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Dual Nature of Radiation and Matter

TOPIC 1 Matter Waves, Cathode and Positive Rays

1. An electron, a doubly ionized helium ion (He^{++}) and a proton are having the same kinetic energy. The relation between their respective de-Broglie wavelengths λ_e, λ_{He++} and λ_p is : **[Sep. 06, 2020 (I)]**

   (a) $\lambda_e > \lambda_{He++} > \lambda_p$ (b) $\lambda_e < \lambda_{He++} = \lambda_p$

   (c) $\lambda_e > \lambda_p > \lambda_{He++}$ (d) $\lambda_e < \lambda_p < \lambda_{He++}$

2. Assuming the nitrogen molecule is moving with r.m.s.velocity at 400 K, the de-Broglie wavelength of nitrongen molecule is close to :

   (Given : nitrogen molecule weight : 4.64×10^{-26} kg, Boltzman constant : 1.38×10^{-23} J/K, Planck constant : 6.63×10^{-34} J.s) **[Sep. 06, 2020 (II)]**

   (a) 0.24 Å (b) 0.20 Å

   (c) 0.34 Å (d) 0.44 Å

3. Particle *A* of mass $m_A = \frac{m}{2}$ moving along the *x*-axis with velocity v_0 collides elastically with another particle *B* at rest having mass $m_B = \frac{m}{3}$. If both particles move along the *x*-axis after the collision, the change $\Delta\lambda$ in de-Broglie wavelength of particle *A*, in terms of its de-Broglie wavelength (λ_0) before collision is : **[Sep. 04, 2020 (I)]**

   (a) $\Delta\lambda = \frac{3}{2}\lambda_0$ (b) $\Delta\lambda = \frac{5}{2}\lambda_0$

   (c) $\Delta\lambda = 2\lambda_0$ (d) $\Delta\lambda = 4\lambda_0$

4. A particle is moving 5 times as fast as an electron. The ratio of the de-Broglie wavelength of the particle to that of the electron is 1.878×10^{-4}. The mass of the particle is close to : **[Sep. 02, 2020 (II)]**

   (a) 4.8×10^{-27} kg (b) 9.1×10^{-31} kg

   (c) 1.2×10^{-28} kg (d) 9.7×10^{-28} kg

5. A particle moving with kinetic energy E has de Broglie wavelength λ. If energy ΔE is added to its energy, the wavelength become $\frac{\lambda}{2}$. Value of ΔE, is: **[9 Jan. 2020 I]**

   (a) E (b) 4E (c) 3E (d) 2E

6. An electron of mass m and magnitude of charge $|e|$ initially at rest gets accelerated by a constant electric field E. The rate of change of de-Broglie wavelength of this electron at time *t* ignoring relativistic effects is: **[9 Jan. 2020 II]**

   (a) $-\frac{h}{|e|E\sqrt{t}}$ (b) $\frac{|e|Et}{h}$

   (c) $-\frac{h}{|e|Et}$ (d) $\frac{-h}{|e|Et^2}$

7. An electron (mass m) with initial velocity $\vec{v} = v_0\hat{i} + v_0\hat{j}$ is in an electric field $\vec{E} = -E_0\hat{k}$. If λ_0 is initial de-Broglie wavelength of electron, its de-Broglie wave length at time *t* is given by: **[8 Jan. 2020 II]**

   (a) $\frac{\lambda_0\sqrt{2}}{\sqrt{1+\frac{e^2E^2t^2}{m^2v_0^2}}}$ (b) $\frac{\lambda_0}{\sqrt{1+\frac{e^2E_0^2t^2}{m^2v_0^2}}}$

   (c) $\frac{\lambda_0}{\sqrt{1+\frac{e^2E^2t^2}{2m^2v_0^2}}}$ (d) $\frac{\lambda_0}{\sqrt{2+\frac{e^2E^2t^2}{m^2v_0^2}}}$

8. A particle 'P' is formed due to a completely inelastic collision of particles '*x*' and '*y*' having de-Broglie wavelengths 'γ_x' and 'γ_y' respectively. If *x* and *y* were moving in opposite directions, then the de-Broglie wavelength of 'P' is: **[9 Apr. 2019 II]**

   (a) $\frac{\gamma_x\gamma_y}{\gamma_x+\gamma_y}$ (b) $\frac{\gamma_x\gamma_y}{|\gamma_x-\gamma_y|}$

   (c) $\gamma_x - \gamma_y$ (d) $\gamma_x + \gamma_y$

9. Two particles move at right angle to each other. Their de Broglie wavelengths are λ_1 and λ_2 respectively. The particles suffer perfectly inelastic collision. The de Broglie wavelength λ, of the final particle, is given by : **[8 April 2019 I]**

(a) $\frac{1}{\lambda^2}=\frac{1}{\lambda_1^2}+\frac{1}{\lambda_2^2}$ (b) $\lambda=\sqrt{\lambda_1\lambda_2}$

(c) $\lambda=\frac{\lambda_2+\lambda_2}{2}$ (d) $\frac{2}{\lambda}=\frac{1}{\lambda_1}+\frac{1}{\lambda_2}$

10. A particle A of mass 'm' and charge 'q' is accelerated by a potential difference of 50v Another particle B of mass '4m' and charge'q' is accelerated by a potential differnce of 2500V. The ratio of de-Broglie wavelength $\frac{\lambda_A}{\lambda_B}$ is **[12 Jan. 2019 I]**

(a) 10.00 (b) 0.07
(c) 14.14 (d) 4.47

11. If the deBroglie wavelength of an electron is equal to 10^{-3} times the wavelength of a photon of frequency 6×10^{14} Hz, then the speed of electron is equal to :
(Speed of light = 3×10^8 m/s)
Planck's constant = 6.63×10^{-34}J.s
Mass of electron = 9.1×10^{-31} kg) **[11 Jan. 2019 I]**

(a) 1.1×10^6 m/s (b) 1.7×10^6 m/s
(c) 1.8×10^6 m/s (d) 1.45×10^6 m/s

12. In an electron microscope, the resolution that can be achieved is of the order of the wavelength of electrons used. To resolve a width of 7.5×10^{-12} m, the minimum electron energy required is close to: **[10 Jan. 2019 I]**

(a) 500 keV (b) 100 keV (c) 1 keV (d) 25 keV

13. Two electrons are moving with non-relativistic speeds perpendicular to each other. If corresponding de Broglie wavelengths are λ_1 and λ_2, their de Broglie wavelength in the frame of reference attached to their centre of mass is: **[Online April 15, 2018]**

(a) $\lambda_{CM}=\lambda_1=\lambda_2$ (b) $\frac{1}{\lambda_1}=\frac{1}{\lambda_1}+\frac{1}{\lambda_2}$

(c) $\lambda_{CM}=\frac{2\lambda_1\lambda_2}{\sqrt{\lambda_1^2+\lambda_2^2}}$ (d) $\lambda_{CM}=\left(\frac{\lambda_1+\lambda_2}{2}\right)$

14. If the de Broglie wavelengths associated with a proton and an α-particle are equal, then the ratio of velocities of the proton and the α-particle will be: **[Online April 15, 2018]**

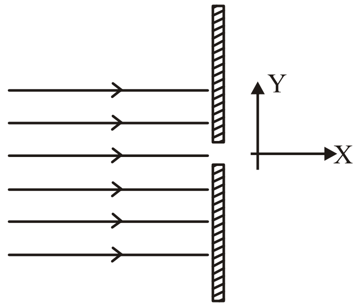
(a) 1 : 4 (b) 1 : 2 (c) 4 : 1 (d) 2 : 1

15. A particle A of mass m and initial velocity v collides with a particle B of mass $\frac{m}{2}$ which is at rest. The collision is head on, and elastic. The ratio of the de-Broglie wavelengths λ_A to λ_B after the collision is **[2017]**

(a) $\frac{\lambda_A}{\lambda_B}=\frac{2}{3}$ (b) $\frac{\lambda_A}{\lambda_B}=\frac{1}{2}$

(c) $\frac{\lambda_A}{\lambda_B}=\frac{1}{3}$ (d) $\frac{\lambda_A}{\lambda_B}=2$

16. A parallel beam of electrons travelling in x-direction falls on a slit of width d (see figure). If after passing the slit, an electron acquires momentum p_y in the y-direction then for a majority of electrons passing through the slit (h is Planck's constant) : **[Online April 10, 2015]**



(a) $|P_y| d > h$ (b) $|P_y| d < h$
(c) $|P_y| d \simeq h$ (d) $|P_y| d >> h$

17. de-Broglie wavelength of an electron accelerated by a voltage of 50 V is close to ($|e| = 1.6 \times 10^{-19}$ C, $m_e = 9.1 \times 10^{-31}$ kg, $h = 6.6 \times 10^{-34}$ Js) : **[Online April 10, 2015]**

(a) 2.4 Å (b) 0.5 Å (c) 1.7 Å (d) 1.2 Å

18. For which of the following particles will it be most difficult to experimentally verify the de-Broglie relationship? **[Online April 9, 2014]**

(a) an electron (b) a proton
(c) an α-particle (d) a dust particle

19. Electrons are accelerated through a potential difference V and protons are accelerated through a potential difference 4 V. The de-Broglie wavelengths are λ_e and λ_p for electrons and protons respectively. The ratio of $\frac{\lambda_e}{\lambda_p}$ is given by : (given m_e is mass of electron and m_p is mass of proton). **[Online April 23, 2013]**

(a) $\frac{\lambda_e}{\lambda_p}=\sqrt{\frac{m_p}{m_e}}$ (b) $\frac{\lambda_e}{\lambda_p}=\sqrt{\frac{m_e}{m_p}}$

(c) $\frac{\lambda_e}{\lambda_p}=\frac{1}{2}\sqrt{\frac{m_e}{m_p}}$ (d) $\frac{\lambda_e}{\lambda_p}=2\sqrt{\frac{m_p}{m_e}}$

20. If the kinetic energy of a free electron doubles, it's de-Broglie wavelength changes by the factor **[2005]**

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

21. Formation of covalent bonds in compounds exhibits **[2002]**

(a) wave nature of electron
(b) particle nature of electron
(c) both wave and particle nature of electron
(d) none of these

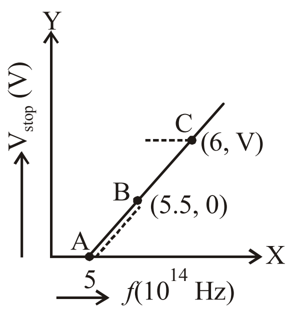
TOPIC 2 Photon, Photoelectric Effect X-rays and Davisson-Germer Experiment

22. A beam of electrons of energy E scatters from a target having atomic spacing of 1Å. The first maximum intensity occurs at $\theta = 60^\circ$. Then E (in eV) is ______.

