times 10^{-31} kg$.

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59. (a) Obtain the de-Broglie wavelength of a neutron of kinetic energy 150 eV. As you have seen in previous problem 31, an electron beam of this energy is suitable for crystal diffraction experiments. Would a neutron beam of the same energy be equally suitable? Explain. Given $m_n = 1.675 \times 10^{-27} kg$.

(b) Obtain the de-Broglie wavelength associated with thermal neutrons at room temperature $(27^\circ C)$. Hence explain why a fast neutrons beam needs to be thermalised with the environment before it can be used for neutron diffraction experiments.

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61. An electron microscope uses electrons accelerated by a voltage of $50kV$. Determine the De Broglie wavelength associated with the electrons. If other factors (such as numerical aperture, etc.) are taken to be roughly the same, how does the resolving power of an electron microscope compare with that of an optical microscope which uses yellow light?

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62. Compute the typical de-Broglie wavelength of an electrons in a metal at $27^{\circ} C$ and compare it with the mean separation between two electrons in a metal which is given to be about $2 \times 10^{-10} m$.

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63. An X-ray beam of wavelength 1.0Å is incident on a crystal of lattice spacing 2.8 Å. Calculate the value of Bragg angle for first order of diffraction.

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64. Is the de-Broglie wavelength of a photon of an electromagnetic radiation equal to the wavelength of the radiation?

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65. An electron and a photon have the same de Broglie wavelength. Which one of these has higher kinetic energy?

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66. An electron and proton are possessing the same amount of kinetic energy. Which of the two have greater wavelength ?

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67. An electron and a photon have the same de Broglie wavelength. Which one of these has higher kinetic energy?

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68. An electron and proton have same de-Broglie wavelength. Which one possess greater energy?

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Problem Solution

1. The distance between the two plates of a cathode-ray oscilloscope is 1 cm and the potential difference between them is 1200 V. If an electron of energy 2000 eV enters at right angles to the field, what will be its deflection if the plate be 1.5 cm long.

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2. An electron enters the region between the plates of a parallel plate capacitor at a point equidistance from either plate. The capacitor plates are $2 \times 10^{-2} m$ apart and $10^{-1} m$ long. A potential difference of 300 V is kept across the plates. Assuming that the initial velocity of the electron is parallel to the capacitor plates, calculate the largest value of the velocity of the electrons so that they do not fly out of the capacitor at the other end.

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3. A charged particle of radius $5 \times 10^{-7} m$ is located in a horizontal electric field of intensity $6.28 \times 10^{5} V m^{-1}$. The surrounding medium has the coefficient of viscosity

$\eta = 1.6 \times 10^5 Nsm^{-2}$. The particle starts moving under the effect of electric field and finally attains a uniform horizontal speed of $0.02ms^{-1}$. Find the number of electrons on it. Assume gravity free space.

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4. A monochromatic light soure of frequency f illuminates a metallic surface and ejects photoelectrons. The photoelectrons having maximum energy are just able to ionize the hydrogen atoms in ground state. When the whole experiment is repeated with an incident radiation of frequency $\frac{5}{6}f$, the photoelectrons so emitted are able to excite the hydrogen atom beam which then emits a radiation of wavelength 1215Å. (a) What is the frequency of radiation? (b) Find the work- function of the metal.

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5. A cylindrical rod of some laser material 5×10^{-2}m long and $10^{-2} m$ in diameter contains 2×10^{25} ions per m^3. If on excitation all the ions are in the upper energy level and de-excite simultaneously emitting photons in the same direction , calculate the maximum energy contained in a polse of radiation of wavlength 6.6×10^{-7}m. If the pulse lasts for $10^{-7} s$, calculate the average power of the laser during the pulse.

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6. A 40 W ultraviolet light source of wavelength $2480A$. Illuminates a magnesium (mg) surface placed 2 m away. Determine the number of photons emitted from the surface per second and the number incident on unit area of Mg surface per second . The photoelectric work function for Mg is $3.68eV$. Calculate the kinetic energy of the fastest electrons ejected from the surface. Determine the maximum wavelength for which the photoelectric effects can be observed with Mg surface.

