SHORT QUESTIONS

19.1 What are the measurements on which two observers in relative motion will always agree upon?

Ans. Two observers in relative motion will always agree that speed of light in free space is constant.

19.2 Does the dilation mean that time really passes more slowly in moving system or that it only seems to pass more slowly?

Ans. Time dilation is a real effect and time really passes slowly.

19.3 If you are moving in a spaceship at a very high speed relative to the Earth, would you notice a difference (a) in your pulse rate (b) in your pulse rate of people on Earth?

Ans. (a) As you are in the frame of events so your pulse rate will remain same.

(b) But the people on earth are in relative motion with respect to the observer in the spaceship, so the time with respect to observer will increase.

$$\text{As pulse rate} = \frac{\text{No. of pulses}}{\text{Time}}$$

So as time increases (dilate), the pulse rate of people on earth will decrease relative to observer in spaceship.

19.4 If the speed of light were infinite, what would the equations of special theory of relativity reduce to?

Ans. When speed of light approaches to infinity then $C = \infty$.

$$t = \frac{t_o}{\sqrt{1-\frac{V^2}{C^2}}}$$

$$t = \frac{t_o}{\sqrt{1-\frac{V^2}{\infty^2}}}$$

$$t = \frac{t_o}{\sqrt{1-0}}$$

$$t = t_o$$

Similarly;

$$l = l_o$$

$$m = m_o$$

And $E = m(\infty)$

$$E = \infty$$

OR

As $\Delta m = \frac{\Delta E}{C^2}$

$$\Delta m = \frac{\Delta E}{\infty}$$

$$\Delta m = 0$$

This shows that energy will not change.

So there is no relativistic effect is observed under this condition. Thus there is no change in mass, time, length and if $E = \infty$, which is impossible.

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19.5 Since mass is a form of energy, can we conclude that a compressed spring has more mass than the same spring when it is not compressed?

Ans. No,

As $\Delta m = \frac{\Delta E}{C^2}$

Because C^2 is a very large quantity, this implies that significant changes in mass changes in require very large energy. In every day world, energy changes are too small to provide measurable mass changes.

19.6 As a solid is heated and begins to glow, why does it first appear red?

Ans. We know that when a body is heated, it emits radiations. At low temperature, it emits radiations of longer wavelength. Since the longest visible wavelength is red, so it first appears red.

19.7 What happens to total radiation from a blackbody if its absolute temperature is doubled?

Ans. According to Stefen Boltz man's law, the amount of energy radiated from the hot body is directly proportional to the fourth power of absolute temperature i.e.,

$$E = \sigma T^4$$

If $T' = 2T$

So $E' = \sigma(2T)^4$

$$E' = 16\,\sigma T^4$$

$$E' = 16\,(\sigma T^4)$$

$$E' = 16E$$

Hence the total radiation from a black body increases 16 times if its absolute temperature is doubled.

19.8 A beam of red light and a beam of blue light have exactly the same energy. Which beam contains the greater number of photons?

Ans. As energy of one photon is

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

For n number of photons

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

$$n = \frac{E\lambda}{hC}$$

As E, h and C are constant. So

$$n \propto \lambda$$

As red light has longer wavelength than blue light, so red light contains greater no. of photons.

19.9 Which photon, red, green, or blue carries the most (a) energy and (b) momentum?

Ans. The expression for energy and momentum of a photon is given by

$$E = hf \quad \text{...... (i)}$$

$$P = \frac{h}{\lambda} = \frac{hf}{C} \quad \text{...... (ii)}$$

In eq. (i) and (ii) h and C are constant then

$$E \propto f$$

and $$P \propto f$$

As blue light (photon) has highest frequency (lowest wavelength). So blue photon carries more energy and momentum.

19.10 Which has the lower energy quanta? Radio waves or X-rays?

Ans. As the energy of photon is

$$E = hf$$

$$E \propto f$$

Since frequency of radio waves is less than X-rays. Therefore radio waves has low energy quanta.