(Plank constant $h = 6.64 \times 10^{-34}$ Js, 1 eV $= 1.6 \times 10^{-19}$ J, electron mass $m = 9.1 \times 10^{-31}$ kg) **[NA Sep. 05, 2020 (I)]**

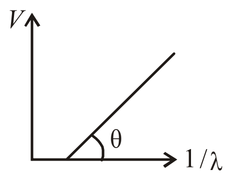
23. The surface of a metal is illuminated alternately with photons of energies $E_1 = 4$ eV and $E_2 = 2.5$ eV respectively. The ratio of maximum speeds of the photoelectrons emitted in the two cases is 2. The work function of the metal in (eV) is ______________. **[NA Sep. 05, 2020 (II)]**

24. Given figure shows few data points in a photo electric effect experiment for a certain metal. The minimum energy for ejection of electron from its surface is : (Plancks constant $h = 6.62 \times 10^{-34}$ J.s) **[Sep. 04, 2020 (I)]**



(a) 2.27 eV (b) 2.59 eV
(c) 1.93 eV (d) 2.10 eV

25. In a photoelectric effect experiment, the graph of stopping potential V versus reciprocal of wavelength obtained is shown in the figure. As the intensity of incident radiation is increased : **[Sep. 04, 2020 (II)]**



(a) Straight line shifts to right
(b) Slope of the straight line get more steep
(c) Straight line shifts to left
(d) Graph does not change

26. When the wavelength of radiation falling on a metal is changed from 500 nm to 200 nm, the maximum kinetic energy of the photoelectrons becomes three times larger. The work function of the metal is close to : **[Sep. 03, 2020 (I)]**

(a) 0.81 eV (b) 1.02 eV
(c) 0.52 eV (d) 0.61 eV

27. Two sources of light emit X-rays of wavelength 1 nm and visible light of wavelength 500 nm, respectively. Both the sources emit light of the same power 200 W. The ratio of the number density of photons of X-rays to the number density of photons of the visible light of the given wavelengths is : **[Sep. 03, 2020 (II)]**

(a) $\frac{1}{500}$ (b) 250 (c) $\frac{1}{250}$ (d) 500

28. When radiation of wavelength λ is used to illuminate a metallic surface, the stopping potential is V. When the same surface is illuminated with radiation of wavelength 3λ, the stopping potential is $\frac{V}{4}$. If the theshold wavelength for the metallic surface is $n\lambda$ then value of n will be __________. **[NA Sep. 02, 2020 (I)]**

29. Radiation, with wavelength 6561 Å falls on a metal surface to produce photoelectrons. The electrons are made to enter a uniform magnetic field of 3×10^{-4} T. If the radius of the largest circular path followed by the electrons is 10 mm, the work function of the metal is close to: **[9 Jan. 2020 I]**

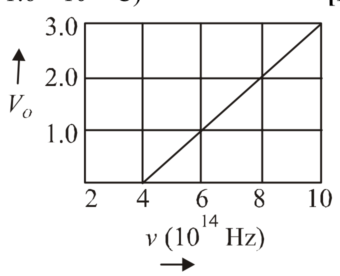
(a) 1.1 ev (b) 0.8 ev
(c) 1.6 ev (d) 1.8 ev

30. When photon of energy 4.0 eV strikes the surface of a metal A, the ejected photoelectrons have maximum kinetic energy T_A eV and de-Broglie wavelength λ_A. The maximum kinetic energy of photoelectrons liberated from another metal B by photon of energy 4.50 eV is $T_B = (T_A - 1.5)$eV. If the de-Broglie wavelength of these photoelectrons $\lambda_B = 2\lambda_A$, then the work function of metal B is: **[8 Jan. 2020 I]**

(a) 4 eV (b) 2 eV
(c) 1.5 eV (d) 3 eV

31. A beam of electromagnetic radiation of intensity 6.4×10^{-5} W/cm² is comprised of wavelength, $\lambda = 310$ nm. It falls normally on a metal (work function $\varphi = 2$eV) of surface area of 1 cm². If one in 10^3 photons ejects an electron, total number of electrons ejected in 1 s is 10^x. ($hc = 1240$ eVnm, 1 eV $= 1.6 \times 10^{-19}$ J), then x is _______. **[NA 7 Jan. 2020 I]**

32. The stopping potential V_0 (in volt) as a function of frequency (ν) for a sodium emitter, is shown in the figure. The work function of sodium, from the data plotted in the figure, will be : (Given : Planck's constant (h) $= 6.63 \times 10^{-34}$ Js, electron charge $e = 1.6 \times 10^{-19}$ C) **[12 Apr. 2019 I]**



(a) 1.82 eV (b) 1.66 eV (c) 1.95 eV (d) 2.12 eV

33. In a photoelectric effect experiment the threshold wavelength of light is 380 nm. If the wavelength of incident light is 260 nm, the maximum kinetic energy of emitted electrons will be:

Given E (in eV) = **[10 Apr. 2019 I]**

(a) 1.5 eV (b) 3.0 eV (c) 4.5 eV (d) 15.1 eV

34. A 2 mW laser operates at a wavelength of 500 nm. The number of photons that will be emitted per second is : [Given Planck's constant $h = 6.6\times10^{-34}$ Js, speed of light $c = 3.0\times10^{8}$ m/s] **[10 Apr. 2019 II]**

(a) 5×10^{15} (b) 1.5×10^{16}
(c) 2×10^{16} (d) 1×10^{16}

35. The electric field of light wave is given as

$$\vec{E} = 10^3 \cos\left(\frac{2\pi x}{5\times10^{-7}} - 2\pi\times6\times10^{14}t\right)\hat{x}\frac{N}{C}$$

This light falls on a metal plate of work function 2eV. The stopping potential of the photo-electrons is:

Given, $E\,(\text{in eV}) = \dfrac{12375}{\lambda(\text{in Å})}$ **[9 April 2019 I]**

(a) 2.0 V (b) 0.72 V (c) 0.48 V (d) 2.48 V

36. When a certain photosensitive surface is illuminated with monochromatic light of frequency v, the stopping potential for the photo current is $-V_0/2$. When the surface is illuminated by monochromatic light of frequency $v/2$, the stoppoing potential is $-V_0$. The threshold frequency for photoelectric emission is : **[12 Jan. 2019 II]**

(a) $\frac{5v}{3}$ (b) $\frac{4}{3}v$ (c) $2v$ (d) $\frac{3v}{2}$

37. In a Frank-Hertz experiment, an electron of energy 5.6 eV passes through mercury vapour and emerges with an energy 0.7 eV. The minimum wavelength of photons emitted by mercury atoms is close to : **[12 Jan. 2019 II]**

(a) 1700 nm (b) 2020 nm
(c) 220 nm (d) 250 nm

38. In a photoelectric experiment, the wavelength of the light incident on a metal is changed from 300 nm to 400 nm. The decrease in the stopping potential is close to : **[11 Jan. 2019 II]**

$\left(\frac{hc}{e} = 1240\ \text{nm-V}\right)$

(a) 0.5 V (b) 1.5 V
(c) 1.0 V (d) 2.0 V

39. A metal plate of area 1×10^{-4} m^2 is illuminated by a radiation of intensity 16 mW/m^2. The work function of the metal is 5 eV. The energy of the incident photons is 10 eV and only 10% of it produces photo electrons. The number of emitted photo electrons per second and their maximum energy, respectively, will be:
[1 eV = 1.6×10^{-19} J] **[10 Jan. 2019 II]**

(a) 10^{14} and 10 eV (b) 10^{12} and 5 eV
(c) 10^{11} and 5 eV (d) 10^{10} and 5 eV

40. Surface of certain metal is first illuminated with light of wavelength $\lambda_1 = 350$ nm and then, by light of wavelength $\lambda_2 = 540$ nm. It is found that the maximum speed of the photo electrons in the two cases differ by a factor of (2) The work function of the metal (in eV) is close to:

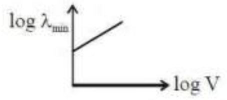
(Energy of photon $= \dfrac{1240}{\lambda\,(\text{in nm})}$ eV) **[9 Jan. 2019 I]**

