PHYSICS

BOOKS - RESNICK AND HALLIDAY PHYSICS (HINGLISH)

PHOTONS AND MATTER WAVES

Sample Problem

1. A sodium vapour lamp is placed at the center of a large sphere that aborbs all the light reaching it. The rate at which the lamp emits energy is 100 W, assume that the emission is entirely at a wavelength of 590 nm. At what rate are photons absorbed by the sphere?

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2. If the threshold wavelength for sodium is 5420Å, then the work function of sodium is

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3. A potassium foil is a distance $r = 3.5m$ from an isotropic light source that emits energy at the rate $P = 1.5W$. The work function F of potassium is 2.2 eV. Suppose that the energy transported by the incident light were transferred to the target foil continuously and smoothly (that is, if classical physics prevailed instead of quantum physics). How long would it take for the foil to absorb enough energy to eject and electron? Assume that the foil totally absorbs all the energy reaching it can that the to - be-ejected electron collects energy from a circular patch of the foil whose radius is $5.0 \times 10^{-11} m$, about that of a typical atom.

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4. A beam of light has three wavelengths $4144 Å$, $4972 Å$ and $6216 Å$ with a total instensity of $3.6 \times 10^{-3} W m^{-2}$ equally distributed amongst the three wavelengths. The beam falls normally on an area $1.0 cm^2$ 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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5. Suppose the 10^{19} photons emitted per second from the 100 W lightbulb in were all focused onto a piece of black paper and absorbed. (a)Calculate the momentum of one photon and (b)estimate the force all these photons could exert on the paper.

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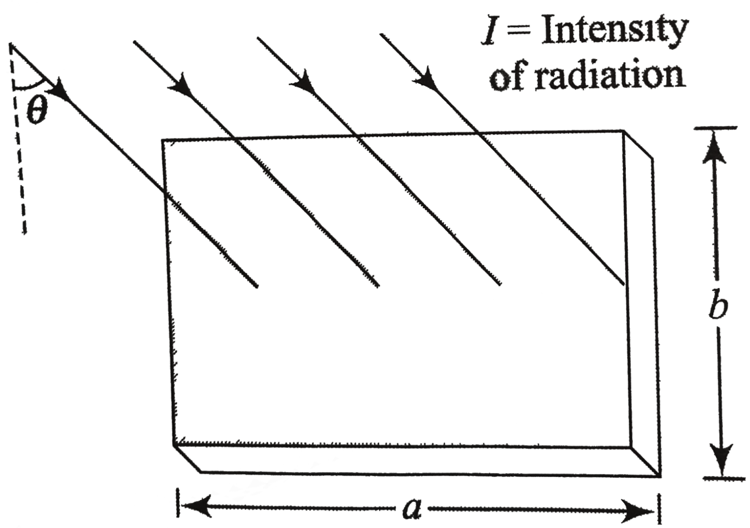
6. 

A plank of mass m is lying on a rough suface having coeffient of frinction as μ is situation as shown in fig Find the acceleration of the plank assuming that it slips and the surface of body exposed to radiaton is black body.

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7. A perfectly reflecting solid hemisphere of radius R is placed in the path of a parallel beam of light of large aperture. If the beam carrries an intensity I, find the force exerted by the beam on the hemisphere.

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8. Find the de-Broglie wavelength of an electron with kinetic energy of 120 eV.

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9. Assume that an electron is moving along an x axis and that you measure its speed to be $2.05 \times 10^6 m/s$, which can be known with a precision of 0.50%. What is the minimum uncertainty (as allowed by the uncertainty principle in quantum theory) with which you can simultaneously measure the position of the electron along the x - axis ?

Calculations : To evaluate the uncertainty Δp_x in the momentum, we must first evaluate the momentum component p_x. Because the electron's speed v_x is much less than the speed of light c, we can evaluate p_x with the classical expression for momentum instead of using a relativistic expression. We find

$$p_x = mv_x = (9.11 \times 10^{-31} kg)(2.05 \times 10^6 m/s)$$

$$= 1.87 \times 10^{-24} kg. m/s.$$

The uncertainty in the speed is given as 0.50% of the measured speed. Because p_x depends directly on speed, the uncertainty Δp_x in the momentum must be 0.50% of the momentum :

$$\Delta p_x = (0.0050)p_x$$

$$= (0.0050)\left(1.87 \times 10^{-24} kg.\ m/s\right)$$

$$= 9.35 \times 10^{-27} kg.\ m/s$$

Then the uncertainty principle gives us

$$\Delta x = \frac{h}{\Delta p_x} = \frac{\left(6.63 \times 10^{-34} J.\ s\right)/2\pi}{9.35 \times 10^{-27} kg.\ m/s}$$

$$= 1.13 \times 10^{-18} m \approx 11 nm,$$

which is about 100 atomic diameters.

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10. Suppose that the electron in Fig. having a total energy E of 5.1 eV, approaches a barrier of height $U_b = 6.8 eV$ and thickness L = 750 pm.

(a) What is the approximate probability that the electron will be transmitted through the barrier, to appear (and be detectable) on the other side of the barrier?

(b) What is the approximate probability that a proton with the same total energy of 5.1 eV will be transmitted through the barrier, to appear (and be detectable) on the other side of the barrier?

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Check Points

1. Rank the following radiations according to their associated photon energies, greatest first : (a) yellow light from a sodium vapour lamp, (b) a gamma ray emitted by a radioactive nucleus, (c) a radio wave emitted by the antenna of a commerical radio station, (d) a microwave beam emitted by airport traffic control radar.

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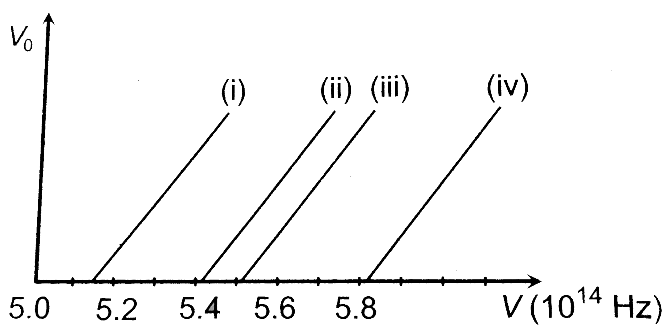
2. The figure shows different graphs between stopping potential (V_0) and frequency (v) for photosensitive surface of cesium , potassium , sodium and lithium. The plots are parallel. Correct ranking of the targets according to their work function greatest forst will be



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3. For an electron and a proton that have the same (a) kinetic energy. (b) momentum, or (c) speed, which particle has the shorter de Broglie wavelength?

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Problems

1. A 100 W sodium lamp is radiating light of wavelength $5890A$, uniformly in all directions,

a. At what rate, photons are emitted from the lamp?

b. At what distance from the lamp, the average flux is 1 photon$(cm^2 - s)^{-1}$?

c. What are the photon flux and photon density at 2m from the lamp?

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2. In an old-fashioned television set, electrons are accelerated through a potential difference of 25.0 kV. What is the de Broglie wavelength of such electrons? (Relativity is not needed.)

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3. Find the maximum kinetic energy of electrons ejected from a certain material if the material's work function is 2.3 eV and the frequency of the incident radiation is $2.5 \times 10^{15} Hz$.