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7. In an experiment on photo electric emission, following observations were made,

(i) Wavelength of the incident light $= 1.98 \times 10^{-7}m$,

(ii) Stopping potential $= 2.5 \text{volt}$.

Find: (a) Kinetic energy of photoelectrons with maximum speed.

(b) Work function and

(c)Threshold frequency,

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8. Light of wavelength 180 nm ejects photoelectrons from a plate of metal whose work - function is 2 eV. If a uniform magnetic field of 5×10^{-5} T be applied parallel to the plate, what would be the radius of the path followed by electrons ejected normally from the plate with maximum energy.

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9. When a surface is irradiated with light of wavelength $4950A$, a photocurrent appears which vanishes if a retarding potential greater than $0.6V$ is applied across the photo tube. When a different source of light is used, it is found that the critical retarding potential is changed to $1.1V$. Find the work function of the emitting surface and the wavelength of the second source.

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10. The maximum KE of photoelectrons emitted from a cetain metallic surface is 30 eV when monochromatic radiation of wavelength λ falls on it. When the same surface is illuminated with light of wavelength 2λ, the minimum KE of photoelectrons is found to be 10 eV. (a) Calculate the wavelength λ and (b) determine the maximum wavelength of incident radiation for which photoelectric emission is possible.

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11. A beam of light has three wavelengths 4144Å, 4972Å and 6216Å with a total instensity of $3.6 \times 10^{-3} Wm^{-2}$ equally distributed amongst the three wavelengths. The beam falls normally on an area $1.0cm^2$ of a clean metallic surface of work function 2.3 eV. Assume that there is no loss of light by reflection and that each energetically capable photon ejects on electron. Calculate the number of photo electrons liberated in two seconds.

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12. A light source, emitting there wavelengths 500nm, 600nm and 700 nm, has a total power of $10^{-3}W$ and a beam diameter $2 \times 10^{-3}m$. The density is distributed equally amongst the three wavelength. The beam shines normally on a metallic surface of area on $10^{-4}m^2$ and having a work function of 1.9 eV. Assuming that each photon liberates an electron, calculate the charge emitted per unit area in one second.

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13. A small plate of a metal (work function $= 1.7eV$) is placed at a distance of 2m from a monochromatic light source of wavelength $4.8 \times 10^{-7}m$ and power 1.0watt. The light falls normally on the plate. Find the number of photons striking the metal plate per square meter per second. If a constant magnetic field of strength $10^{-4}T$ is applied parallel to the metal surface, find the radius of the largest circular path followed by the emitted photoelectrons. (use $h = 6.63 \times 10^{-34} Js$, mass of electron=$9.1 \times 10^{-31} kg$, charge of electron=$1.6 \times 10^{-19} C$

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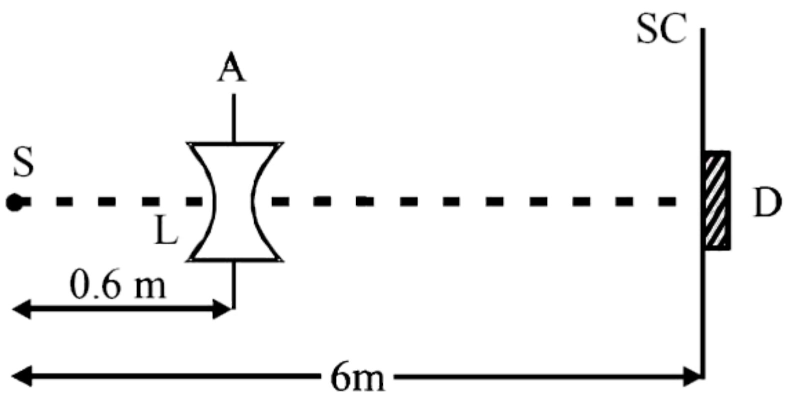
14. A monochromatic point source radiating wavelength 6000Å with power 2 watt, an aperture A of diameter $0.1m$ and a large screen SC are placed as shown in fig, A photoemissive detector D of surface area $0.5cm^2$ is placed at the centre of the screen . The efficiency of the detector for the photoelectron generation per incident photon is 0.9



(a) Calculate the photon flux at the centre of the screen and the photo current in the detector.