19.11 Does the brightness of a beam of light primarily depends on the frequency of photons or on the number of photons?

Ans. The brightness or intensity of a beam of light depends upon no. of photons not on the frequency the energy of photon depends upon the frequency.

19.12 When ultraviolet light falls on certain deyes, visible light is emitted. Why does this not happen when infrared light falls on these dyes.

Ans. The ultraviolet light contains photons of high energy. They excite the atoms of dyes which emit visible light on de-excitation. However infrared has less energy, so on de-excitation of atoms, invisible light is emitted.

OR

As frequency of ultraviolet light is greater than that of infrared light.

19.13 Will bright light eject more electrons from a metal surface than dimmer light of the same colour?

Ans. As number of electrons depends on number of photon and bright light contains more photons, so it will emit greater number of electrons provided its frequency is greater than threshold frequency of metal.

19.14 Will higher frequency light eject greater number of electrons than low frequency light?

Ans. No, because number of ejected electrons depend on the intensity of light and not on the frequency. Therefore higher frequency and lower frequency will eject same number of electrons.

19.15 When light shines on a surface, is momentum transferred to the metal surface?

Ans. Yes, momentum of photons is transferred to the atoms of the metal surface. When light falls on metal surface, the photons are absorbed by the surface.

19.16 Why can red light be used in a photographic dark room when developing films, but a blue or white light cannot?

Ans. Red light has very small energy than blue or white because

$E = \frac{hC}{\lambda}$, where λ is greater for red light. This mean that in visible region photon of red light has smallest energy therefore, it does not affect the photographic film.

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19.17 Photon 'A' has twice the energy of photon 'B' what is the ratio of momentum of 'A' to that of 'B'.

Ans. As energy of photon is given by

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

Therefore energy of photon A is

$$E_A = \frac{hC}{\lambda_A} \qquad \ldots\ldots \text{(i)}$$

and the energy of photon B is

$$E_B = \frac{hC}{\lambda_B} \qquad \ldots\ldots \text{(ii)}$$

But

$$E_A = 2E_B$$

$$\frac{hC}{\lambda_A} = \frac{2hC}{\lambda_B}$$

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

$$\lambda_B = 2\lambda_A$$

Therefore the momentum of photon B is

$$P_B = \frac{h}{\lambda_B}$$

or

$$P_B = \frac{h}{2\lambda_A}$$

$$P_B = \frac{h}{2\lambda_A}$$

$$P_B = \frac{1}{2} \times \frac{h}{\lambda_A}$$

$$P_B = \frac{1}{2} \times P_A$$

$$\frac{P_B}{P_A} = \frac{1}{2}$$

$$P_B : P_A = 1 : 2$$

19.18 Why don't we observe a Compton effect with visible light?

Ans. In order to observe Compton's effect, minimum energy of photon must be 0.51 MeV or greater as photon of visible light does not has this energy range and momentum therefore Compton's effect cannot be observed with visible light it can only be observed from X-rays.

19.19 Can pair production take place in vacuum? Explain?

Ans. No pair production cannot take place in vacuum rather it must take place near a nucleus. Which recoils to conserve the momentum.

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19.20 Is it possible to create a single electron from energy? Explain.

Ans. No, because energy has no charge and electron has negative charge. So a single electron cannot be created from energy because it is against the law of conservation of charge and momentum.

19.21 If electrons behaved only like particles, what pattern would you expect on the screen after the electrons pass through the double slit?

Ans. Electrons will strike only those points of the screen which are infront of double slits, causing it to glow and produces exact images of the slits.

19.22 If an electron and a proton have the same de Broglie wavelength, which particle has greater speed?

Ans. The wavelength associated with the particle of mass m when moving with velocity v is given by

$$\lambda = \frac{h}{mv}$$

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

Since both electron and proton have the same de Broglie wavelength. Also "h" is constant

$$\therefore \quad v \propto \frac{1}{m}$$

This shows that, if wavelength is same, speed is inversely proportional to mass therefore electron will have greater speed as its mass is less than that of proton.