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4. Calculate the de Broglie wavelength of (a) a 2.00 keV electron, (b) a 2.00 keV photon, and (c) a 2.00 keV neutron.

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5. Solar radiations fall on Earth's surface at a rate of $1400W/m?$. Assuming that the radiation has an average wavelength of 550 nm, how many photos per square meter per second fall on the surface?

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6. How fast must an electron move to have a kinetic energy equal to the photon energy of sodium light at wavelength 500 nm?

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7. 1.5 mW of 400 nm light is directed at a photoelectric cell. If 0.1% of the incident photons produce photoelectrons, find the current in the cell.

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8. The uncertainty in the position of an electron along an x axis is given as 50 pm, which is about equal to the radius of a hydrogen atom. What is the least uncertainty in any simultaneous measurement of the momentum component P_x of this electron?

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9. Suppose the fractional efficiency of a cesium surface (with work function 1.80 eV) is 1.0×10^{-16}, that is, on average one electron is ejected for every 10^{16} photons that reach the surface. What would be the current of electrons ejected from such a surface if it were illuminated with 600 nm light from a 3.00 mW laser and all the ejected electrons took part in the charge flow?

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10. An electron and a photon each have a wavelength of 0.25 nm. What is the momentum $(\text{in } kgm/s)$ of the (a) electron and (b) photon? What is the energy (in eV) of the (c) electron and (d) photon?

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11. The function $\Psi(x)$ displayed in Eq. 37-19 can describe a free particle, for which the potential energy is U(x) = 0 in Schrodinger's equation (Eq. 37-11). Assume now that $U(x) = U_0 = a$ constant in that equation. Show that Eq. 37-19 is a solution of Schrodinger's equation, with

$$k = \frac{2\pi}{h}\sqrt{2m(E - U_0)}$$

giving the angular wave number k of the particle.

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12. Show that the angular wave number k for a nonrelativistic free particle of mass m can be written as

$$k = \frac{2\pi\sqrt{2mk}}{h}$$

in which K is the particle's kinetic energy.

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13. An electron with total energy E = 5.1 eV approaches a barrier of height $U_h = 6.8eV$ and thickness L = 750 pm. What percentage change in the transmission coefficient T occurs for a 1.0% change in (a) the barrier height, (b) the barrier thickness, and (c) the kinetic energy of the incident electron?

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14. An ultraviolet lamp emits light of wavelength 400 nm at the rate of 400 W. An infrared lamp emits light of wave-length 700 nm, also at the rate of 400 W. (a) Which lamp emits photons at the greater rate and (b) what is that greater rate?

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15. The smallest dimension (resolving power) that can be resolved by an electron microscope is equal to the de Broglie wavelength of its electrons. What accelerating voltage would be required for the electrons to have the same resolving power as could be obtained using 120 keV gamma rays?

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16. The wavelength of the yellow spectral emission line of sodium is 590 nm. At what kinetic energy would an electron have that wavelength as its de Broglie wavelength?

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17. A nonrelativistic particle is moving three times as fast as an electron. The ratio of the de Broglie wavelength of the particle to that of the electron is 1.813×10^{-4}. By calculating its mass, identify the particle.

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18. (a) Suppose a beam of 4.5 eV protons strikes a potential energy barrier of height 6.0 eV and thickness 0.70 nm, at a rate equivalent to a current of 1000 A. How long would you have to wait-on average-for one proton to be transmitted? (b) How long would you have to wait if the beam consisted of electrons rather than protons?

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19. An isolated copper sphere of radius 5.0 cm, initially uncharged, is illuminated by ultraviolet light of wave- length 200 nm. What charge will the photoelectric effect induce on the sphere. The work function for copper is 4.70 eV.

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20. An orbiting satellite can become charged by the photoelectric effect when sunlight ejects electrons from its outer surface. Satellites must be designed to minimize such charging because it can ruin the sensitive microelectronics. Suppose a satellite is coated with platinum, a metal with a very large work function $(\Phi = 5.32 eV)$. Find the longest wavelength of incident sunlight that can eject an electron from the platinum.

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21. The work function of tungsten is 4.50 eV. Calculate the speed of the fastest electrons ejected from a tungsten surface when light whose photon energy is 5.80 eV shines on the surface.

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22. A helium-neon laser emits red light at wavelength λ=633 nm in a beam of diameter 3.0 mm and at an energy-emission rate of 5.0 mW. A detector in the beam's path totally absorbs the beam. At what rate per unit area does the detector absorb photons?

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23. A light detector (your eye) has an area of $2.00 \times 10^{-6} m^2$ and absorbs 80% of the incident light, which is at wavelength 500 nm. The detector faces an isotropic source, 3.00 m from the source. If the detector absorbs photons at the rate of exactly $4.000 s^{-1}$, at what power does the emitter emit light?

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24. If the de Broglie wavelength of a proton is 100 fm, (a) what is the speed of the proton and (b) through what electric potential would the proton have to be accelerated to acquire this speed?

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25. What is the wavelength of (a) a photon with energy 1.00 eV, (b) an electron with energy 1.00 eV and (c) a photon of energy 1.00 GeV?

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26. The wavelength associated with the cutoff frequency for silver is 325 nm. Find the maximum kinetic energy of electrons ejected from a silver surface by ultraviolet light of wavelength 275 nm.

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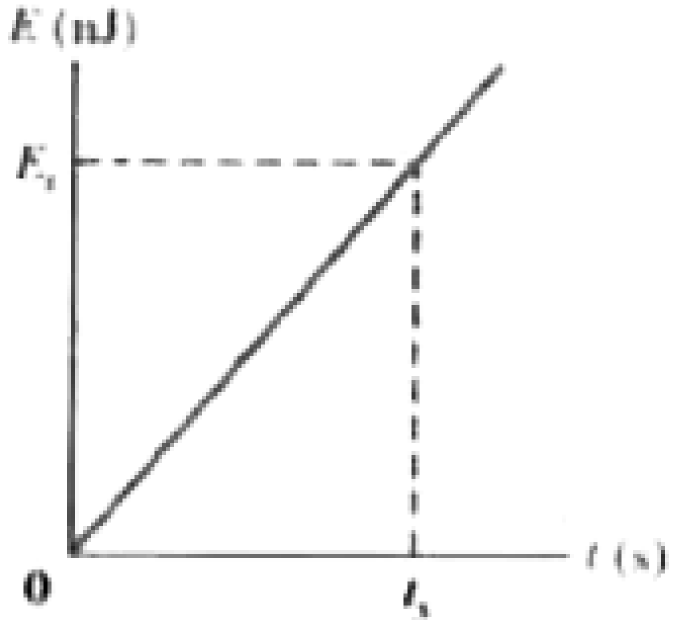
27. A light detector has an absorbing area of $3.00 \times 10^{-6} m^2$ and absorbs 50% of the incident light, which is at wavelength 600 nm. The detector faces an isotropic source, 12.0 m from the source. The energy E emitted by the source versus time t is given in Fig. 37-19 Problem 28.

At what rate are photons absorbed by the detector?



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28. At what rate does the Sun emit photons? For simplicity, assume that the Sun's entire emission at the rate of 3.9×10^{26} W is at the single wavelength of 550 nm.