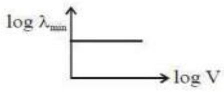
(a) 1.8 (b) 2.5 (c) 5.6 (d) 1.4

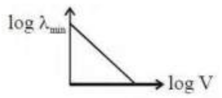
41. The magnetic field associated with a light wave is given at the origin by
$B = B_0\,[\sin(3.14\times10^7)ct + \sin(6.28\times10^7)ct]$.
If this light falls on a silver plate having a work function of 4.7 eV, what will be the maximum kinetic energy of the photoelectrons? **[9 Jan. 2019 II]**
($c = 3\times10^8$ ms^{-1}, $h = 6.6\times10^{-34}$ J-s)

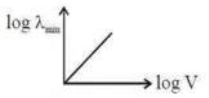
(a) 6.82 eV (b) 12.5 eV
(c) 8.52 eV (d) 7.72 eV

42. An electron beam is accelerated by a potential difference V to hit a metallic target to produce X-rays. It produces continuous as well as characteristic X-rays. If λ_{min} is the smallest possible wavelength of X-ray in the spectrum, the variation of log λ_{min} with log V is correctly represented in : **[2017]**

(a) 

(b) 

(c) 

(d) 

43. A Laser light of wavelength 660 nm is used to weld Retina detachment. If a Laser pulse of width 60 ms and power 0.5 kW is used the approximate number of photons in the pulse are : [Take Planck's constant $h = 6.62\times10^{-34}$ Js] **[Online April 9, 2017]**

(a) 10^{20} (b) 10^{18} (c) 10^{22} (d) 10^{19}

44. The maximum velocity of the photoelectrons emitted from the surface is v when light of frequency n falls on a metal surface. If the incident frequency is increased to 3n, the maximum velocity of the ejected photoelectrons will be : **[Online April 8, 2017]**

(a) less than $\sqrt{3}$v (b) v
(c) more than $\sqrt{3}$v (d) equal to $\sqrt{3}$v

45. Radiation of wavelength λ, is incident on a photocell. The fastest emitted electron has speed v. If the wavelength is changed to $\frac{3\lambda}{4}$, the speed of the fastest emitted electron will be: **[2016]**

(a) $= v\left(\frac{4}{3}\right)^{\frac{1}{2}}$ (b) $= v\left(\frac{3}{4}\right)^{\frac{1}{2}}$

(c) $> v\left(\frac{4}{3}\right)^{\frac{1}{2}}$ (d) $< v\left(\frac{4}{3}\right)^{\frac{1}{2}}$

46. A photoelectric surface is illuminated successively by monochromatic light of wavelengths λ and $\frac{\lambda}{2}$. If the maximum kinetic energy of the emitted photoelectrons in the second case is 3 times that in the first case, the work function of the surface is : **[Online April 10, 2016]**

(a) $\frac{hc}{2\lambda}$ (b) $\frac{hc}{\lambda}$

(c) $\frac{hc}{3\lambda}$ (d) $\frac{3hc}{\lambda}$

47. When photons of wavelength λ_1 are incident on an isolated sphere, the corresponding stopping potential is found to be V. When photons of wavelength λ_2 are used, the corresponding stopping potential was thrice that of the above value. If light of wavelength λ_3 is used then find the stopping potential for this case : **[Online April 9, 2016]**

(a) $\frac{hc}{e}\left[\frac{1}{\lambda_3}+\frac{1}{\lambda_2}-\frac{1}{\lambda_1}\right]$

(b) $\frac{hc}{e}\left[\frac{1}{\lambda_3}+\frac{1}{2\lambda_2}-\frac{1}{\lambda_1}\right]$

(c) $\frac{hc}{e}\left[\frac{1}{\lambda_3}-\frac{1}{\lambda_2}-\frac{1}{\lambda_1}\right]$

(d) $\frac{hc}{e}\left[\frac{1}{\lambda_3}+\frac{1}{2\lambda_2}-\frac{3}{2\lambda_1}\right]$

48. Match **List - I** (Fundamental Experiment) with **List - II** (its conclusion) and select the correct option from the choices given below the list: **[2015]**

List-I	List-II
A. Franck-Hertz Experiment	(i) Particle nature of light
B. Photo-electric experiment	(ii) Discrete energy levels of atom
C. Davison-Germer experiment	(iii) Wave nature of electron
	(iv) Structure of atom

(a) (A)-(ii); (B)-(i); (C)-(iii)
(b) (A)-(iv); (B)-(iii); (C)-(ii)
(c) (A)-(i); (B)-(iv); (C)-(iii)
(d) (A)-(ii); (B)-(iv); (C)-(iii)

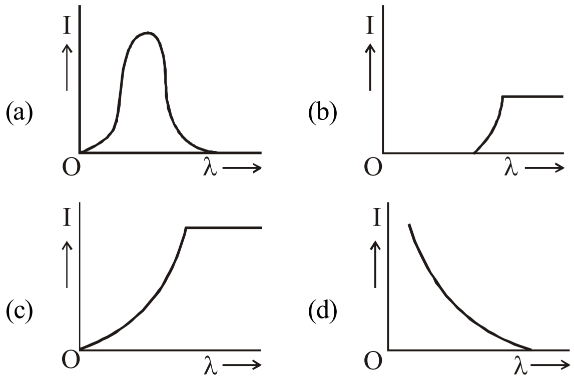
49. A beam of light has two wavelengths of 4972Å and 6216Å with a total intensity of 3.6×10^{-3} Wm^{-2} equally distributed among the two wavelengths. The beam falls normally on an area of 1 cm^2 of a clean metallic surface of work function 2.3 eV. Assume that there is no loss of light by reflection and that each capable photon ejects one electron. The number of photoelectrons liberated in 2s is approximately: **[Online April 12, 2014]**

(a) 6×10^{11} (b) 9×10^{11}
(c) 11×10^{11} (d) 15×10^{11}

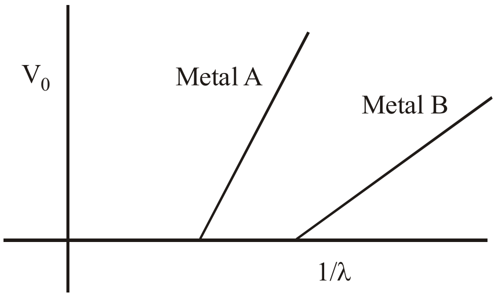
50. A photon of wavelength λ is scattered from an electron, which was at rest. The wavelength shift $\Delta\lambda$ is three times of λ and the angle of scattering θ is 60°. The angle at which the electron recoiled is ϕ. The value of tan ϕ is : (electron speed is much smaller than the speed of light) **[Online April 11, 2014]**

(a) 0.16 (b) 0.22 (c) 0.25 (d) 0.28

51. The anode voltage of a photocell is kept fixed. The wavelength λ of the light falling on the cathode is gradually changed. The plate current I of the photocell varies as follows : **[2013]**



52. In an experiment on photoelectric effect, a student plots stopping potential V_0 against reciprocal of the wavelength λ of the incident light for two different metals A and B. These are shown in the figure. **[Online April 25, 2013]**



Looking at the graphs, you can most appropriately say that:

(a) Work function of metal B is greater than that of metal A
(b) For light of certain wavelength falling on both metal, maximum kinetic energy of electrons emitted from A will be greater than those emitted from B.
(c) Work function of metal A is greater than that of metal B
(d) Students data is not correct

53. A copper ball of radius 1 cm and work function 4.47eV is irradiated with ultraviolet radiation of wavelength 2500 Å. The effect of irradiation results in the emission of electrons from the ball. Further the ball will acquire charge and due to this there will be a finite value of the potential on the ball. The charge acquired by the ball is : **[Online April 25, 2013]**

(a) 5.5×10^{-13}C (b) 7.5×10^{-13}C
(c) 4.5×10^{-12}C (d) 2.5×10^{-11}C

54. This equation has statement 1 and statement 2. Of the four choices given after the statements, choose the one that describes the two statements.

Statement 1: Davisson-Germer experiment established the wave nature of electrons.

Statement 2 : If electrons have wave nature, they can interfere and show diffraction. **[2012]**

(a) Statement 1 is false, Statement 2 is true.
(b) Statement 1 is true, Statement 2 is false
(c) Statement 1 is true, Statement 2 is true, Statement 2 is the correct explanation of statement 1
(d) Statement 1 is true, Statement 2 is true, Statement 2 is not the correct explanation of Statement 1

55. Photoelectrons are ejected from a metal when light of frequency υ falls on it. Pick out the wrong statement from the following. **[Online May 26, 2012]**

(a) No electrons are emitted if υ is less than W/h, where W is the work function of the metal
(b) The ejection of the photoelectrons is instantaneous.
(c) The maximum energy of the photoelectrons is $h\upsilon$.
(d) The maximum energy of the photoelectrons is independent of the intensity of the light.

56. This question has Statement 1 and Statement 2. Of the four choices given after the Statements, choose the one that best describes the two Statements.

Statement 1: A metallic surface is irradiated by a monochromatic light of frequency $\upsilon > \upsilon_0$ (the threshold frequency). If the incident frequency is now doubled, the photocurrent and the maximum kinetic energy are also doubled.