(b) If the concave lens L of focal length 0.6 m is inserted in the aperture as shown . find the new values of photon flux and photocurrent Assume a uniform average transmission of 80 % from the lens .

(c) If the work function of the photoemissive surface is

$1eV$. calculate the values of the stopping potential in the two cases (within and with the lens in the aperture).

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15. A neutron is an uncharged particle of mass $1.67 \times 10^{-27} kg.$ Calculate the de-Broglie wavelength of the neutron moving with a velocity, such that K.E. is 0.04 eV, $h = 6.62 \times 10^{-34} Js.$

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16. Assume that the de Broglie wave associated with an electron can from a standing wave between the atom arrange in a one dimensional array with nodes at each of the atomic sites. It is found that one such standing wave if the distance d between the atoms of the array is $2A^0$ A similar standing wave is again formed if d is increased to 2.5Å . Find the energy of the electrons in electron volts and the least value of d for which the standing wave type described above can from .

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17. When photons of energy $4.25eV$ strike the surface of metal A, the ejected photoelectrons have maximum kinetic energy T_A eV and De-broglie wavelength λ_A. The maximum energy of photoelectron liberated from another metal B by photon of energy 4.70 eV is $T_B = (T_A - 1.50)eV$ if the de

Brogle wavelength of these photoelectrons is $\lambda_B = 2\lambda_A$, then

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18. In a photoelectric effect set up, a point source of light of power $3.2 \times 10^{-3} W$ emits monochromatic photons of energy $5eV$.The source is located at a distance of a stationary metallic sphere of work function $3eV$ and radius $8 \times 10^{-3} m$.The efficiency of photoelectron emission is one for every 10^6 incident photons.Assume that the sphere is isolated and initially neutral and the photoelectrons are initially swept away after emission.

Find the number of photons emitted per second

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19. The voltage across the electrodes of a cathode ray tube is $1000V$. Calculate the speed of the electron. Given mass of an electron $= .1 \times 10^{-31} kg$ and charge on electron $= 1.6 \times 10^{16} C$.

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Type A Problem For Self Practice

1. An $X -$ ray tube operates at $27kV$. Find the maximum speed of an electron striking the anticathode. Given mass of electron $= 9 \times 10^{31} kg$ and charge on electron $= 1.6 \times 10^{-19} C$.

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2. An $\alpha-$particle is accelerated through a potential difference of $25,000V$. What will be the increase in its energy in joule ?

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3. Two parallel plates kept in air $5cm$ apart are at a potential difference of $500V$. If there be an electron (ii) kinetic energy an (iii) velocity of the electron, when it reaches the other plate.

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4. A stream of electrons moving with a speed of $3 \times 10^{7} ms^{-1}$ is deflected on passing through an electric field of $1800 Vm^{-1}$, perpendicular to its path. If the radius iof the deflected beam is $3m$, calculate the value of $e/m = 1.76 \times 10^{11} C kg^{-1}$.

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5. What is the magnitude of acceleration of an electron of speed $2.5 \times 10^{6} ms^{-1}$ in a magnetic field of $2.0G$, given that its $e/m = 1.76 \times 10^{11} C kg^{-1}$.

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6. A stream of electrons moving with a velocity of $6 \times 10^7 ms^{-1}$ passes between two parallel plates. An electric field of $3000 Vm^{-1}$ is applied between the plates. Calculate the strength of the magnetic field required to keep the electron undeflected.

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7. In $J. J$ Thomson's experiment, a magnetic field of $4 \times 10^{-2} Wbm^{-2}$ is used. If the electrons entering this field have a speed of $5 \times 10^{10} ms^{-1}$, what potential difference applied between the two plates $0.8 cm$ apart will keep them undeflected ?

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8. An electron is accelerated through a potential difference of $1000V$ and directed into space between two parallel plates separated by $2cm$ with a potential difference of $100V$ applied across them. If the electron enters perpendicular to the electric field between the polates, what magnetic field perpendicular to both the electron path and the electric field will be neccessary so that the electron may travel undeflected. Take $e = 1.6 \times 10^{-19}C$ and $m = 9 \times 10^{31}kg$.