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29. What (a) frequency, (b) photon energy, and (c) photon momentum magnitude are associated with x rays having wavelength 35.0 pm?

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30. The beam emerging from a 1.5 W argon laser $(\lambda = 515 nm)$ has a diameter d of 3.5 mm. The beam is focused by a lens system with an effective focal length f_L of 2.5 mm. The focused beam strikes a totally absorbing screen, where it forms a circular diffraction pattern whose central disk has a radius R given by $1.22 f_L \lambda / d$. It can be shown that 84% of the incident energy ends up within this central disk.

At what rate are photons absorbed by the screen in the central disk of the diffraction pattern?

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31. An electron moves through a region of uniform electric potential of -200 V with a (total) energy of 500 eV. What are its (a) kinetic energy (in electron-volts), (b) momentum, (c) speed, (d) de Broglie wavelength, and (e) angular wave number?

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32. (a) If the work function for a certain metal is 1.8 e V, what is the stopping potential for electrons ejected from the metal when light of wavelength 400 nm shines on the metal?

(b) What is the maximum speed of the ejected electrons?

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33. How fast must an electron move to have a kinetic energy equal to the photon energy of sodium light at wavelength 588 nm?

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34. A special kind of light bulb emits monochromatic light of wavelength 630 nm. Electrical energy is supplied to it at the rate of 60 W, and the bulb is 93% efficient at converting that energy to light energy. How many photons are emitted by the bulb during its lifetime of 730 h?

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35. The stopping potential for electrons emitted from a surface illuminated by light of wavelength 491 nm is 0.710 V. When the incident wavelength is changed to a new value, the stopping potential is 1.43 V. (a) What is this new wave-length? (b) What is the work function for the surface?

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36. What is the photon energy for yellow light from a highway sodium lamp at a wavelength of 589 nm?

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37. You wish to pick an element for a photocell that will operate via the photoelectric effect with visible light. Which of the following are suitable (work functions are in parentheses): tantalum (4.2 eV), tungsten (4.5 eV), aluminum (4.2 eV), barium (2.5 eV), lithium (2.3 eV)?

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38. Light strikes a sodium surface, causing photoelectric emission. The stopping potential for the ejected electrons is 5.0 V, and the work function of sodium is 2.2 eV. What is the wavelength of the incident light?

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39. In a photoelectric experiment using a sodium surface, you find a stopping potential of 1.85 V for a wavelength of 300 nm and a stopping potential of 0.820 V for a wavelength of 400 nm. From these data find (a) a value for the Planck constant, (b) the work function Φ for sodium, and (c) the cutoff wavelength λ_0 for sodium.

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40. Singly charged sodium ions are accelerated through a potential difference of 300 V. (a) What is the momentum acquired by such an ion? (b) What is its de Broglie wavelength?

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41. A satellite in Earth orbit maintains a panel of solar cells of area $2.90 m^2$ perpendicular to the direction of the Sun's light rays. The intensity of the light at the panel is $1.39 kW/m^2$. (a) At what rate does solar energy arrive at the panel? (b) At what rate are solar photons absorbed by the panel? Assume that the solar radiation is mono- chromatic, with a wavelength of 550 nm, and that all the solar radiation striking the panel is absorbed. (c) How long would it take for a "mole of photons" to be absorbed by the panel?

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42. Light of wavelength 200 nm shines on an aluminum surface, 4.20 eV is required to eject an electron. What is the kinetic energy of (a) the fastest and (b) the slowest ejected electrons? (c) What is the stopping potential for this situation? (d) What is the cutoff wavelength for aluminum?

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43. At one time, the metre was defined as 1650763.73 wavelengths of the orange light emitted by a light source containing Kr^{86} atoms. What is the corresponding photon energy of this radiation?

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44. X rays with a wavelength of 71 pm are directed onto a gold foil and eject tightly bound electrons from the gold atoms. The ejected electrons then move in circular paths of radius r in a region of uniform magnetic field $\vec{B}$. For the fastest of the ejected electrons, the product Br is equal to 1.88×10^{-4} T.m. Find (a) the maximum kinetic energy of those electrons and (b) the work done in removing them from the gold atoms.

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45. What are (a) the energy of a photon corresponding to wavelength 1.00 nm, (b) the kinetic energy of an electron with de Broglie wavelength 1.00 nm, (c) the energy of a photon corresponding to wavelength 1.00 fm, and (d) the kinetic energy of an electron with de Broglie wavelength 1.00 fm?

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46. Find the (a) maximum kinetic energy of photoelectrons ejected from potassium surface, for which , $\phi = 2.1 eV$, by photons of wavelengths 2000 Å and 5000 Å. (b) What is the threshold frequency v_0 and (c) the corresponding wavelength?

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47. A parellel beam of monochromatic light of wavelength 500 nm is incident normally on a perfectly absorbing surface. The power through any cross section of the beam is 10 W. Find

(a) the number of photons absorbed per second by the surface and

(b) the force exerted by the light beam on the surface.

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48. A parallel beam of monochromatic light of wavelength 663 nm is incident on a totally reflecting plane mirror. The angle of incidence is 60° and the number of photons striking the mirror per second is $\left(1.0 \times \left(10^{19}\right)\right)$. Calculate the force exerted by the light beam on the mirror.

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49. A beam of white light is incident normally on a plane surface absorbing $50\,\%$ of the light and reflecting the rest. If the incident beam carries 10 W of power, find the force exerted by it on the surface.

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50. A small laser emits light at power 5.00 mW and wave-length 633 nm. The laser beam is focused (narrowed) until its diameter matches the 1266 nm diameter of a sphere placed in its path. The sphere is perfectly absorbing and has density `5.00 xx 10^(3)' kg/m^(3). What are (a) the beam intensity at the sphere's location, (b) the radiation pressure on the sphere, (c) the magnitude of the corresponding force, and (d) the magnitude of the acceleration that force alone would give the sphere?

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Practice Questions Single Correct Choice Type

1. Protons and α-particles have the same de Broglie wavelength. What is same for both of them?

A. Energy

B. Time

C. Frequency

D. Momentum

Answer: D

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2. The specific charge of a proton is $9.6 \times 10^7 C / kg$. The specific charge of an alpha particle is

A. $9.6 \times 10^7 C / kg$

B. $19.2 \times 10^7 C / kg$

C. $4.8 \times 10^7 C / kg$

D. $2.4 \times 10^7 C / kg$

Answer: B

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3. An electron of mass m when accelerated through a potential difference V, has de Broglie wavelength λ. The de

Broglie wavelength associated with a proton of mass M accelerated through the same potential difference, will be :-

A. $\frac{\lambda m}{M}$

B. $\lambda\sqrt{\frac{m}{M}}$

C. $\frac{\lambda M}{m}$

D. $\lambda\sqrt{\frac{M}{m}}$

Answer: B

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4. What is the de Broglie wavelength of an electron accelerated from rest through a potential difference of V volts?