Statement 2: The maximum kinetic energy of photoelectrons emitted from a surface is linearly dependent on the frequency of the incident light. The photocurrent depends only on the intensity of the incident light. **[Online May 19, 2012]**

(a) Statement 1 is true, Statement 2 is true, Statement 2 is the correct explanation of Statement 1.
(b) Statement 1 is false, Statement 2 is true.
(c) Statement 1 is true, Statement 2 is false.
(d) Statement 1 is true, Statement 2 is true, Statement 2 is not the correct explanation of Statement 1.

57. This question has Statement – 1 and Statement – 2. Of the four choices given after the statements, choose the one that best describes the two statements. **[2011]**

Statement – 1: A metallic surface is irradiated by a monochromatic light of frequency $v > v_0$ (the threshold frequency). The maximum kinetic energy and the stopping potential are $K_{\max}$ and V_0 respectively. If the frequency incident on the surface is doubled, both the $K_{\max}$ and V_0 are also doubled.

Statement – 2 : The maximum kinetic energy and the stopping potential of photoelectrons emitted from a surface are linearly dependent on the frequency of incident light.

(a) Statement–1 is true, Statement–2 is true, Statement – 2 is the correct explanation of Statement – 1.
(b) Statement–1 is true, Statement–2 is true, Statement – 2 is not the correct explanation of Statement – 1.
(c) Statement – 1 is false, Statement – 2 is true.
(d) Statement – 1 is true, Statement – 2 is false.

58. **Statement -1 :** When ultraviolet light is incident on a photocell, its stopping potential is V_0 and the maximum kinetic energy of the photoelectrons is K_{max}. When the ultraviolet light is replaced by X-rays, both V_0 and K_{max} increase.

Statement -2 : Photoelectrons are emitted with speeds ranging from zero to a maximum value because of the range of frequencies present in the incident light. **[2010]**

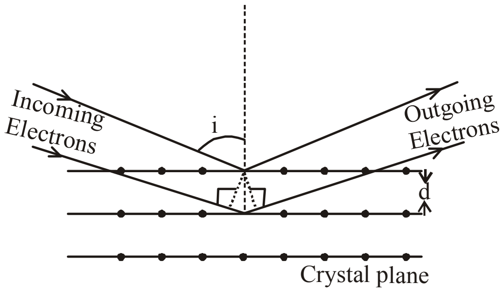
(a) Statement -1 is true, Statement -2 is true ; Statement -2 is the correct explanation of Statement -1.
(b) Statement -1 is true, Statement -2 is true; Statement -2 is **not** the correct explanation of Statement -1
(c) Statement -1 is false, Statement -2 is true.
(d) Statement -1 is true, Statement -2 is false.

59. The surface of a metal is illuminted with the light of 400 nm. The kinetic energy of the ejected photoelectrons was found to be 1.68 eV. The work function of the metal is : (hc = 1240 eV.nm) **[2009]**

(a) 1.41 eV (b) 1.51 eV
(c) 1.68 eV (d) 3.09 eV

Directions: Question No. 60 and 61 are based on the following paragraph.

Wave property of electrons implies that they will show diffraction effects. Davisson and Germer demonstrated this by diffracting electrons from crystals. The law governing the diffraction from a crystal is obtained by requiring that electron waves reflected from the planes of atoms in a crystal interfere constructively (see figure).



60. Electrons accelerated by potential V are diffracted from a crystal. If d = 1Å and i = 30°, V should be about **[2008]**
($h = 6.6 \times 10^{-34}$ Js, $m_e = 9.1 \times 10^{-31}$ kg, $e = 1.6 \times 10^{-19}$ C)

(a) 2000 V (b) 50 V (c) 500 V (d) 1000 V

61. 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 figure), de Broglie wavelength λ_{dB} of electrons can be calculated by the relationship (n is an integer) **[2008]**

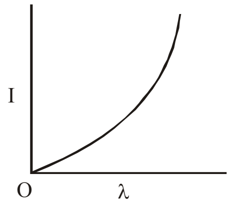
(a) $d \sin i = n\lambda_{dB}$ (b) $2d \cos i = n\lambda_{dB}$
(c) $2d \sin i = n\lambda_{dB}$ (d) $d \cos i = n\lambda_{dB}$

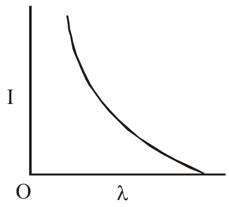
62. Photon of frequency ν has a momentum associated with it. If c is the velocity of light, the momentum is **[2007]**
(a) hν / c (b) ν /c (c) h ν c (d) hν / c^2

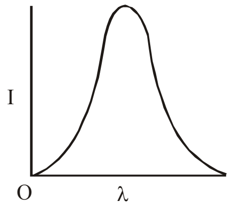
63. The threshold frequency for a metallic surface corresponds to an energy of 6.2 eV and the stopping potential for a radiation incident on this surface is 5 V. The incident radiation lies in **[2006]**
(a) ultra-violet region (b) infra-red region
(c) visible region (d) *X*-ray region

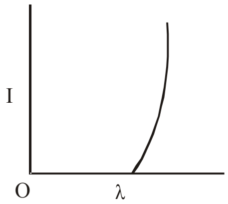
64. The time taken by a photoelectron to come out after the photon strikes is approximately **[2006]**
(a) 10^{-4} s (b) 10^{-10} s (c) 10^{-16} s (d) 10^{-1} s

65. The anode voltage of a photocell is kept fixed. The wavelength λ of the light falling on the cathode is gradually changed. The plate current I of the photocell varies as follows **[2006]**

(a) 

(b) 

(c) 

(d) 

66. A photocell is illuminated by a small bright source placed 1 m away. When the same source of light is placed $\frac{1}{2}$ m away, the number of electrons emitted by photocathode would **[2005]**
(a) increase by a factor of 4
(b) decrease by a factor of 4
(c) increase by a factor of 2
(d) decrease by a factor of 2

67. A radiation of energy E falls normally on a perfectly reflecting surface. The momentum transferred to the surface is **[2004]**
(a) Ec (b) $2E/c$ (c) E/c (d) E/c^2

68. According to Einstein's photoelectric equation, the plot of the kinetic energy of the emitted photo electrons from a metal Versus the frequency, of the incident radiation gives a straight line whose slope **[2004]**
(a) depends both on the intensity of the radiation and the metal used
(b) depends on the intensity of the radiation
(c) depends on the nature of the metal used
(d) is the same for the all metals and independent of the intensity of the radiation

69. The work function of a substance is 4.0 eV. The longest wavelength of light that can cause photoelectron emission from this substance is approximately **[2004]**
(a) 310 nm (b) 400 nm (c) 540 nm (d) 220 nm

70. Two identical photocathodes receive light of frequencies f_1 and f_2. If the velocites of the photo electrons (of mass m) coming out are respectively v_1 and v_2, then **[2003]**

(a) $v_1^2 - v_2^2 = \frac{2h}{m}(f_1 - f_2)$

(b) $v_1 + v_2 = \left[\frac{2h}{m}(f_1 + f_2)\right]^{1/2}$

(c) $v_1^2 + v_2^2 = \frac{2h}{m}(f_1 + f_2)$

(d) $v_1 - v_2 = \left[\frac{2h}{m}(f_1 - f_2)\right]^{1/2}$

71. Sodium and copper have work functions 2.3 eV and 4.5 eV respectively. Then the ratio of the wavelengths is nearest to **[2002]**
(a) 1 : 2 (b) 4 : 1 (c) 2 : 1 (d) 1 : 4

Hints & Solutions

1. **(c)** de-Broglie wavelength, $\lambda = \frac{h}{P} = \frac{h}{\sqrt{2m(\text{KE})}}$

$\therefore \lambda \propto \frac{1}{\sqrt{m}}$

As $m_{\text{He}^{++}} > m_P > m_e$

$\lambda_{\text{He}^{++}} > \lambda_P > \lambda_e$ or $\lambda_e > \lambda_P > \lambda_{\text{He}^{++}}$

2. **(a)** Rms speed of gas molecule, $V_{rms} = \sqrt{\frac{3kT}{m}}$

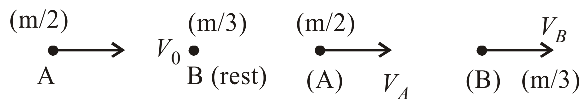
de Broglie wavelength, $\lambda = \frac{h}{p} = \frac{h}{\sqrt{2mk}}$

$$\therefore \lambda = \frac{h}{\sqrt{2m \times \frac{1}{2} mV_{rms}^2}} = \frac{h}{\sqrt{m \times \frac{3}{2} kT}} = \frac{h}{\sqrt{3mkT}}$$

Substituting the respective values we get

$$\lambda = \frac{6.63 \times 10^{-34}}{\sqrt{3 \times 4.64 \times 10^{-26} \times 1.38 \times 10^{-13} \times 400}} = 0.24 \text{Å}$$

3. **(d)**



Before collision — After collision

Applying momentum conservation

$$\frac{m}{2} \times V_0 + \frac{m}{3} \times (0) = \frac{m}{2} V_A + \frac{m}{3} V_B$$

$$= \frac{V_0}{2} = \frac{V_A}{2} + \frac{V_B}{3} \qquad ...(i)$$

Since, collision is elastic

$$e = 1 = \frac{V_B - V_A}{V_0} \Rightarrow V_0 = V_B - V_A \qquad ...(ii)$$

On solving equations (i) and (ii) : $V_A = \frac{V_0}{5}$

Now, de-Broglie wavelength of A before collision :

$$\lambda_0 = \frac{h}{m_A V_0} = \frac{h}{\left(\frac{m}{2}\right) V_0} \Rightarrow \lambda_0 = \frac{2h}{mV_0}$$