19.23 We do not notice the de-Broglie wavelength for a pitched cricket ball. Explain why?

Ans. According to de-Broglie hypothesis, wavelength of moving particle is inversely proportional to momentum.

As $$\lambda = \frac{h}{mv}$$

Due to large mass and small speed, the de-Broglie wavelength for a cricket ball is extremely small that it is not measurable or detectable.

19.24 If the following particles all have the same energy, which has the shortest wavelength? Electron, alpha particle, neutron and proton.

Ans. According to de-Broglie, the wavelength of the particle of mass m when moving with velocity v is given by

$$\lambda = \frac{h}{mv}$$

But $$mv = \sqrt{2mVe}$$

As $$Ve = E \text{ (Energy)}$$

$$\lambda = \frac{h}{\sqrt{2mVe}}$$

$$\lambda = \frac{h}{\sqrt{2mE}}$$

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As all the particle have same energy. Also "h" is constant

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

As alpha particle has the greatest mass, so it has the shortest wavelength.

19.25 When does light behave as a wave? When does it behave as a particle?

Ans. Light behaves as wave in interference, diffraction, polarization, reflection, refraction i.e., during its propagation.

Light behave as particle in photoelectric effect, Compton's effect and black body radiation i.e., during its interaction with matter.

19.26 What advantages an electron microscope has over an optical microscope?

Ans. Resolving power of an electron microscope is greater than optical microscope.

$$\text{As} \qquad R = \frac{D}{1.22\,\lambda}$$

Since wavelength of electrons is very short therefore its resolving power is very high.

19.27 If measurements show a precise position for an electron, can those measurements show precise momentum also? Explain.

Ans. No,

According to uncertainty principle "position and momentum of a particle cannot be measured simultaneously with perfect accuracy". So if measurement show a precise position for electron in an experiment then precise measurement of momentum of electron is impossible in that experiment.

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PROBLEMS WITH SOLUTIONS

PROBLEM 19.1

A particle called the pion lives on the average only about 2.6×10^{-8} s when at rest in the laboratory. It then changes to another form. How long would such a particle live when shooting through the space at 0.95 C?

Data

Velocity of a particle = v = $0.95\,C$

Proper life time = t_o = 2.6×10^{-8} sec.

To Find

Time dilated = t = ?

SOLUTION

By using formula

$$\boxed{t = \frac{t_o}{\sqrt{1 - \frac{V^2}{C^2}}}}$$

$$t = \frac{2.6 \times 10^{-8}}{\sqrt{1 - \frac{(0.95C)^2}{C^2}}}$$

$$= \frac{2.6 \times 10^{-8}}{\sqrt{1 - \frac{0.9025c^2}{C^2}}} = \frac{2.6 \times 10^{-8}}{\sqrt{1 - 0.9025}}$$

$$t = \frac{2.6 \times 10^{-8}}{\sqrt{0.0975}}$$

$$t = \frac{2.6 \times 10^{-8}}{0.312}$$

$$= 8.32 \times 10^{-8} \text{ sec}$$

Result

Time dilated = t = 8.32×10^{-8} sec

PROBLEM 19.2

What is the mass of a 70 kg man in a space rocket traveling at 0.8 c from us as measured from Earth?

Data

Mass of man = m_o = 70 kg

Velocity of man = v = $0.8\,C$

To Find

Increased mass of man = m = ?

SOLUTION

According to special theory of relativity

$$m = \frac{m_o}{\sqrt{1-\frac{V^2}{C^2}}}$$

$$m = \frac{70}{\sqrt{1-\frac{(0.8C)^2}{C^2}}} = \frac{70}{\sqrt{1-\frac{0.64C^2}{C^2}}}$$

$$= \frac{70}{\sqrt{1-0.64}} = \frac{70}{0.6}$$

$$m = 116.6\ \text{kg}$$

Result

Mass of man increased = m = 116.6 kg

PROBLEM 19.3

Find the energy of photon in

(a) Radio wave of wavelength 100 m

(b) Green light of wavelength 550 nm

(c) X-ray with wavelength 0.2 nm.