View Text Solution

9. Find the strength of the magnetic field required to deflect an electron beam of energy $1/16MeV$ into a circular path of radius $5cm$. Given $m = 9 \times 10^{-31} kg$ and $e = 1.6 \times 10^{-19} C$.

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10. An electron is moving with a velocity of $10^7 ms^{-1}$ on a circular path of radius $0.57cm$ in a magnetic field of $10^{-2} Wbm^{-2}$. Find the value of e/m for the electron.

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11. An $\alpha -$ particle of mass $6.65 \times 10^{-27} kg$ travels perpendicular to a magnetic of $0.2T$ with a speed of $6 \times 10^5 ms^{-1}$. Calculate the acceleration of the $\alpha -$ particle. Given the charge on the electron is $1.6 \times 10^{-19} C$.

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12. When a beam of electrons passes through an electrostatic field of $300 V cm^{-1}$ at right angles to the direction of field, it describes a circular path of radius $8 cm$. On entering the magnetic field of 15 oersted at right angles to the electrostatic field, the beam remains undeflected. Find specific charge of the electron.

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13. An electron is deflected by $1.76 mm$ in traversing a distance of $10 cm$ through an electric field of 1800 volt per metre perpendicular to its path. Find the electron charge

to mass ratio, if average velocity of the electrons is $3 \times 10^7 ms^{-1}$.

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14. An electron beam having a speed of $10^7 ms^{-1}$ passes through the two plates of a parallel plate capacitor. The electric intensity between the plates is $20 Vm^{-1}$ and the length of the plates is $10 cm$. Calculate the deflection angle of the beam, if the mass of electron, $m = 9.1 \times 10^{-31} kg$ and charge on electron,$e = 1.6 \times 10^{-19} C$.

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15. Electron, initially almost at rest, are accelerated by a potenetial difference of 200 volt. They then pass through an electric field and a magnetic field at right angle to each other and also at right angles to the electron beam. The magnitudes of two fields are so adjusted that the electrons emerge out straight without any deviation. Determine the specific charge, if the electric field is 1117.6 volt cm^{-1} and magnetic field is 14 gauss.

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16. A beam of electrons is under the effect of potential difference of 1.36×10^4 volt applied across two parallel plates $4cm$ apart and a magnetic field of $0.002Wbm^{-2}$ at right angles to each other. If these two field produces no deflection in the beam. find the velocity of electrons. What will be radius of the orbit in which the beam will move, if the electric field is made zero ? Given, Mass of electron $= 9.1 \times 10^{-31} kg.$

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17. A narrow beam of electrons, accelerated by a potential difference of $250V$, passes between two parallel metal plates $0.030m$ long and $0.005m$ apart in an evacuated tube and then strikes a fluorescent screen $0.175m$ from the centre of the plates. A potential difference of $10V$ is established between the plates. What is the deflection produced on the screen.

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18. In a cathode ray tube a potential difference of 3000 volt is maintained between the electrodes $2cm$ apart. A magnetic field of $2.5 \times 10^{-4} Wb/m^2$ at right angles to the electric field gives no deflection of the electron beam which received an initial acceleration by a potential difference of 1000 volt. Calculate e/m.

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19. An electron moving with a speed of $2.5 \times 10^{-7} ms^{-1}$ enters a space between two horizontal metal plates which a uniform electric field of $1600 Vm^{-1}$ is maintained. What will be its deflection from its straight line path on

emerging out if the length of each plate is $10cm$ and the electron enters in a direction perpendiular to the electric field ?

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20. Two parallel horizontal plane plates are $30mm$ long and $10mm$ apart. A fine horizontal beam of electrons, moving with a velocity of $5 \times 10^6 ms^{-1}$ enters the plates mid-way and produces a bright spot of light on a vertical screen $100mm$ beyond the edges of the plates. A potential difference of $10V$ is applieed to the plates. Calculate the deflection of the spot from its initial position.