A. $\frac{12.3}{\sqrt{V}}$ Å

B. $\frac{12.3}{V}$ Å

C. $\frac{12.3}{V^2}$ Å

D. None of these

Answer: A

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5. The frequency of incident light falling on a photosensitive metal plate is doubled, the K.E of the emitted photo-electrons is

A. Double the earlier value

B. Unchanged

C. More than doubled

D. Less than doubled

Answer: C

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6. A light of wavelength 5000Å falls on a photosensitive plate with photoelectric work function 1.90 eV. Kinetic energy of the emitted photoelectrons will be $\left(h = 6.63 \times 10^{-34} J.\ s\right)$

A. 0.1 eV

B. 0.59 eV

C. 1.581 eV

D. 2 eV

Answer: B

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7. Lights of two different frequencies whose photons have energies 1 and 2.5 eV, respectively, successively illuminate a metal whose work function is 0.5 eV. The ratio of the maximum speeds of the emitted electrons

A. $1:5$

B. $1:4$

C. $1:2$

D. $1:1$

Answer: C

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8. Photoelectric work- function of a metal is $1eV$. Light of wavelength $\lambda = 3000\text{Å}$ falls on it. The photoelectrons come out with maximum velocity

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9. The de-Broglie wavelength of proton $(\text{ charge} = 1.6 \times 10^{-19}C, \text{mass} = 1.6 \times 10^{-27}Kg)$ accelerated through a potential difference of 1kV is

A. 600Å

B. 0.9×10^{-12}

C. 7Å

D. 0.9nm

Answer: B

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10. In Davisson-Germer experiment, the correct relation between angle of diffraction ϕ and glancing angle θ is-

A. $\theta = 90^\circ - \frac{\phi}{2}$

B. $\theta = 90^\circ + \frac{\phi}{2}$

C. $\theta = \frac{\phi}{2}$

D. $\theta = \phi$

Answer: A

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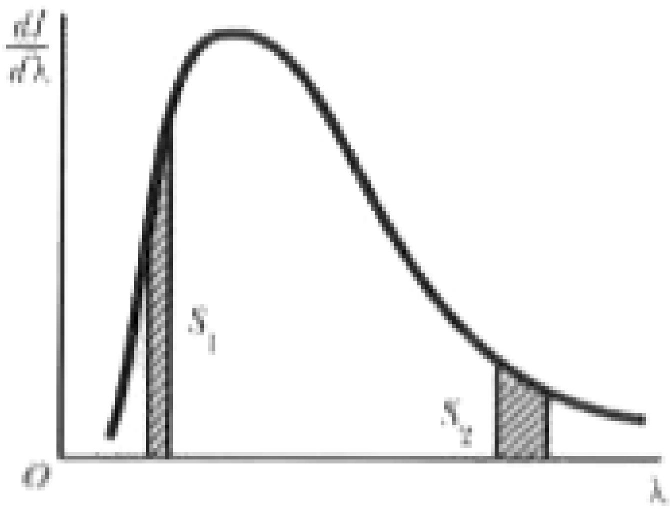
11. Two separate segments of equal area are isolated in the energy distribution of black body radiation (As shown in the following figure). Let us assume that the number of photons emitted by the body per unit time in the segments is n_1 and n_2 and the energy of the photons are E_1 and E_2 respectively. Then



A. $n_1 > n_2$

B. $n_1 < n_2$

C. $E_1 < E_2$

D. $E_1 > E_2$

Answer: D

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12. Let `(n_r) and (n_b) be respectively the number of photons emitted by a red bulb and a blue blub of equal power in a given time.

A. $n_r = n_b$

B. $n_r > n_b$

C. $n_r < n_b$

D. The information is insufficient to get a relation between n_r and n_b

Answer: B

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13. Consider tuning a radio to higher frequency station. The energy of radio photons detected

A. Is zero because radio waves do not carry energy

B. Is smaller

C. Is greater

D. Is the same as before, but the radio waves are of higher frequency

Answer: C

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14. A beam of ultraviolet light is incident on the metal ball of an electroscope that is initially uncharged. Does the electroscope acquire a charge?

A. Yes, it acquires a positive charge

B. Yes, it acquires a negative charge

C. No, it does not acquire a charge

D. Its acquiring the charge depends on the work function of the metal

Answer: D

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15. A xenon are lamp is covered with an interference filter that only transmits light of 400 nm wavelength. When the transmitted light strikes a metal surface, a stream of electrons emerges from the metal. If the intensity of the light striking the surface is doubled, then

A. More electrons are emitted in a given time interval

B. The electrons that are emitted are more energetic

C. Both of the above

D. Neither of the above

Answer: A

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16. A girl is performing a photoelectric experiment but no photoelectrons are being ejected. To eject electrons, she should change the light by

A. Decreasing the frequency

B. Increasing the frequency

C. Increasing the intensity

D. Increasing the wavelength

Answer: B

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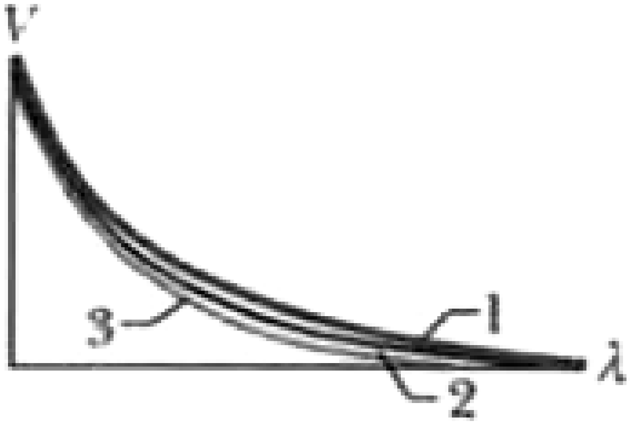
17. In the following figure gives the stopping voltage V versus the wavelength λ of light for three different materials. Rank the materials according to their work function, greatest first.



A. $\phi_3 > \phi_2 > \phi_1$

B. $\phi_1 > \phi_2 > \phi_3$

C. $\phi_2 > \phi_3 > \phi_1$

D. $\phi_3 > \phi_1 > \phi_2$

Answer: A

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18. A non-monochromatic light is used in an experiment on photoelectric effect. The stopping potential

A. Related to the mean wavelength

B. Related to the longest wavelength

C. Related to the shortest wavelength

D. Not related to the wavelength

Answer: C

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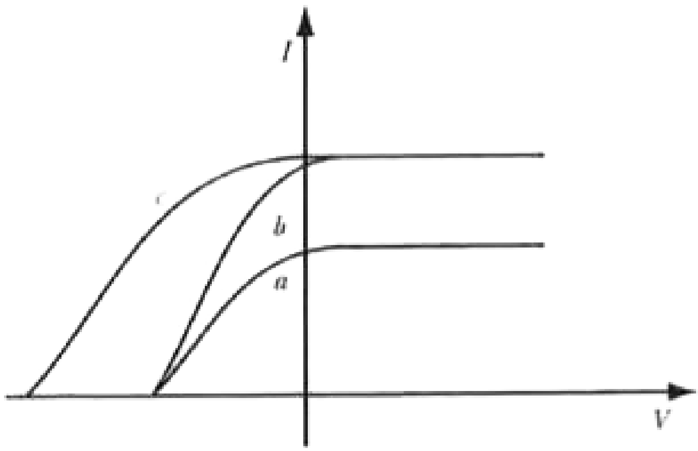
19. In the following figure shows the variation of photocurrent with potential of the collector plate for a photosensitive surface for three different radiations. Let I_a, I_b and I_c be the intensities and f_a, f_b and f_c be the frequencies for the curves a, b, and c, respectively.