Final de-Broglie wavelength :

$$\lambda_f = \frac{h}{m_A V_0} = \frac{h}{\frac{m}{2} \times \frac{V_0}{5}} \Rightarrow \lambda_f = \frac{10h}{mV_0}$$

$$\therefore \Delta\lambda = \lambda_f - \lambda_0 = \frac{10h}{mV_0} - \frac{2h}{mV_0}$$

$$\Rightarrow \Delta\lambda = \frac{8h}{mv_0} \Rightarrow \Delta\lambda = 4 \times \frac{2h}{mv_0}$$

$\therefore \Delta\lambda = 4\lambda_0$

4. **(d)** de Broglie wavelength

$$\lambda = \frac{h}{mv} \Rightarrow m = \frac{h}{\lambda v}$$

Clearly, $m \propto \frac{1}{\lambda v}$

If λ and v be the wavelength and velocity of electron and λ' and v' be the wavelength and velocity of the particle then

$$\Rightarrow \frac{m'}{m} = \frac{v\lambda}{v'\lambda'} = \frac{1}{5} \times \frac{1}{1.878} \times 10^{-4}$$

$\Rightarrow m = 9.7 \times 10^{-28}$ kg

5. **(c)** As per question, when KE of particle E, wavelength λ and when KE becomes $E + \Delta E$ wavelength becomes $\lambda/2$

Using, $\lambda = \frac{h}{\sqrt{2mKE}}$

$$\frac{\lambda}{2} = \frac{h}{\sqrt{2m(KE + \Delta E)}}$$

$$\Rightarrow \frac{\lambda}{\lambda/2} = \sqrt{\frac{KE + \Delta E}{KE}}$$

$$\Rightarrow 4 = \frac{KE + \Delta E}{KE}$$

$\Rightarrow \quad 4KE - KE = \Delta E$

$\therefore \quad \Delta E = 3\,KE = 3\,E$

6. **(d)** Acceleration of electron in electric field, $a = \frac{eE}{m}$

Using equation

$v = u + at$

$\Rightarrow \quad v = 0 + \frac{eE}{m} t$

$$\Rightarrow \quad v = \frac{eEt}{m} \qquad \text{..... (i)}$$

De-broglie wavelength λ is given by

$$\lambda = \frac{h}{mv} = \frac{h}{m\left(\frac{eEt}{m}\right)} \qquad \text{[using (i)]}$$

$$\Rightarrow \quad \lambda = \frac{h}{eEt}$$

Differentiating w.r.t. t

$$\frac{d\lambda}{dt} = \frac{d\left(\frac{h}{eEt}\right)}{dt} \quad \Rightarrow \quad \frac{d\lambda}{dt} = \frac{-h}{eEt^2}$$

7. **(c)** Given, Initial velocity, $u = v_0\hat{i} + v_0\hat{j}$

Acceleration, $a = \frac{qE_0}{m} = \frac{eE_0}{m}$

Using $v = u + at$

$$v = v_0\hat{i} + v_0\hat{j} + \frac{eE_0}{m}t\hat{k}$$

$$\therefore |\vec{v}| = \sqrt{2v_0^2 + \left(\frac{eE_0 t}{m}\right)^2}$$

de-Broglie wavelength, $\lambda = \frac{h}{p}$

$$\Rightarrow \lambda = \frac{h}{mv} \quad (\because p = mv)$$

Initial wavelength, $\lambda_0 = \frac{h}{mv_0\sqrt{2}}$

Final wavelength,

$$\lambda = \frac{h}{m\sqrt{2v_0^2 + \left(\frac{eE_0 t}{m}\right)^2}}$$

$$\frac{\lambda}{\lambda_0} = \frac{1}{\sqrt{1 + \left(\frac{eE_0 t}{\sqrt{2}mv_0}\right)^2}}$$

$$\Rightarrow \lambda = \frac{\lambda_0}{\sqrt{1 + \frac{e^2E_0^2t^2}{2m^2v_0^2}}}$$

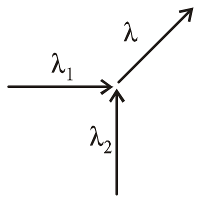
8. **(b)** $P_1 - P_2 = (P_1 + P_2) = P$

As $P \propto \frac{1}{\lambda}$

or $\frac{1}{\lambda_x} - \frac{1}{\lambda_y} = \frac{1}{\lambda}$

or $\frac{\lambda_y - \lambda_x}{\lambda_x\lambda_y} = \frac{1}{\lambda}$

9. **(a)** From the de-Broglie relation,



$$p_1 = \frac{h}{\lambda_1}$$

$$p_2 = \frac{h}{\lambda_2}$$

Momentum of the final particle (p_f) is given by

$$\therefore \quad p_f = \sqrt{p_1^2 + p_2^2}$$

$$\Rightarrow \frac{h}{\lambda} = \sqrt{\frac{h^2}{\lambda_1^2} + \frac{h^2}{\lambda_2^2}}$$

$$\Rightarrow \frac{1}{\lambda^2} = \frac{1}{\lambda_1^2} + \frac{1}{\lambda_2^2}$$

10. **(c)** de Broglie wavelength (λ) is given by
K = qV

$$\lambda = \frac{h}{p} = \frac{h}{\sqrt{2mK}} = \frac{h}{\sqrt{2mqV}} \left(\because p = \sqrt{2mK}\right)$$

Substituting the values we get

$$\therefore \frac{\lambda_A}{\lambda_B} = \frac{\sqrt{2m_Bq_BV_B}}{\sqrt{2m_Aq_AV_A}} = \sqrt{\frac{4m.q.2500}{m.q.50}}$$

$$= 2\sqrt{50} = 2 \times 7.07 = 14.14$$

11. **(d)** de-Broglie wavelength,

$$\lambda = \frac{h}{mv} = 10^{-3}\left(\frac{3 \times 10^8}{6 \times 10^{14}}\right) \qquad \left[\because \lambda = \frac{c}{v}\right]$$

$$v = \frac{6.63 \times 10^{-34} \times 6 \times 10^{14}}{9.1 \times 10^{-31} \times 3 \times 10^5}$$

$v = 1.45 \times 10^6$ m/s

12. **(d)** Using, $\lambda = \frac{h}{p}$ {given: $\lambda = 7.5 \times 10^{-12}$}

$$\Rightarrow P = \frac{h}{\lambda}$$

Minimum energy required,

$$KE=\frac{P^2}{2m}=\frac{(h/\lambda)^2}{2m}=\frac{\left\{\frac{6.6\times10^{-34}}{7.5\times10^{-12}}\right\}^2}{2\times9.1\times10^{-31}}J=25keV$$

13. **(c)** Momentum (p) of each electron $\frac{h}{\lambda_1}\hat{i}$ and $\frac{h}{\lambda_2}\hat{j}$

Velocity of centre of mass

$$V_{cm}=\frac{h}{2m\lambda_1}\hat{i}+\frac{h}{2m\lambda_2}\hat{j}\quad(\because p=mv)$$

Velocity of 1st particle about centre of mass

$$V_{1cm}=\frac{h}{2m\lambda_1}\hat{i}-\frac{h}{2m\lambda_2}\hat{j}$$

$$\lambda_{cm}=\frac{h}{\sqrt{\frac{h^2}{4\lambda_1^2}+\frac{h^2}{4\lambda_2^2}}}=\frac{2\lambda_1\lambda_2}{\sqrt{\lambda_1^2+\lambda_2^2}}\quad\left(\because\lambda=\frac{h}{p}\right)$$

14. **(c)** According to question, $\lambda_p=\lambda_\alpha$

Using, $\lambda=\frac{h}{p}=\frac{h}{mv}$

So, $\frac{h}{m_p\times v_p}=\frac{h}{m_\alpha\times v_\alpha}$

$\Rightarrow\quad\frac{v_p}{v_\alpha}=\frac{m_\alpha}{m_p}=\frac{4m_p}{m_p}$

($\because$ mass of α-particle is 4 times of mass of proton)

So, $\frac{v_p}{v_\alpha}=\frac{4}{1}$; i.e., 4 : 1

15. **(d)** From question, $m_A=M;\ m_B=\frac{m}{2}$

$u_A=V\quad u_B=0$

Let after collision velocity of $A=V_1$ and velocity of $B=V_2$

Applying law of conservation of momentum,

$$mu\ =mv_1+\left(\frac{m}{2}\right)v_2$$

or, 24 $=2v_1+v_2$....(*i*)

By law of collision

$$e=\frac{v_2-v_1}{u-0}$$

or, $u=v_2-v_1$ ....(*ii*) $\qquad[\because$ collision is elastic, $e=1]$

using eqns (*i*) and (*ii*)

$$v_1=\frac{4}{3}\text{ and }v_2=\frac{4}{3}u$$

de-Broglie wavelength $\lambda=\frac{h}{p}$

$$\therefore\ \frac{\lambda_A}{\lambda_B}=\frac{P_B}{P_A}=\frac{\frac{m}{2}\times\frac{4}{3}u}{m\times\frac{4}{3}}=2$$

16. **(a)** From Bragg's equation

$d\sin\theta=\lambda$

$\sin\theta=\frac{\lambda}{d}<1\quad\therefore\quad\lambda<d$

$\frac{h}{|p_y|}<d\qquad\left[\because\lambda=\frac{h}{|p_y|}\right]$

$\therefore\quad h<|p_y|\,d$

17. **(c)** de-Broglie wavelength,

$$\lambda=\frac{h}{P}=\frac{h}{mv}=\frac{h}{\sqrt{2mqV}}$$

or, $\lambda=\frac{6.6\times10^{-34}}{\sqrt{2\times9.1\times10^{-31}\times1.6\times10^{-19}\times50}}$

$=1.7$ Å

18. **(d)** Among the given particles most difficult to experimentally verify the de-broglie relationship is for a dust particle.