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21. In a cathode ray tube the length of deflection plates is $78mm$ and their separation is $0.24m$, while the distance form the centre orf the plate to the screen is $0.33m$. No deflection of the electron beam is observed when the potential difference is $2800V$ and the magnitude field is $8.2 \times 10^{-4} Wbm^{-2}$. When only the magnetic field is applied, deflection on the screen is $28mm$. Find e/m.

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Type B Problem For Self Practice

1. An oil drop of radius $10^{-6}m$ carries a charge equal to that on an electron. If the density of the oil is $2 \times 10^{3} kgm^{3}$

, find the electric field required to keep it stationary. Take $e = 1.6 \times 10^{-19} C$ and $g = 9.8 ms^{-2}$.

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2. A charged oil drop is suspended in a uniform filed of $3 \times 10^4 v/m$ so that it neither falls nor rises. The charge on the drop will be (Take the mass of the charge $= 9.9 \times 10^{-15} kg$ and $g = 10 m/s^2$)

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3. In a Millikan's oil drop experiment, an oil drop of mass $4.9 \times 10^{-14} kg$ is balanced by a potential difference of

$4000V$ between two plates which are $8mm$ apart. Find the number of elementary charges on the drop.

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4. Calculate the voltage needed to balance on all drop carrying 10 electrons when located between the plates of a capacitor which are 5 mm apart. Mass of oil drop is $3 \times 10^{-16} kg$(take $g = 10m/s^2$)

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5. An ail drop having charge $2e$ is kept stationary between two parallel horizontal plates $2.0cm$ apart when a potential difference of 12000 volts is applied between

them. If the density of oil is $900kg/m^3$, the radius of the drop will be

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6. In Millikan's oil drop experiment, what is the terminal speed of a speed of a drop of radius $2.0 \times 10^5 m$ and density $1.2 \times 10^3 m^{-3}$? Take the viscosity of air at the temperature of the experimental to be $1.8 \times 10^{-5} Nsm^2$. How much is the viscous force on the drop at that speed? Neglect buoyancy of the drop due to air.

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7. In an oil drop experiment, the distance between the capacitor plates = 0.076 m, the p.d. between the plates = 5000 V and the radius of drop = $2.75 \times 10^{-6} cm$. The minimum change in velocity with the field $= 5.27 \times 10^{5} cms^{-1}$. If viscosity of air -1.83×10^{-5} Ns m^{-2}, calculate the charge on the electron.

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8. In an oil drop experiment, the following data were recorded :

Plate separation = 15 mm, Distance of fall = 10 mm

Potential difference = 3.2 kV, Viscosity of air = 1.82×10^{-5} Ns m^{-2}

Sucessive times of rise of the drop = 42 s and 78 s.

Radius of drop = $2.76m \times 10^{-6} m$

Calculate the change in charge on the drop between the two sets of observation. To how many electrons does this correspond ?

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9. A charged oil dop falls 4.0 mm in 16.0 s at constant speed in air in the absence of an electric field. The relative density of oil is 0.80, that of air is 1.3×10^{-3} and the viscosityf of air is 1.8×10^{-5} Ns m^{-2}. Find (i) the radius of the drop (ii) the mass of the drop. (iii) If the drop carries one electronic unit of charge and is an electric field of

2000 V cm^{-1}, what is the ratio of the force of the electric field on the drop to its weight ?

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10. A charged oil dop is held stationary between the two horizontal plates of a capacitor when a field of 576 kV m^{-1} is applied between them. When the field is removed the drop falls freely with a steady velocity of $0.120 \times 10^{-3} ms^{-1}$. Find values for (i) the radius of the drop and (ii) its charge assuming that $6\eta = 0.109 \times 10^{-4} kgm^{-1}s^{-1}$ and the difference between the densities of oil and air may be taken as 800 kg m^{-3}.

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Type C Problem For Self Practice

1. Find the effectiveness of a photon of energy 5 eV.

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2. Calculate the energy of a photon in eV for a radio wave of frequency one M Hz.

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3. Calculate the frequency of a photon, having energy 41.25 eV. $\left(h = 6.6 \times 10^{-34} Js\right)$.