A. $f_a = f_b$ and $I_a = I_b$

B. $f_a = f_c$ and $I_a = I_c$

C. $f_a = f_b$ and $I_a < I_b$

D. $f_a = f_c$ and $I_b = I_c$

Answer: C

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20. In a photoelectric tube, the voltage applied is such that the photoelectrons emitted reverse in direction after traveling half the distance. we keep the voltage same but halve the distance, then

A. The photoelectrons reverse the direction at half of the new distance

B. The photoelectrons are just able to reach the other electrode

C. The photoelectrons reverse the direction at one fourth of the new distance

D. The photoelectrons reach the other electrode with some kinetic energy

Answer: B

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21. An image of the sun is formed by a lens, of the focal length of 30 cm, on the metal surface of a photoelectric cell and a photoelectric current I is produced. The lens forming the image is then replaced by another of the same diameter but of focal length 15 cm. The photoelectric current in this case is

A. $i/2$

B. i

C. 2i

D. 4i

Answer: B

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22. If a parallel beam of light having intensity I is incident normally on a perfectly reflecting surface, the force exerted on the surface, equal F. When the surface is held at an angle θ, the force is

A. $2F\tan\theta$

B. $F \cos \theta$

C. $2F \cos^2 \theta$

D. 2F

Answer: C

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23. The difference between the photons and other material particles that we know of is that

A. The photon is always chargeless whereas all the material particles have some charge

B. The rest mass of photon is zero whereas all the material particles have some mass

C. Photon cannot be accelerated by applying some force

D. Photons have a wave associated with them but material particles cannot be associated with a wave

Answer: B

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24. A beta particle, gamma ray, and alpha particle all have the same momentum. Which has the longest wavelength?

A. Beta particle

B. Gamma ray

C. Alpha particle

D. All the same

Answer: D

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25. If a proton and an electron have the same kinetic energy, which has the longer de Broglie wavelength?

A. Electron

B. Proton

C. Both have the same wavelength

D. None of the above

Answer: A

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26. The equation E=pc is valid

A. For an electron

B. For a photon

C. For a photon as well as for an electron

D. Neither for an electron nor for a photon

Answer: B

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27. A particle of mass 4m at rest decays into two particles of masses m and 3m having nonzero velocities. The ratio of the de Broglie wavelengths of the particles 1 and 2 is (take h = $6.6 \times 10^{-34} m^2 kgs^{-1}$)

A. $1/2$

B. $1/4$

C. 2

D. 1

Answer: D

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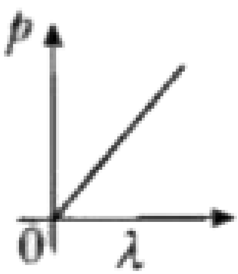
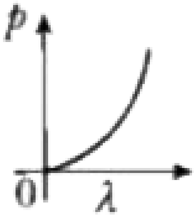
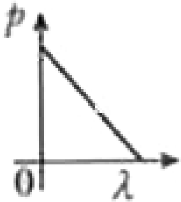
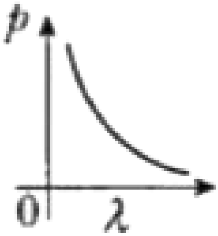
28. Which of the following graph represent the variation of particle momentum and associated de Broglie wavelength?

A. 

B. 

C. 

D. 

Answer: D

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29. The frequency of matter waves is expressed as

A. hf

B. E/h

C. $1/T$

D. None of these

Answer: B

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30. $\Psi(x)$ is the wave function for a particle moving along the x axis. The probability that the particle is in the interval from x = a to x = b is given by

A. $\Psi(b) - \Psi(a)$

B. $|\Psi(b)|/|\Psi(a)|$

C. $|\Psi(b)|^2 / |\Psi(a)|^2$

D. $\int_a^b \Psi(x)dx$

Answer: C

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31. The significance of $|\Psi|^2 x$ is

A. Probability

B. Energy

C. Probability density

D. Energy density

Answer: C

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32. A free electron in motion along the x axis has a localized wave function. The uncertainty in its momentum is decreased if

A. The wave function is made more narrow

B. The wave function is made less narrow

C. The wave function remains the same but the energy of the electron is increased

D. The wave function remains the same but the energy of the electron is decreased

Answer: A

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33. The uncertainty in position of an electron in a certain state is $5 \times 10^{-10} m$. The uncertainty in its momentum might be

A. $5.0 \times 10^{-24} kg. m/s$

B. $4.0 \times 10^{-24} kg. m/s$

C. $3.0 \times 10^{-24} kg. m/s$

D. All of the above

Answer: D

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34. The reflection coefficient R for a certain barrier tunneling problem is 0.80. The corresponding transmission coefficient T is

A. 0.8

B. 0.6

C. 0.5

D. 0.2

Answer: D

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35. An electron with energy E is incident on a potential energy barrier of height E_{pot} and thickness L. The probability of tunneling increases if

A. E decreases without any other changes

B. E_{pot} increases without any other changes

C. L decreases without any other changes

D. E and E_{pot} increase by the same amount

Answer: C

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36. An electron with energy E is incident upon a potential energy barrier of height $E_{pot} > E$ and thickness L. The transmission coefficient T

A. Is zero

B. Decreases exponentially with L

C. Is proportional to $1/L$

D. Is proportional to $1/L^2$

Answer: B

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37. A laser emits a single, 2.0 ms pulse of light that has a frequency of $2.83 \times 10^{11} Hz$ and a total power of 75 000 W. How many photons are in the pulse?

A. 8.0×10^{23}

B. 2.4×10^{25}

C. 1.6×10^{24}

D. 3.2×10^{25}

Answer: A

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38. A laser emits a pulse of light with energy $5.0 \times 10^{3} J$. Determine the number of photons in the pulse if the wavelength of light is 480 nm.

A. 5.2×10^{16}

B. 1.2×10^{22}

C. 2.5×10^{19}

D. 3.1×10^{22}

Answer: B

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39. An x-ray generator produces photons with energy 49 600 eV or less. Which one of the following phrases most accurately describes the wavelength of these photons?

A. 0.025 nm or longer

B. 0.75 nm or longer

C. 0.050 nm or longer

D. 0.25 nm or shorter

Answer: A

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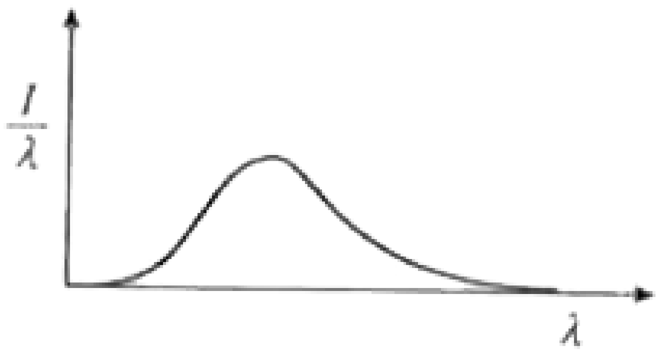
40. The graph shows the variation in radiation intensity per unit wavelength versus wavelength for a perfect black- body at temperature T. Complete the following statement: As the blackbody temperature is increased, the peak in intensity of this curve



A. Will remain constant

B. Will be shifted to longer wavelengths and its magnitude will increase

C. Will be shifted to shorter wavelengths and its magnitude will increase

D. Will be shifted to longer wavelengths and its magnitude will decrease

Answer: C

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41. Which one of the following quantities is the same for all photons in vacuum?