Data

(a) Wavelength of radio wave = λ_r = 100 m

(b) Wavelength of green light = λ_g = 550 nm

= 550×10^{-9} m

(c) Wavelength of x-ray = λ_x = 0.2 nm

= 0.2×10^{-9}m

To Find

(a) Energy of radio wave photon = E_r = ?

(b) Energy of green light photon = E_g = ?

(c) Energy of x-ray = E_x = ?

SOLUTION

Using

$$E = hf \quad \text{but } f = \frac{c}{\lambda}$$

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

(a) For radio wave

$$E_r = \frac{hc}{\lambda_r} = \frac{6.36 \times 10^{-34} \times 3 \times 10^{8}}{100}$$

Since $h = 6.63 \times 10^{-34}$ J.S

So
$$E_r = 19.89 \times 10^{-34+8-2}$$
$$= 19.89 \times 10^{-28} \text{ J}$$
$$E_r = \frac{19.89 \times 10^{-28}}{1.6 \times 10^{-19}} \text{ eV}$$
$$= 12.43 \times 10^{-28+19}$$
$$= 12.43 \times 10^{-9}$$
$$E_r = 1.24 \times 10^{-8} \text{ eV}$$

(b) For green light

$$E_g = \frac{hc}{\lambda_g}$$
$$= \frac{6.63 \times 10^{-34} \times 3 \times 10^{8}}{550 \times 10^{-9}}$$
$$= 0.036 \times 10^{-34+8+9}$$
$$= 0.036 \times 10^{-17} \text{ J}$$
$$= \frac{0.036 \times 10^{-17}}{1.6 \times 10^{-19}} \text{ eV}$$
$$= 0.0226 \times 10^{-17+19}$$
$$= 0.0226 \times 10^{2}$$
$$E_g = 2.26 \text{ eV}$$

(c) For x-rays

$$E_x = \frac{hc}{\lambda_x}$$
$$= \frac{6.63 \times 10^{-34} \times 3 \times 10^{8}}{0.2 \times 10^{-9}}$$
$$= 99.45 \times 10^{-34+8+9}$$
$$E_x = 99.45 \times 10^{-17} \text{ J}$$
$$E_x = \frac{99.45 \times 10^{-17}}{1.6 \times 10^{-19}} \text{ eV}$$
$$= 62.156 \times 10^{-17+19}$$
$$= 62.156 \times 10^{2} \text{ eV}$$
$$E_x = 6215.6 \text{ eV}$$

Result

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(a) Energy of radio wave photon $= E_r = 1.24 \times 10^{-8}$ eV

(b) Energy of green light photon $= E_g = 2.26$ eV

(c) Energy of x-ray photon $= E_x = 6215.6$ eV

PROBLEM 19.4

Yellow light of 577 nm wavelength is incident on a cesium surface. The stopping voltage is found to be 0.25 V. Find

(a) The maximum K.E. of the photoelectrons.

(b) The work function of cesium.

Data

Wavelength of yellow light $= \lambda = 577$ nm

$= 577 \times 10^{-9}$ m

Stopping voltage $= V_o = 0.25$ volt

To Find

(a) Maximum Kinetic Energy $= K.E_{max} = ?$

(b) Work function of cesium $= \phi = ?$

SOLUTION

(a) For maximum kinetic energy of photoelectrons

$$(K.E)_{max} = \frac{1}{2} mv^2_{max} = V_o e$$

$$\boxed{(K.E)_{max} = v_o e}$$

$$= 0.25 \times 1.6 \times 10^{-19}$$

$$(K.E)_{max} = 0.4 \times 10^{-19} \text{ J}$$

$$= 4.0 \times 10^{-20} \text{ J}$$

(b) For work function

$$\boxed{\phi = \frac{hc}{\lambda} - V_o e}$$

$$= \frac{6.63 \times 10^{-34} \times 3 \times 10^{8}}{577 \times 10^{-9}} - 4.0 \times 10^{-20}$$