19. **(d)** Energy in joule (E)

= charge × potential diff. in volt

$E_{electron}=q_eV$ and $E_{proton}=q_p4V$

de-Broglie wavelength $\lambda=\frac{h}{P}=\frac{h}{\sqrt{2mE}}$

$$\lambda_e=\frac{h}{\sqrt{2m_eeV}}\text{ and }\lambda_P=\frac{h}{\sqrt{2m_Pe4V}}\quad(\because q_e=q_P)$$

$$\therefore\ \frac{\lambda_e}{\lambda_P}=\frac{\frac{h}{\sqrt{2m_eeV}}}{\frac{h}{\sqrt{2m_Pe4V}}}=\sqrt{\frac{2m_Pe4V}{2m_eeV}}=2\sqrt{\frac{m_P}{m_e}}$$

20. **(d)** de-Broglie wavelength,

$\lambda=\frac{h}{p}=\frac{h}{mv}$ ....(i)

but $K.E=\frac{1}{2}mv^2$

$\Rightarrow\quad K.E=\frac{(mv)^2}{2m}$

$\Rightarrow\quad mv=\sqrt{2m\,K.E}$

$\lambda=\frac{h}{\sqrt{2m\,K.E}}$

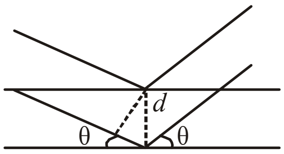
$\therefore\ \lambda\propto\frac{1}{\sqrt{K.E}}$

So, if *K.E.* is doubled, wavelength becomes $\frac{\lambda}{\sqrt{2}}$

21. **(a)** Covalent bonds are formed by sharing of electrons with different compounds. Formation of covalent bond is best explained by molecular orbital theory.

22. **(50)**

From Bragg's equation $2d\sin\theta = \lambda$ and de-Broglie wavelength, $\lambda = \frac{h}{P} = \frac{h}{\sqrt{2mE}}$



$$2d\sin\theta = \lambda = \frac{h}{\sqrt{2mE}}$$

$$\Rightarrow 2\times10^{-10}\times\frac{\sqrt{3}}{2} = \frac{6.6\times10^{-34}}{\sqrt{2mE}}$$

$[\because \theta = 60°$ and $d = 1\mathring{A} = 1\times10^{-10}\,\text{m}]$

$$\therefore E = \frac{1}{2}\times\frac{6.64^2\times10^{-48}}{9.1\times10^{-31}\times3\times1.6\times10^{-19}} \simeq 50\text{ eV}$$

23. **2**

From the Einstein's photoelectric equation

Energy of photon

= Kinetic energy of photoelectrons + Work function

$\Rightarrow$ Kinetic energy = Energy of Photon – Work Function

Let ϕ_0 be the work function of metal and v_1 and v_2 be the velocity of photoelectrons. Using Einstein's photoelectric equation we have

$$\frac{1}{2}mv_1^2 = 4-\phi_0 \quad \text{...(i)}$$

$$\frac{1}{2}mv_2^2 = 2.5-\phi_0 \quad \text{...(ii)}$$

$$\Rightarrow \frac{\frac{1}{2}mv_1^2}{\frac{1}{2}mv_2^2} = \frac{4-\phi_0}{2.5-\phi_0}$$

$$\Rightarrow (2)^2 = \frac{4-\phi_0}{2.5-\phi_0} \Rightarrow 10-4\phi_0 = 4-\phi_0$$

$$\phi_0 = 2eV$$

24. **(a)** Graph of V_s and f given at B (5.5, 0)

Minimum energy for ejection of electron

= Work function (ϕ).

$$\phi = hV \text{ joule or } \phi = \frac{hV}{e}\text{ eV (for } V=0)$$

$$\therefore \phi = \frac{6.62\times10^{-34}\times5.5\times10^{14}}{1.6\times10^{-19}}\text{eV} = 2.27\,\text{eV}$$

25. **(d)** According to Einstein's photoelectric equation

$$K_{\max} = hv - \phi_0$$

$$\Rightarrow eV_s = \frac{hc}{\lambda} - \phi_0$$

$$\Rightarrow V_s = \frac{hc}{\lambda e} - \frac{\phi_0}{e}$$

where λ = wavelength of incident light

ϕ_0 = work function

V_s = stopping potential

Comparing the above equation with $y = mx + c$, we get

slope $= \frac{hc}{e}$

Increasing the frequency of incident radiation has no effect on work function and frequency. So, graph will not change.

26. **(d)** Using equation, $= \frac{hc}{\lambda} - \phi$

$$KE_{\max} = \frac{hc}{\lambda} - \phi = \frac{hc}{500} - \phi \quad \text{...(1)}$$

$$\text{Again, } 3KE_{\max} = \frac{hc}{200} - \phi \quad \text{...(2)}$$

Dividing equation (2) by (1),

$$\frac{3KE_{\max}}{KE_{\max}} = \frac{3}{1} = \frac{\frac{hc}{200}-\phi}{\frac{hc}{500}-\phi}$$

Putting the value of hc = 1237.5 and solving we get, work function, ϕ = 0.61 eV.

27. **(a)** Given,

Wavelength of X-rays, $\lambda_1 = 1\text{ nm} = 1\times10^{-9}\text{m}$

Wavelength of visible light, $\lambda_2 = 500\times10^{-9}\text{m}$

The number of photons emitted per second from a source of monochromatic radiation of wavelength λ and power P is given as

$$n = \frac{P}{E} = \frac{P}{h\nu} = \frac{P\lambda}{hc} \quad \left(\because E = h\nu \text{ and } \nu = \frac{c}{\lambda}\right)$$

$\Rightarrow$ Clearly $n \propto \lambda$

$$\Rightarrow \frac{n_1}{n_2} = \frac{\lambda_1}{\lambda_2} = \frac{1}{500}$$

28. **(9)**

When radiation of wavelength A, λ_A is used to illuminate, stopping potential $V_A = V$

$$\frac{hc}{\lambda} = \phi + eV \quad \text{...(i)}$$

When radiation of wavelength B, λ_B is used to illuminate, stopping potential, $V_B = \frac{V}{4}$

$$\frac{hc}{3\lambda} = \phi + \frac{eV}{4} \quad ...(ii)$$

From eq. (i) – (ii),

$$\frac{hc}{\lambda}\left(1-\frac{1}{3}\right) = \frac{3}{4}eV$$

$$\Rightarrow \frac{hc}{\lambda}\frac{2}{3} = \frac{3}{4}eV \Rightarrow eV = \frac{8}{9}\frac{hc}{\lambda}$$

$$\frac{hc}{\lambda} = \phi + \frac{8}{9}\frac{hc}{\lambda}$$

$$\therefore \phi = \frac{hc}{9\lambda} = \frac{hc}{n\lambda}, \text{ so, } n = 9.$$

29. **(a)** Using Einstein's photoelectric equation,

$E = \omega_0 + KE_{max}$

$\Rightarrow \omega_0 = KE_{max} - E$

$$p = \sqrt{2mKE} \Rightarrow KE = \frac{p^2}{2m}$$

$$r = \frac{p}{eB} \Rightarrow p = reB$$

$$K_{max} = \frac{r^2e^2B^2}{2m} \qquad KE_{max} = \frac{12420}{\lambda} - \omega_0$$

$$\Rightarrow \omega_0 = \frac{12420}{6561} - \frac{r^2eB^2}{2m}(In\,\text{eV})$$

$$= 1.89(eV) - \frac{(10^{-4})(1.6\times10^{-19})9\times10^5}{2\times9.07\times10^{-31}}$$

$$= 1.89(eV) - \frac{(10^{-4})(1.6\times10^{-19})9\times10^5}{2\times9.07\times10^{-31}}$$

$= (1.89 - 0.79)\, eV = 1.1\, eV$

30. **(a)** de-Broglie wavelength (λ),

Momentum, $mv = \frac{h}{\lambda} = p = \sqrt{2m(KE)}$

$$\therefore \lambda = \frac{h}{\sqrt{2mKE}} \Rightarrow \lambda \propto \frac{1}{\sqrt{KE}}$$

$$\therefore \frac{\lambda_A}{\lambda_B} = \sqrt{\frac{K_B}{K_A}} = \sqrt{\frac{T_A - 1.5}{T_A}} \quad \text{(as given)}$$

Also, $\frac{\lambda_A}{\lambda_B} = \frac{1}{2}$

On solving we get, $T_A = 2\, eV$

$\therefore KE_B = T_A - 1.5 = 2 - 1.5 = 0.5\, eV$

$\therefore$ Work function of metal B is

$\phi_B = E_B - KE_B = 4.5 - 0.5 = 4\, eV$

31. **(11.00)** Energy of proton

$$E = \frac{hc}{\lambda} = \frac{1240}{310} = 4eV > 2eV \quad [= \phi]$$

(so emission of photoelectron will take place)