A. Speed

B. Kinetic energy

C. Frequency

D. Wavelength

Answer: A

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42. Complete the following statement: The term photon applies

A. Only to x-rays

B. To any form of particle motion

C. Only to visible light

D. To any form of electromagnetic radiation

Answer: D

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43. Which one of the following statements concerning photons is false?

A. Photons have zero mass

B. The rest energy of all photons is zero

C. Photons travel at the speed of light in a vacuum

D. Photons have been brought to rest by applying a strong magnetic field to them.

Answer: D

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44. Photons of what minimum frequency are required to remove electrons from gold?

Note: The work function for gold is 4.8 eV.

A. $7.3 \times 10^{14} Hz$

B. $3.8 \times 10^{17} Hz$

C. $1.2 \times 10^{15} Hz$

D. $6.5 \times 10^{14} Hz$

Answer: C

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45. White light consisting of wavelengths $380nm \leq \lambda \leq 750nm$ is incident on a lead surface. For which one of the following ranges of wavelengths will photoelectrons be emitted from the lead surface that has a work function $W_0 = 6.63 \times 10^{-19} J$?

A. $380nm \leq \lambda \leq 750nm$

B. $380nm \leq \lambda \leq 410nm$

C. $380nm \leq \lambda \leq 630nm$

D. No photoelectrons will be emitted

Answer: D

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46. A photon of wavelength 200 nm is scattered by an electron that is initially at rest. Which one of the following statements concerning the wavelength of the scattered photon is true?

A. The wavelength is zero nm.

B. The wavelength is greater than 200 nm.

C. The wavelength is 200 nm.

D. The wavelength is 100 nm.

Answer: B

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47. The de Broglie wavelength of an electron $(m = 9.11 \times 10^{-31} kg)$ is $1.2 \times 10^{-10} m.$ Determine the kinetic energy of the electron.

A. $1.5 \times 10^{-15} J$

B. $1.7 \times 10^{-17} J$

C. $1.6 \times 10^{-16} J$

D. $1.8 \times 10^{-15} J$

Answer: B

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Practice Questions More Than One Correct Choice Type

1. In which of the following situations, the heavier of the two particles has smaller de broglie wavelength ? The two particle

A. Move with the same speed

B. Move with the same linear momentum

C. Move with the same kinetic energy

D. Have the same change of potential energy in a conservative field

Answer: A::C::D

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2. When photons of energy 4.25eV strike the surface of a metal A, the ejected photoelectrons have maximum kinetic energy, T_A (expressed in eV) and deBroglie wavelength λ_A. The maximum kinetic energy of photoelectrons liberated from another metal B by photons of energy 4.20V is $T_B = T_A - 1.50eV$. If the deBroglie wavelength of those photoelectrons is $\lambda_B = 2\lambda_A$ then

A. The work function of A is 2.25 eV

B. The work function of A is 4.20 eV

C. T = 2.00 eV

D. T= 2.75 eV

Answer: A::B::C

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3. When a monochromatic point source of light is at a distance

of 0.2 m from a photoelectric cell, the cut off voltage and the saturation current

are respectively 0.6 V and 18.0 mA. If the same source is placed 0.6 m away

from the photoelectric cell, then

(a) the stopping potential will be 0.2 V

(b) the stopping potential will be 0.6 V

(c) the saturation current will be 6.0 mA

(d) the saturation current will be 2.0 mA

A. The stopping potential will be 0.2 V

B. The stopping potential will be 0.6 V

C. The stopping potential will be 2.0 mA

D. The stopping potential will be 6.0 mA

Answer: B::C

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4. Photoelectric effect supports quantum nature of light because

(a) there is a minimum frequency of light below which no photo electrons are emitted

(b) the maximum kinetic energy of photo electrons depends only on the frequency of light and not on its intensity

(c) even when the metal surface is faintly illuminated, the photo electrons leave the surface immediately

(d) electric charge of the photo electrons is quantised

A. There is minimum frequency of light below which no photoelectrons are emitted

B. Electric charge of photoelectrons is quantized

C. The maximum kinetic energy of photoelectrons depends only on the frequency of light and not on its intensity

D. Even when the metal surface is faintly illuminated, the photoelectrons leave the surface immediately

Answer: A::C::D

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5. At the stopping potential

A. The electrons are not at all emitted by the plate

B. The electrons are emitted by the plate but reverse their direction of motion just before reaching the collector plate

C. The most energetic electrons emitted reverse their direction of motion just before reaching the other plate

D. The collector plate is negatively charged with respect to the emitter

Answer: C::D

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Practice Questions Link Comprehension

1. which of the following are not dependent on the intensity of the incident radiation in a photoelectric experiment?

A. Amount of photoelectric current

B. Stopping potential to reduce the photoelectric current to zero

C. Work function of the surface

D. Maximum kinetic energy of photoelectrons

Answer: B::C::D

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2. It is desired to obtain a diffraction pattern for electrons using a diffraction grating with lines separated by 10 nm. The mass of an electron is $9.11 \times 10^{-31} kg$.

What is the approximate kinetic energy of electrons that would be diffracted by such a grating?

A. $1.5 \times 10^{-6} eV$

B. $1.5 \times 10^{-2} eV$

C. $1.5 \times 10^{-4} eV$

D. $1.5 \times 10^{2} eV$

Answer: B

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3. It is desired to obtain a diffraction pattern for electrons using a diffraction grating with lines separated by 10 nm. The mass of an electron is $9.11 \times 10^{-31} kg$.

Suppose it is desired to observe diffraction effects for a beam of electromagnetic radiation using the same grating.

Roughly, what is the required energy of the individual photons in the beam?

A. $10^{-6}eV$

B. $10^{-2}eV$

C. $10^{-4}eV$

D. $10^{2}eV$

Answer: D

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4. A physicist wishes to eject electrons by shining light on a metal surface. The light source emits light of wavelength of 450 nm. The table lists the only available metals and their work functions.

Metal	$W_0(eV)$
Barium	2.5
Lithium	2.3
tantalum	4.2
Tungsten	4.5

Which metal(s) can be used to produce electrons by the photoelectric effect from given source of light?

A. Barium only

B. Barium or lithium

C. Tungsten only

D. Lithium, tantalum, or tungsten

Answer: B

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5. A physicist wishes to eject electrons by shining light on a metal surfac. The light source emits light of wavelenght of 450 nm. The table lists the only available metals and their work functions.

Metal	$W_0(eV)$
Barium	2.5
Lithium	2.3
tantalum	4.2
Tungsten	4.5

Which option correctly identifies the metal that will produce the most energetic electrons and their energies?