$$= 0.0344 \times 10^{-34+17} - 4.0 \times 10^{-20}$$

$$= 0.0344 \times 10^{-17} - 4.0 \times 10^{-20}$$

$$= 34.4 \times 10^{-20} - 4.0 \times 10^{-20}$$

$$\phi = 30.4 \times 10^{-20} \text{ J}$$

$$\phi = \frac{30.4 \times 10^{-20}}{1.6 \times 10^{-19}} \text{ eV}$$

$$= 19 \times 10^{-20+19}$$

$$\phi = 19 \times 10^{-1} \text{ eV}$$

$$\phi = 1.9 \text{ eV}$$

Result

(a) Maximum kinetic energy $= (K.E)_{max} = 4 \times 10^{-20}$ J

(b) Work function for cesium $= \phi = 1.9$ eV

PROBLEM 19.5

X-rays of wavelength 22 pm are scattered from carbon target. The scattered radiation being viewed 85° to the incident beam. What is compton shift?

Data

Wavelength of x-rays $= \lambda = 22$ pm

$= 22 \times 10^{-12}$ m

Scattering angle $= \theta = 85^o$

To Find

Compton shift $= \Delta\lambda = ?$

SOLUTION

Using

$$\boxed{\Delta\lambda = \frac{h}{m_o c}(1 - \cos\theta)}$$

$$= \frac{6.63 \times 10^{-34}}{9.1 \times 10^{-31} \times 3 \times 10^{8}}(1 - \cos 85^o)$$

when $h = 6.63 \times 10^{-34}$ J.S

m_o = Mass of electron

$= 9.1 \times 10^{-31}$ kg

C = Speed of light

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

Therefore

$$\Delta\lambda = 0.242 \times 10^{-34+31-8}(1 - 0.087)$$

$$= 0.242 \times 10^{-11} \times 0.913$$

$$= 0.22 \times 10^{-11}$$

$$= 2.2 \times 10^{-12} \text{ m}$$

Result

Compton shift $= \Delta\lambda = 2.2 \times 10^{-12}$ m

PROBLEM 19.6

A 90 keV X-ray photon is fired at a carbon target and compton scattering occurs. Find the wavelength of the incident photon and the wavelength of the scattered photon for scattering angle of (a) 30° (b) 60°.

Data

Energy of x-ray photon = 90 KeV

$$= 90 \times 1000 \text{ eV}$$
$$= 90{,}000 \times 1.6 \times 10^{-19} \text{ J}$$
$$= 1.44 \times 10^{-16} \text{ J}$$

(a) Scattering angles $= \theta_1 = 30^\circ$

(b) Scattering angles $= \theta_2 = 60^\circ$

To Find

Wavelength of incident photon $= \lambda_i = ?$

Wavelength of scattered photon $= \lambda_s = ?$

SOLUTION

For the wavelength of incident photon

$$\boxed{E = \frac{hc}{\lambda_i}}$$

$$\lambda_i = \frac{hc}{E}$$
$$= \frac{6.63 \times 10^{-34} \times 3 \times 10^{8}}{144 \times 10^{-16}}$$
$$= 0.138 \times 10^{-34+8+16}$$
$$= 0.138 \times 10^{-10}$$
$$\lambda_i = 13.8 \times 10^{-12} \text{m}$$
$$\lambda_i = 13.8 \text{ pm}$$