$= 4 \times 1.6 \times 10^{-19} = 6.4 \times 10^{-19}$ joule

$$N = \frac{6.4\times10^{-5}\times1}{4\times6.4\times10^{-19}} = 10^{14}$$

No. of photoelectrons emitted per second

$$= \frac{10^{14}}{10^3} = 10^{11} \quad (\because 1 \text{ in } 10^3 \text{ photons ejects an electron})$$

$\therefore$ Value of $X = 11.00$

32. **(b)** $f_0 = 4 \times 10^{14}$ Hz

$W_0 = hf_0 = 6.63 \times 10^{-34} \times (4 \times 10^{14})$ J

$$= \frac{(6.63\times10^{-34})\times(4\times10^{14})}{1.6\times10^{-19}}$$

$= 1.66$ eV

33. **(a)** $KE_{max} = E - \phi_0$

(where E = energy of incident light ϕ_0 = work function)

$$= \frac{hc}{\lambda} - \frac{hc}{\lambda_0}$$

$$= 1237\left[\frac{1}{260} - \frac{1}{380}\right]$$

$$= \frac{1237\times120}{380\times260} = 1.5\text{eV}$$

34. **(a)** Energy of photon (E) is given by

$$E = \frac{hc}{\lambda}$$

Number of photons of wavelength λ emitted in t second from laser of power P is given by

$$n = \frac{Pt\lambda}{hc}$$

$$\Rightarrow n = \frac{2\times\lambda}{hc} = \frac{2\times10^{-3}\times5\times10^{-7}}{2\times10^{-25}} \quad (\because t = 1\text{S})$$

$\Rightarrow n = 5 \times 10^{15}$

35. **(c)** Here $w = 2\pi \times 6 \times 10^{14}$ or $f = 6 \times 10^{14}$ Hz

Wavelength $\lambda = \frac{C}{f} = \frac{3\times10^8}{6\times10^{14}} = 0.5\times10^{-6}\,m = 5000\text{A}^o$

Now $E = \frac{12374}{5000} = 2.48\, eV$

Using $E = w + eV_s$

$2.48 = 2 + eV_s$ or $V_s = 0.48$ V

36. **(BONUS)**

37. **(d)** Using, wavelength, $\lambda = \frac{12375}{\Delta E}$

or, $\lambda = \frac{12375}{4.9} \simeq 250\text{nm}$

38. **(c)** Let ϕ = work function of the metal,

$$\frac{hc}{\lambda_1} = \phi + eV_1 \quad ......(i)$$

$$\frac{hc}{\lambda_2} = \phi + eV_2 \quad ......(ii)$$

Sutracting (ii) from (i) we get

$$hc\left(\frac{1}{\lambda_1} - \frac{1}{\lambda_2}\right) = e(V_1 - V_2)$$

$$\Rightarrow V_1 - V_2 = \frac{hc}{e}\left(\frac{\lambda_2 - \lambda_1}{\lambda_1 \cdot \lambda_2}\right) \quad \begin{bmatrix} \lambda_1 = 300\,\text{nm} \\ \lambda_2 = 400\,\text{nm} \\ \frac{hc}{e} = 1240\,\text{nm} - \text{V} \end{bmatrix}$$

$$= (1240\,\text{nm} - \text{v})\left(\frac{100\text{nm}}{300\text{ nm} \times 400\,\text{nm}}\right)$$

$= 1.03\text{ V} \approx 1\text{V}$

39. **(c)** using, intensity $I = \frac{nE}{At}$

n = no. of photoelectrons

$$\Rightarrow 16 \times 10^{-3} = \left(\frac{n}{t}\right) \times \frac{10 \times 1.6 \times 10^{-19}}{10^{-4}} \text{ or, } \frac{n}{t} = 10^{12}$$

So, effective number of photoelectrons ejected per unit time $= 10^{12} \times 10/100 = 10^{11}$

40. **(a)** From Einstein's photoelectric equation,

$$\frac{hc}{\lambda_1} = \phi + \frac{1}{2}m(2v)^2 \quad ....(i)$$

and $\frac{hc}{\lambda_2} = \phi + \frac{1}{2}mv^2 \quad ....(ii)$

As per question, maximum speed of photoelectrons in two cases differ by a factor 2

From eqn. (i) & (ii)

$$\Rightarrow \frac{\frac{hc}{\lambda_1} - \phi}{\frac{hc}{\lambda_2} - \phi} = 4 \Rightarrow \frac{hc}{\lambda_1} - \phi = \frac{4hc}{\lambda_2} - 4\phi$$

$$\Rightarrow \frac{4hc}{\lambda_2} - \frac{hc}{\lambda_1} = 3\phi \Rightarrow \phi = \frac{1}{3}hc\left(\frac{4}{\lambda_2} - \frac{1}{\lambda_1}\right)$$

$$= \frac{1}{3} \times 1240\left(\frac{4 \times 350 - 540}{350 \times 540}\right) = 1.8\,\text{eV}$$

41. **(d)** According to question, there are two EM waves with different frequency,

$B_1 = B_0 \sin(\pi \times 10^7 c)t$

and $B_2 = B_0 \sin(2\pi \times 10^7 c)t$

To get maximum kinetic energy we take the photon with higher frequency

using, $B = B_0 \sin \omega t$ and $\omega = 2\pi v \Rightarrow v = \frac{\omega}{2\pi}$

$B_1 = B_0 \sin(\pi \times 10^7 c)t \Rightarrow v_1 = \frac{10^7}{2} \times c$

$B_2 = B_0 \sin(2\pi \times 10^7 c)t \Rightarrow v_2 = 10^7 c$

where c is speed of light $c = 3 \times 10^8$ m/s

Clearly, $v_2 > v_1$

so KE of photoelectron will be maximum for photon of higher energy.

$v_2 = 10^7 c$ Hz

$hv = \phi + KE_{max}$

energy of photon

$E_{ph} = hv = 6.6 \times 10^{-34} \times 10^7 \times 3 \times 10^9$

$E_{ph} = 6.6 \times 3 \times 10^{-19}$J

$$= \frac{6.6 \times 3 \times 10^{-19}}{1.6 \times 10^{-19}} \text{eV} = 12.375\text{eV}$$

$KE_{max} = E_{ph} - \phi$

$= 12.375 - 4.7 = 7.675\text{ eV} \approx 7.7\text{ eV}$

42. **(c)** In X-ray tube, $\lambda_{min} = \frac{hc}{eV}$

$$\text{In } \lambda_{min} = In\left(\frac{hc}{e}\right) - InV$$

Clearly, log λ_{min} versus log V graph slope is negative hence option (c) correctly depicts.

43. **(a)** Given, $\lambda = 660$ nm, Power = 0.5 kW, t = 60 ms

Power $P = \frac{nhc}{\lambda t} \Rightarrow n = \frac{p\lambda t}{hc}$

$$= 0.5 \times 10^3 \times \frac{660 \times 10^{-9} \times 60 \times 10^{-3}}{6.6 \times 10^{-34} \times 3 \times 10^8}$$

$= 100 \times 10^{18} = 10^{20}$

44. **(c)** As the metal surface is same, work function (ϕ) is same for both the case.

Initially $KE_{max} = nh - \phi \quad ..... (i)$

After increase

$KE'_{max} = 3\,nh - \phi \quad .... (ii)$

For work function ϕ – not to be –ve or zero, $v' > \sqrt{3}v$

45. **(c)** $h\frac{c}{\lambda} - h\nu_0 = \frac{1}{2}mv^2$

$\therefore \frac{4}{3}\frac{hc}{\lambda} - h\nu_0 = \frac{1}{2}mv'^2$

$\therefore \frac{v'^2}{v^2} = \frac{\frac{4}{3}\nu - \nu_0}{\nu - \nu_0} \quad \therefore v' = v\sqrt{\frac{\frac{4}{3}\nu - \nu_0}{\nu - \nu_0}}$

$\therefore v' > v\sqrt{\frac{4}{3}}$

46. **(a)** From Einstein's photoelectric equation

$K.E._{\lambda} = \frac{hc}{\lambda} - \phi \quad$ ...(i)

(for monochromatic light of wavelength λ)
where ϕ is work function

$K.E._{\lambda/2} = \frac{hc}{\lambda/2} - \phi \quad$ ...(ii)

(for monochromatic light of wavelength $\lambda/2$)
From question,

$K.E._{\lambda/2} = 3(K.E._{\lambda}) \Rightarrow \frac{hc}{\lambda/2} - \phi = 3\left(\frac{hc}{\lambda} - \phi\right)$

$\frac{2hc}{\lambda} - \phi = 3\frac{hc}{\lambda} - 3\phi$

$\Rightarrow 2\phi = \frac{hc}{\lambda} \therefore \phi = \frac{hc}{2\lambda}$

47. **(None)**
From Einstein's photoelectric equation, we have

$\frac{hc}{\lambda_1} = \frac{hc}{\lambda_0} + eV \quad$ ...(1)

$\frac{hc}{\lambda_2} = \frac{hc}{\lambda_0} + eV \quad$ ...(2)

$\frac{hc}{\lambda_3} = \frac{hc}{\lambda_0} + 3eV' \quad$ ...(3)

From equation (1) & (2)

$\frac{3}{2\lambda_1} - \frac{2}{2\lambda_2} = \frac{1}{\lambda_0}$

$\frac{hc}{\lambda_1} - hc\left[\frac{3}{2\lambda_1} - \frac{1}{2\lambda_2}\right] = eV'$

$\frac{hc}{e}\left[\frac{1}{\lambda_3} - \frac{3}{2\lambda_1} + \frac{1}{2\lambda_2}\right] = V'$

48. **(a)** Frank-Hertz experiment - Discrete energy levels of atom, Photoelectric effect - Particle nature of light.
Davison - Germer experiment - wave nature of electron.