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6. When a particle is restricted to move aong $x$axis between $x = 0$ and $x = a$, where a is of nanometer dimension. Its energy can take only certain specific values. The allowed energies of the particle moving in such a restricted region, correspond to the formation of standing waves with nodes at its ends $x = 0$ and $x = a$. The wavelength of this standing wave is realated to the linear momentum p of the particle according to the de Breogile relation. The energy of the particl e of mass m is reelated to its linear momentum as $E = \frac{p^2}{2m}$. Thus, the energy of the particle can be denoted by a quantum number $'n'$ taking values $1, 2, 3, ...(n = 1,$ called the ground state) corresponding to the number of loop in the standing wave.

Use the model decribed above to answer the following three questions for a particle moving in the line $x = 0$ to $x = a$. Take $h = 6.6 \times 10^{-34} Js$ and $e = 1.6 \times 10^{-19} C$.

The allowed energy for the particle for a particular value of n is proportional to

A. a^{-2}

B. $a^{3/2}$

C. a^{-1}

D. a^{2}

Answer: A

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7. When a particle is restricted to move aong $x$axis between $x=0$ and $x=a$, where a is of nanometer dimension. Its energy can take only certain specific values. The allowed energies of the particle moving in such a restricted region, correspond to the formation of standing waves with nodes at its ends $x=0$ and $x=a$. The wavelength of this standing wave is realated to the linear momentum p of the particle according to the de Breogile relation. The energy of the particl e of mass m is reelated to its linear momentum as $E = \frac{p^2}{2m}$. Thus, the energy of the particle can be denoted by a quantum number $'n'$ taking values $1, 2, 3, \ldots\ldots (n = 1,$ called the ground state) corresponding to the number of loop in the standing wave.

Use the model decribed above to answer the following three questions for a particle moving in the line $x = 0$ to $x = a$. Take $h = 6.6 \times 10^{-34} Js$ and $e = 1.6 \times 10^{-19} C$.

The speed of the particle, that can take disrete values, is proportional to

A. $n^{-3/2}$

B. n^{-1}

C. $n^{1/2}$

D. n

Answer: D

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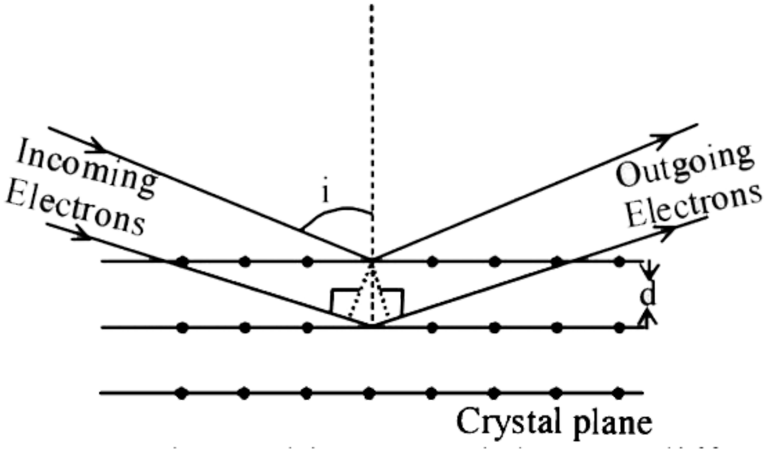
8. Wave property of electron implies that they will show diffraction effected . Davisson and Germer demonstrated this by diffracting electron from crystals . The law governing the diffraction from a crystals is obtained by requiring that electron waves reflected from the planes of atoms in a crystal interfere constructiely



Electron accelerated by potential V are diffracted from a crystal if $d = 1Å$ and $i = 30^\circ, V$ should be about $(h = 6.6 \times 10^{-34} Js, m_e = 9.1 \times 10^{-31} kg, e = 1.6 \times 10^{-19} C)$

A. 1000 V

B. 2000 V

C. 50 V

D. 500 V

Answer: C

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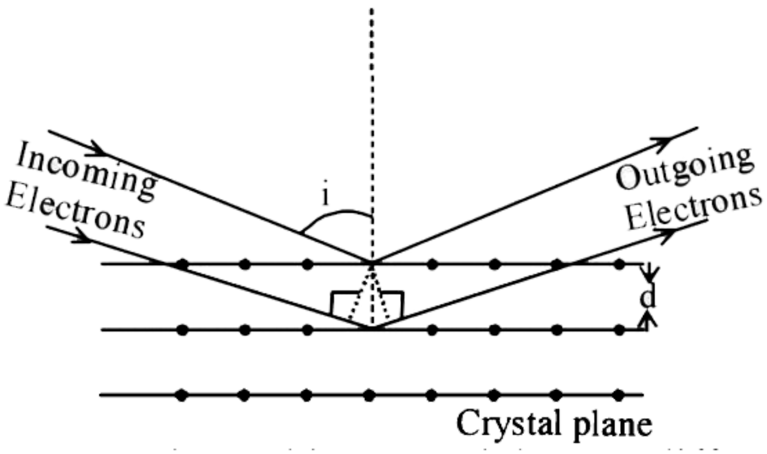
9. Wave property of electron implies that they will show diffraction effected . Davisson and Germer demonstrated this by diffracting electron from crystals . The law governing the diffraction from a crystals is obtained by requiring that electron waves reflected from the planes of atoms in a crystal inter fere constructiely



If a strong diffraction peak is observed when electrons are incident at an angle i from the normal to the crystal planes with distance d between them (see fig) de Brogle wavelength λ_{dB} of electrons can be calculated by the relationship (n is an intenger)

A. $d\cos i = n\lambda_{dB}$

B. $d\sin i = n\lambda_{dB}$

C. $2d\cos i = n\lambda_{dB}$

D. $2d\sin i = n\lambda_{dB}$

Answer: C

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10. Photoelectrons ar ejected from a surface when light of wavelenght $\lambda_1 = 550nm$ is incident on it. The stopping potential for such electrons is $\lambda_{S1} = 0.19V$. Suppose that radiation of wavelength $\lambda_2 = 190nm$ is incident of the surface.

Q. Calculate the stopping potential V_{S2}.

A. 4.47

B. 3.16

C. 2.76

D. 5.28

Answer: A

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11. Photoelectrons ar ejected from a surface when light of wavelenght $\lambda_1 = 550nm$ is incident on it. The stopping potential for such electrons is $\lambda_{S1} = 0.19V$. Suppose that radiation of wavelength $\lambda_2 = 190 nm$ is incident of the surface.

Q. Calulate the work function of the surface.

A. 3.75 eV

B. 2.07 eV

C. 4.20 eV

D. 3.60 eV

Answer: B

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12. Photoelectrons ar ejected from a surface when light of wavelenght $\lambda_1 = 550 nm$ is incident on it. The stopping potential for such electrons is $\lambda_{S1} = 0.19 V$. Suppose that radiation of wavelength $\lambda_2 = 190nm$ is incident of the surface. ltbRgt Q. Calculate the threshold frequency for the surface.

A. 500 THz

B. 480 T Hz

C. 520 T Hz

D. 460 T Hz

Answer: A

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13. When a surface is irradiated with light of wavelength $4950Å$, a photocurrent appears which vanishes if a retarding potential greater than 0.6 volt is applied across the phototube. When a second source of light is used, it is found that the critical potential is changed to 1.1 volt.