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4. Visible light has wavelengths in the range of 400 nm to 780nm. Calculate the range of energy of the photons of visible light.

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5. If the energy of a photon corresponding to a wavelength of $6000\text{Å} is 3.32 \times 10^{-19} J$, the photon energy for a wavelength of 4000Å will be

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6. A certain spectral line has wavelength of 4000Å. Calculate the frequency and the energy in electron volts of the photons associated with it.

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7. An X-ray tube produces a continuous spectrum of radiation with its short wavelength end at 0.66Å. What is the maximum energy of the photon in the radiation ?

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8. How many photons are emitted per second by a 5 mW laser source operating at 632.8 nm?

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9. A monochromatic source of light operation at 200 W emits 4×10^{20} photons per second. Find the wavelength of the light $(\text{in} 10^{-7} m)$.

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10. A bulb lamp emits light of mean wavelength of $4500 A$. The lamp is rated at $150 W$ and 8% of the energy appears as emitted light. How many photons are emitted by the lamp per second?

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11. Find the number of photons emitted per second by a 25 W source of monochromatic light of wavelength 6600Å. What is the photoelectric current assuming 3% efficiency for photoelectric effect. Given $h = 6.6 \times 10^{-34} Js$.

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Type D Problem For Self Practice

1. If a photoemissive surface has a threshold frequency of 3×10^{14} Hz, calculate the energy of the photons in eV.

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2. The work function for a metal surface is 2.0 eV. Determine the longest wavelength that will eject photoelectrons from the metal surface.

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3. A metal has a threshold wavelength fo 6000Å. Calculate (i) threshold frequency (ii) work function. Will there be photoelectric emission or not ?

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4. Photoelectric work function for a surface is 2.4 eV. Light of wavelength 6.8×10^{-7}m shines on the surface. Find the frequency of incident light and also the threshold frequency. Will there be photoelectric emission or not ?

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5. Calculate the kinetic energy of a photoelectron (in eV) emitted on shining light of wavelength $6.2 \times 10^{-6} m$ on a metal surface. The work function of the metal is 0.1 eV ?

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6. What is the energy of emitted photoelectrons is light of frequency $10^{16} Hz$ is incident on a sodium target ? Work function of sodium is = 2.5 eV.

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7. If the speed of photoelectrons is $10^4 ms^{-1}$, what should be the frequency of incident radiation on the potassium metal ? Work function of potassium = 2.3 eV.

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8. Which of the metal sodium and copper will be suitable for photelectric cell using light of wavelength 4000Å. The work functions of sodium and copper are respectively 2.0 eV and 4.0 eV. Take $h = 6.6 \times 10^{-34} Js, c = 3.0 \times 10^8 ms^{-1}$ and 1 eV = $1.6 \times 10^{-19} J$

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9. (a) The work function for the surface of aluminium is 4.2eV. How much potential difference will be required to stop the emission of maximum energy electrons emitted by light of 2000Å wavelength?

(b) What will be the wavelength of that incident light for which stopping potential will be zero ? $h = 6.6 \times 10^{-34} Js, c = 3 \times 10^{8} ms^{-1}$.

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10. The photoelectric threshold wavelength for lithium is 8000Å. Find the maximum kinetic energy in eV of the emitted electrons from the surface by light of wavelength 6000Å. Take $h = 6.6 \times 10^{-34} Js$.

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11. The wavelength of a photon is 1.4Å. It collides with an electron. Its wavelength after collision is 2.0Å. Calculate the energy of the scattered electron.

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12. The energy of photoelectrons emitted from a sensitive plate is 1.56 eV. If its threshold old wavelength is 2500Å, calculate the wavelength of incident light.

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13. The mercury line of wavelength 2356Å is used to eject photoelectrons from silver. The difference in potentials required to bring the electrons to rest is 0.11 eV. Calculate the energy in electron volts necessary to remove an electron from silver.

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14. The photoelectric threshold wavelength for tungsten is 2400Å. Determine the energy of the electrons ejected from its surface when exposed to ultraviolet radiations of wavelength 1200Å.