49. **(b)** Given, $\lambda_1 = 4972Å$

and $\lambda_2 = 6216Å$

and $I = 3.6 \times 10^{-3} Wm^{-2}$
Intensity associated with each wavelength

$= \frac{3.6 \times 10^{-3}}{2}$
$= 1.8 \times 10^{-3}$ Wm^{-2}
work function $\phi = h\nu$

$= \frac{hc}{\lambda}$

$= \frac{(6.62 \times 10^{-34})(3 \times 10^8)}{\lambda}$

$= \frac{12.4 \times 10^3}{\lambda}$ ev

for different wavelengths

$\phi_1 = \frac{12.4 \times 10^3}{\lambda_1} = \frac{12.4 \times 10^3}{4972} = 2.493$ eV $= 3.984 \times 10^{-19}$ J

$\phi_2 = \frac{12.4 \times 10^3}{\lambda_2} = \frac{12.4 \times 10^3}{6216} = 1.994$ eV $= 3.184 \times 10^{-19}$ J

Work function for metallic surface $\phi = 2.3$ eV (given)
$\phi_2 < \phi$
Therefore, ϕ_2 will not contribute in this process.
Now, no. of electrons per m^2-s = no. of photons per m^2-s

no. of electrons per m^2-s $= \frac{1.8 \times 10^{-3}}{3.984 \times 10^{-19}} \times 10^{-4}$

$(\because 1\,cm^2 = 10^{-4} m^2)$ $= 0.45 \times 10^{12}$

So, the number of photo electrons liberated in 2 sec.
$= 0.45 \times 10^{12} \times 2$
$= 9 \times 10^{11}$

50. **(b)**

51. **(d)** As λ is increased, there will be a value of λ above which photoelectrons will be cease to come out so photocurrent will become zero. Hence (d) is correct answer.

52. **(d)** $\frac{hc}{\lambda} - \phi = eV_0$

$V_0 = \frac{hc}{e\lambda} - \frac{\phi}{e}$

For metal A: $\frac{\phi A}{hc} = \frac{1}{\lambda}$

For metal B: $\frac{\phi B}{hc} = \frac{1}{\lambda}$

As the value of $\frac{1}{\lambda}$ (increasing and decreasing) is not specified hence we cannot say that which metal has comparatively greater or lesser work function (ϕ).

53. **(a)**

54. **(a)** Davisson Germer experiment showed that electron beams can undergo diffraction when passed through atomic crystal. This established wave nature of electron as waves can exhibit interference and diffraction.

55. **(c)** According to photo-electric equation :
$K.E_{max} = h\nu - h\nu_0$ (Work function)
Some sort of energy is used in ejecting the photoelectrons.

56. **(b)** The maximum kinetic energy of photoelectrons depends upon frequency on incident light and photo current depends upon intensity of incident light.

57. **(c)** By Einstein photoelectric equation,
$K_{max} = eV_0 = h\nu - h\nu_0$
When ν is doubled, K_{max} and V_0 become more than double.

58. **(d)** We know that
$eV_0 = K_{max} = h\nu - \phi$
where, ϕ is the work function.
X-rays have higher frequency (ν) than ultraviolet rays. Therefore as ν increases $K.E$ and V_0 both increases.
The kinetic energy ranges from zero to maximum because of loss of energy due to subsequent collisions before getting ejected.

59. **(a)** Wavelength of incident light, $\lambda = 400$ nm $hc = 1240$ eV.nm
$K.E = 1.68$ eV
Using Einstein's photoelectric equation

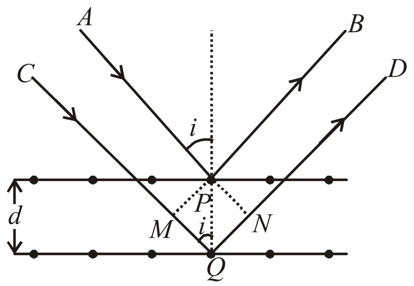
$$\frac{hc}{\lambda} - W = K.E$$

$$\Rightarrow W = \frac{hc}{\lambda} - K.E$$

$$\Rightarrow W = \frac{1240}{400} - 1.68$$

$= 3.1 - 1.68$
$= 1.41$ eV

60. **(b)** The path difference between the rays APB and CQD is
$\Delta x = MQ + QN = d\cos i + d\cos i$
$\Delta x = 2d\cos i$



For constructive interference the path difference is integral multiple of wavelength
$\therefore\ n\lambda = 2d\cos i$
From de-broglie concept
Wavelength,

$$\lambda = \frac{h}{p} = \frac{h}{\sqrt{2mK.E}} = \frac{h}{\sqrt{2meV}}$$

$$\therefore \frac{nh}{\sqrt{2meV}} = 2d\cos i$$

Squaring both side

$$\frac{n^2h^2}{2meV} = 4d^2\cos^2 i$$

For first order interference $n = 1$

$$\therefore V = \frac{h^2}{8med^2\cos^2 i}$$

$$= \frac{(6.6\times10^{-34})^2}{8\times9.1\times10^{-31}\times1.6\times10^{-19}\times(10^{-10})^2\times\cos^2 30}$$

$= 50$ V

61. **(b)** For constructive interference,
$2d\cos i = n\lambda_{dB}$

62. **(a)** Energy of a photon of frequency ν is given by $E = h\nu$.
Also, $E = mc^2$, $mc^2 = h\nu$

$$\Rightarrow mc = \frac{h\nu}{c} \quad \Rightarrow p = \frac{h\nu}{c}$$

63. **(a)** Work function, $\phi = 6.2\,\text{eV} = 6.2\times1.6\times10^{-19}$ J
Stopping potential, $V = 5$ volt
From the Einstein's photoelectric equation

$$\frac{hc}{\lambda} - \phi = eV_0$$

$$\Rightarrow \lambda = \frac{hc}{\phi + eV_0}$$

$$= \frac{6.6\times10^{-34}\times3\times10^8}{1.6\times10^{-19}(6.2+5)} \approx 10^{-7}\text{ m}$$

This range lies in ultra violet range.

64. **(b)** The photoelectric emission is an instantaneous process without any apparent time lag. It is known that emission starts in the time of the order of 10^{-9} second. So, the approximate time taken by a photoelectron to come out after the photon strikes is 10^{-10} second.

65. **(b)** As λ decreases, ν increases and hence the speed of photoelectron increases. The chances of photo electron to meet the anode increases and hence photo electric current increases.

66. **(a)** $I \propto \frac{I}{r^2};\ \frac{I_1}{I_2} = \left(\frac{r_2}{r_1}\right)^2 = \frac{1}{4}$

$I_2 \to 4$ times I_1
When intensity becomes 4 times, no. of photoelectrons emitted would increase by 4 times, since number of electrons emitted per second is directly proportional to intensity.

67. **(b)** Momentum of photon of energy E is $= \frac{E}{c}$

When a photon hits a perfectly reflecting surface, it reflects black in opposite direction with same energy and momentum.

$\therefore$ Change in momentum $= \frac{E}{C} - \left(\frac{-E}{C}\right) = \frac{2E}{C}$

This is equal to momentum transferred to the surface.

68. **(d)** From the Einstein photoelectric equation $K.E. = h\nu - \phi$

Here, ϕ = work function of metal

h = Plank's constant

slope of graph of $K.E.$ & ν is h (Plank's constant) which is same for all metals.

69. **(a)** Work function of metal (ϕ) is given by

$$\phi = \frac{hc}{\lambda}$$

$$\Rightarrow \lambda = \frac{hc}{\phi}$$

$$\Rightarrow \lambda = \frac{6.63\times10^{-34}\times3\times10^{8}}{4\times1.6\times10^{-19}} = 310\text{ nm}$$

70. **(a)** Let work function be W and v_1 and v_2 be the velocity of electrons for frequencies f_1 and f_2.

Using Einstein's photo electric equation for one photodiode, we get

$$hf_1 - W = \frac{1}{2}mv_1^2 \quad ....(i)$$

Using Einstein's photo electric equation for another photodiode we get,

$$hf_2 - W = \frac{1}{2}mv_2^2 \quad ....(ii)$$

Subtracting (ii) from (i) we get

$$(hf_1 - W) - (hf_2 - W) = \frac{1}{2}mv_1^2 - \frac{1}{2}mv_2^2$$

$$\therefore h(f_1 - f_2) = \frac{m}{2}(v_1^2 - v_2^2)$$

$$\therefore v_1^2 - v_2^2 = \frac{2h}{m}(f_1 - f_2)$$

71. **(c)** We know that work function,

$$E = h\upsilon = \frac{hC}{\lambda}$$

where

h = Planck's constant

C = velocity of light

λ = wavelength of light

$$\therefore \frac{E_{Na}}{E_{Cu}} = \frac{\lambda_{Cu}}{\lambda_{Na}}$$

$$\Rightarrow \frac{\lambda_{Na}}{\lambda_{Cu}} = \frac{E_{Cu}}{E_{Na}} = \frac{4.5}{2.3} \approx \frac{2}{1}$$