The work- function of the emitting surface is i

A. 9.1 eV

B. 1.9 eV

C. 0.9 eV

D. 0.6 eV

Answer: B

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14. When a surface is irradiated with light of wavelength 4950Å, a photocurrent appears which vanishes if a retarding potential greater than 0.6 volt is applied across the phototube. When a second source of light is used, it is found that the critical potential is changed to 1.1 volt.

The wavelength of the second source is

A. 4125Å

B. 4950Å

C. 2125Å

D. 5124Å

Answer: A

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15. When a surface is irradiated with a light of wavelength 4950Å, a photocurrent appears which vanishes if a retarding potential greater that 0.6 V is applied across the phototube.

When a different source of light is used, it is found that the critical retarding potential is changed to 1.1 V.

Change in two stopping potentials is

A. Not observed

B. Significant

C. Nominal

D. Not possible to calculate because of insufficient data-

____

Answer: A

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16. In Young's double slit experiment an electron beam is used to form a fringe pattern instead of light. If speed of the electrons is increased then the fringe

A. The spacing increases

B. The spacing decreases

C. The spacing remains the same

D. None of the above

Answer: B

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17. A beam of electrons with speed v_0 passes through double slits and then is allowed to strike a fluorescent screen. An interference pattern is observed on the screen.

The electrons are instead replaced by protons moving with speed v_0 Compared to electrons at the same speed, what happens to the spacing of the interference fringes on the screen?

A. The spacing increases

B. The spacing decreases

C. The spacing remains the same

D. None of the above

Answer: B

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Practice Questions Matrix Match

1. Match the statements in Column I labeled as (a), (b), (c), and (d) with those in Column II labeled as (p), (q), (r), and (s). Any given statement in Column I can have correct matching with one or more statements in Column II.

Column I	Column II
(a) Einstein's photoelectric equation	**(p)** $\sqrt{V} = a(Z-1)$
(b) Duane–Hunt law of continuous x-rays	**(q)** $L = \frac{nh}{2\pi}$
(c) Moseley's law for characteristic x-rays	**(r)** $\lambda_{min} = \frac{hc}{eV}$
(d) Bohr's quantum condition	**(s)** $K_{max} = hv - W_0$

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2. Match the statements in Column I labeled as (a), (b), (c), and (d) with those in Column II labeled as (p), (q), (r), and (s). Any given statement in Column I can have correct matching with one or more statements in Column II.

Column I	Column II
(a) A wooden table does not emit photoelectrons when exposed to visible light	(p) Photocell
(b) The stopping potential is same for both the intense and dim ultraviolet light	(q) Establishes particle nature of light
(c) Einstein's photoelectric equation threshold	(r) Frequency of visible light is less than the frequency of wood
(d) Light energy is converted into electric energy	(s) Stopping potential depends on the frequency and not on the intensity of incident radiation

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3. de-Broglie equation gives the relation between particle and wave nature of the matter. In the given table, Column I shows the mass of the matter, Column II shows the speed of the matter and column III shows the kinetic energy of matter.

Column I	Column II	Column III
(I) Mass = 9.11×10^{-31} kg	(i) Speed = 255,000,000 m/s	(J) Kinetic energy = 5.84226×10^{-27} J
(II) Mass = 1.674×10^{-27} kg	(ii) Speed = 100.0 miles per hour	(K) Kinetic energy = 1.28433×10^{-17} J
(III) Mass = 5.00 ounce	(iii) Speed = 698 cm/s	(L) Kinetic energy = 5.43934×10^{-11} J
(IV) Mass = 1.673×10^{-27} kg	(iv) Speed = 5.31×10^{6} m/s	(M) Kinetic energy = 141.6146 J

What are the conditions for an electron with a wavelength at

1.37Å?

A. $(I)(iv)(M)$

B. $(I)(iv)(K)$

C. $(II)(i)(J)$

D. $(II)(i)(L)$

Answer: A::B::C::D

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4. de-Broglie equation gives the relation between particle and wave nature of the matter. In the given table, Column I shows the mass of the matter, Column II shows the speed of the matter and column III shows the kinetic energy of matter.

Column I	Column II	Column III
(I) Mass = 9.11×10^{-31} kg	(i) Speed = 255,000,000 m/s	(J) Kinetic energy = 5.84226×10^{-27} J
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(III) Mass = 5.00 ounce	(iii) Speed = 698 cm/s	(L) Kinetic energy = 5.43934×10^{-11} J
(IV) Mass = 1.673×10^{-27} kg	(iv) Speed = 5.31×10^{6} m/s	(M) Kinetic energy = 141.6146 J

What are the conditions for a proton with a wavelength at $1.55 \times 10^{-15} m$?

A. $(I)(ii)(J)$

B. $(III)(iv)(M)$

C. $(IV)(i)(L)$

D. $(I)(i)(M)$

Answer:

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5. de-Broglie equation gives the relation between particle and wave nature of the matter. In the given table, Column I shows the mass of the matter, Column II shows the speed of the matter and column III shows the kinetic energy of matter.

Column I		Column II		Column III	
(I)	Mass = 9.11×10^{-31} kg	(i)	Speed = 255,000,000 m/s	(J)	Kinetic energy = 5.84226×10^{-27} J
(II)	Mass = 1.674×10^{-27} kg	(ii)	Speed = 100.0 miles per hour	(K)	Kinetic energy = 1.28433×10^{-17} J
(III)	Mass = 5.00 ounce	(iii)	Speed = 698 cm/s	(L)	Kinetic energy = 5.43934×10^{-11} J
(IV)	Mass = 1.673×10^{-27} kg	(iv)	Speed = 5.31×10^{6} m/s	(M)	Kinetic energy = 141.6146 J

What are the conditions for hydrogen ion with a wavelength at $1.50 \times 10^{-7} m$?

A. $(II)(ii)(J)$

B. $(I)(iii)(J)$

C. $(IV)(i)(L)$

D. $(IV)(iv)(J)$

Answer:

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Practice Questions Integer Type

1. When a beam of $10.6eV$ photons of intensity $2.0W/m^2$ falls on a platinum surface of area $1.0 \times 10^{-4}m^2$ and work function $5.6eV, 0.53\%$ of the incident photons eject photoelectrons. Find the number of photoelectrons emitted per second and their minimum and maximum energy (in eV).

Take $1eV = 1.6 \times 10^{-19}J$.

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2. A sample of monatomic hydrogen gas contains n atoms all in third excited state. Find the minimum value of n so that on subsequent de-excitation, all positive different energy photons are emitted.

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3. A proton $\left(m_p = 1.673 \times 10^{-27} kg\right)$ and an electron $\left(m = 9.109 \times 10^{-31} kg\right)$ are confined such that the position x of each is known within $1.50 \times 10^{-10} m$. What is the ratio of the minimum uncertainty in the x component of the velocity of the electron to that of the proton, $\Delta v_e / \Delta v_p$?

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4. The position of a hydrogen atom $\left(m = 1.7 \times 10^{-27} kg\right)$ is known within $2.0 \times 10^{-6} m.$ What is the minimum uncertainty in the atom's velocity?

(a) $zerom / s$

(b) $0. .011m / s$

(c) $0.0085m / s$

(d) $0.016m / s$

(e) $0.031m / s$

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