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15. The cathode of a photocell is irradiated with light of wavelength 3000Å. The current through the cell is found to stop when the potential of the plate is 2.1 V just below the cathode. Calculate the work function of the cathode.

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16. Find the maximum velocity of photoelectrons emitted by radiation of frequency 3×10^{15} Hz from a photoelectric surface having a work function of 4.0 eV. Given $h = 6.6 \times 10^{-34}$ Js and 1 eV = 1.6×10^{-19} J.

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17. Given that a photon of light of wavelength 10,000Å has an energy equal to 1.23eV. When light of wavelength 5000Å and intensity I_0 falls on a photoelectric cell and the saturation current is 0.40×10^{-6} ampere and the stopping potential is 1.36 volt, then (i)what is the work function? (ii) If intensity of light is made $4I_0$, what should be the saturation current and stopping potential?

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18. Ultraviolet light of wavelength $800A$ and $700A$ when allowed to fall on hydrogen atoms in their ground states is found to liberate electrons with kinetic energies $1.8eV$ and $4.0eV$, respectively. Find the value of Planck's constant.

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19. When light of wavelength 400nm is incident on the cathode of photocell, the stopping potential recorded is 6V. If the wavelength of the incident light is to 600nm, calculate the new stopping potential. [Given $h = 6.6 \times 10^{-34} Js, c = 3 \times 10^{8} m/s, e = 1.6 \times 10^{-19} C$]

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20. (a) If the wavelength of the light incident on a photoelectric cell be reduced from λ_1 to $\lambda_2 \text{Å}$, then what will be the change in the cut-off potential?

(b) Light is incident on the cathode of a photocell and the stopping voltages are measured for light of two different wavelengths. From the data given below, determine the work function of the metal of the cathode in eV and the value of the universal constant hc/e.

WavelengthÅ	Stopping voltage (volt)
4000	1.3
4500	0.9

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Type E Problem For Self Practice

1. Calculate the de Broglie wavelength associated with the following :

(i) electrons moving with a speed of $10^5 ms^{-1}$

(ii) protons moving with a speed of $10^5 ms^{-1}$

(iii) a proton of momentum 2.26×10^{-23} kg ms^{-1}

(iv) a thermal neutron of energy 0.025 eV.

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2. Calculate the de-Broglie wavelength in nm associated with a ball of mass 66 g moving with a speed of $2.5 \times 10^5 ms^{-1}$. Given $h = 6.6 \times 10^{-34} Js$.

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3. Calculate the de-Broglie wavelength associated with an α-particle accelerated through a potential difference of 200 V. Given $m_P = 1.67 \times 10^{-27} kg$.

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4. Calculate the velocity of a neutron having de Broglie wavelength of 10 fermi. Mass of neutron, $m_n = 1.7 \times 10^{-27} kg$. Neglect the relative effects.

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5. Calculate the de-Broglie wavelength of an electron of kinetic energy 100 eV. Given $m_e = 9.1 \times 10^{-31} kg, h = 6.62 \times 10^{-34} Js$.

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6. For what kinetic energy of a neutron will the associated de-Broglie wavelength be $1.40 \times 10^{-10} m$? Mass of neutron = $1.675 \times 10^{-27} kg, h = 6.63 \times 10^{-34} Js.$

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7. The de-Broglie wavelength of an electron is 4Å. What is its momentum ?

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8. What voltage must be applied to an electron microscope to produce electrons of wavelength $0.4 A$?

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9. Energy of a particle at absolute temperature T is of the order kT. Calculate the wavelength of thermal neutrons at $27^{\circ}C$. Take mass of neutron = $1.67 \times 10^{-27} kg, h = 6.6 \times 10^{-34} Js$ and k = 1.38 J $\text{mol}^{-1}K^{-1}$.

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10. The angle of reflection for first order monochromatic X-rays from a crystal whose atomic spacing is 2.5Å is 15°. Calculate the wavelength of X-rays.

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11. Monochromatic X-rays, when reflected from a crystal with lattice spacing 2.0Å, produce first order diffraction maximum at $\theta = 30^{\circ}$. What is the wavelength of X-rays ?

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