For scattered wavelength

$$\Delta\lambda = \frac{h}{m_o c}(1 - \cos\theta)$$

But $\Delta\lambda = \lambda_s - \lambda_i$

$$\lambda_s - \lambda_i = \frac{h}{m_o c}(1 - \cos\theta)$$

$$\boxed{\lambda_s = \frac{h}{m_0 c}(1 - \cos\theta) + \lambda_i}$$

(a) Scattered wavelength when $\theta = 30^\circ$

$$\lambda_s = \frac{6.63 \times 10^{-34}}{9.1 \times 10^{-31} \times 3 \times 10^{8}}(1 - \cos 30) + 13.8 \times 10^{-12}$$
$$= 2.42 \times 10^{-34+31-8}(1 - 0.866) + 13.8 \times 10^{-12}$$
$$= 2.42 \times 10^{-11} \times 0.134 + 132.8 \times 10^{-12}$$
$$\lambda_s = 0.0324 \times 10^{-11} + 13.8 \times 10^{-12}$$
$$= 0.324 \times 10^{-12} + 13.8 \times 10^{-12}$$

$$= (0.324 + 13.8) \times 10^{-12}$$
$$= 14.12 \times 10^{-12} \text{ m}$$
$$\lambda_s = 14.12 \text{ pm}$$

(b) Scattered wavelength when $\theta = 60^o$

$$\lambda_s' = \frac{h}{m_o c}(1 - \cos 60^o) + 13.8 \times 10^{-12}$$
$$= \frac{6.63 \times 10^{-34}}{9.1 \times 10^{-31} \times 3 \times 10^8}(1 - \cos 60^\circ) + 13.8 \times 10^{-12}$$
$$\lambda_s' = 0.242 \times 10^{-34+31-8}(1 - 0.5) + 13.8 \times 10^{-12}$$
$$= 0.242 \times 10^{-11} \times 0.5 + 13.8 \times 10^{-12}$$
$$\lambda_s' = 0.121 \times 10^{-11} + 13.8 \times 10^{-12}$$
$$= 1.21 \times 10^{-12} + 13.8 \times 10^{-12}$$
$$= (1.21 + 13.8) \times 10^{-12}$$
$$= 15.0 \times 10^{-12} \text{ m}$$
$$= 15.0 \text{ pm}$$

Result

Wavelength of incident photon $= \lambda_i = 13.8$ pm

(a) Wavelength of scattered photon when $= \theta = 30^\circ$

$\lambda_s = 14.12$ pm

(b) Wavelength of scattered photon when $= \theta = 60^o$

$\lambda_s' = 15.0$ pm

PROBLEM 19.7

What is the maximum wavelength of the two photons produced when a positron annihilates an electron? The rest mass energy of each is 0.51 Mev.

Data

Rest mass energy of photon $= E = 0.51$ Mev

$$= 0.51 \times 10^6 \times 1.6 \times 10^{-19} \text{ J}$$
$$= 0.816 \times 10^{-13} \text{ J}$$
$$= 8.16 \times 10^{-14} \text{ J}$$

To Find

Maximum wavelength $= \lambda = ?$

SOLUTION

By the formula

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

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

As $h = 6.63 \times 10^{-34}$ J-S

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

So $\lambda = \frac{6.63 \times 10^{-34} \times 3 \times 10^{8}}{8.16 \times 10^{-14}}$

$= 2.43 \times 10^{-34+8+14}$

$\lambda = 2.43 \times 10^{-12}$

$\lambda = 2.43$ pm

Result

Maximum wavelength $= \lambda = 2.43 \times 10^{-12}$ m

PROBLEM 19.8

Calculate the wavelength of

(a) a 140 g ball moving at 40 ms^{-1}

(b) a proton moving at the same speed

(c) an electron moving at the same speed.

Data

(a) Mass of ball $= m_1 = 140$ g $= 0.14$ kg

Speed of ball $= V = 40$ m/s

(b) Mass of proton $= m_2 = 1.67 \times 10^{-27}$ kg

(c) Mass of electron $= m_3 = 9.1 \times 10^{-31}$ kg

To Find

Wavelength of ball $= \lambda_b = ?$

Wavelength of proton $= \lambda_p = ?$

Wavelength of electron $= \lambda_e = ?$

SOLUTION

According to de-Broglie relation

$$\boxed{\lambda = \frac{h}{mv}}$$

(a) For Ball

$$\lambda_b = \frac{h}{m_1 v}$$

$$= \frac{6.63 \times 10^{-34}}{0.14 \times 40}$$

$$\lambda_b = 1.18 \times 10^{-34} \text{ m}$$

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(b) For Proton

$$\lambda_p = \frac{h}{m_2 v}$$

$$= \frac{6.63 \times 10^{-34}}{1.67 \times 10^{-27} \times 40}$$

$$\lambda_p = 0.09925 \times 10^{-34+27}$$

$$\lambda_p = 0.099 \times 10^{-7}$$

$$= 9.9 \times 10^{-9} \text{ m}$$

$$\lambda_p = 9.9 \text{ nm}$$

(c) For Electron

$$\lambda_e = \frac{h}{m_3 v}$$

$$= \frac{6.63 \times 10^{-34}}{9.1 \times 10^{-31} \times 40}$$

$$= 0.0182 \times 10^{-34+31}$$

$$= 0.0182 \times 10^{-3}$$

$$= 1.82 \times 10^{-5} \text{ m}$$

Result

(a) Wavelength of ball $= \lambda_b = 1.18 \times 10^{-34}$ m

(b) Wavelength of proton $= \lambda_p = 9.9$ nm

(c) Wavelength of electron $= \lambda_e = 1.82 \times 10^{-5}$ m

PROBLEM 19.9

What is de-Broglie wavelength of an electron whose kinetic energy is 120 eV?

Data

Kinetic energy of electron = K.E = 120 eV

$$= 120 \times 1.6 \times 10^{-19} \text{ J}$$

$$= 192 \times 10^{-19} \text{ J}$$

To Find

De-Broglie wavelength of Electron $= \lambda = ?$

SOLUTION

By formula

$$\boxed{\lambda = \frac{h}{mv}} \quad \ldots\ldots \text{(i)}$$

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

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$$v^2 = \frac{2\text{ K-E}}{m}$$

$$v^2 = \frac{2 \times 192 \times 10^{-19}}{9.1 \times 10^{-31}}$$

$$= 42.19 \times 10^{-19+31}$$

$$v^2 = 42.19 \times 10^{12}$$

$$v = 6.49 \times 10^{6}\text{ m/s}$$

$$= 6.5 \times 10^{6}\text{ m/s}$$

Putting in equation (i)

$$\lambda = \frac{6.63 \times 10^{-34}}{9.1 \times 10^{-31} \times 6.5 \times 10^{6}}$$

$$= 0.112 \times 10^{-34+31-6}$$

$$= 0.112 \times 10^{-9}$$

$$\lambda = 1.12 \times 10^{-10}\text{ m}$$

Result

De-Broglie wavelength $= \lambda = 1.12 \times 10^{-10}$ m

PROBLEM 19.10

An electron is placed in a box about the size of an atom that is about 1.0×10^{-10} m. What is the velocity of the electrons?

Data

Size of an atom $= \Delta x = 1.0 \times 10^{-10}$ m

Mass of electron $= m = 9.1 \times 10^{-31}$ kg

To Find

Velocity of the electron $= \Delta V = ?$

SOLUTION

Using

$$\Delta P \,.\, \Delta x = h$$

But $\Delta P = m\Delta V$

So $m\Delta V \,.\, \Delta x = h$

$$\boxed{\Delta V = \frac{h}{m\,\Delta x}}$$

Putting the values

$$\Delta V = \frac{6.63 \times 10^{-34}}{9.1 \times 10^{-31} \times 1.0 \times 10^{-10}}$$

$$= 0.728 \times 10^{-34+31+10}$$

$$= 0.728 \times 10^{7}$$

$$\Delta V = 7.28 \times 10^{6} \text{ m/s}$$

Result

Velocity of the electron $= \Delta V = 7.28 \times 10^{6}$ m/s

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