

01. A particle moves with a velocity of $\frac{2\sqrt{2}}{3}c$. What is the ratio of its kinetic energy to rest energy?

Answer: 3 : 1

Explanation:

Relativistic total energy,

$$E = \gamma m_0 c^2$$

where

$$\gamma = \frac{1}{\sqrt{1 - \frac{v^2}{c^2}}}$$

Given,

$$v = \frac{2\sqrt{2}}{3}c \Rightarrow \frac{v^2}{c^2} = \frac{8}{9}$$

So,

$$\gamma = \frac{1}{\sqrt{1 - \frac{8}{9}}} = \frac{1}{\sqrt{\frac{1}{9}}} = 3$$

Thus,

$$E = 3m_0 c^2$$

Kinetic energy,

$$K = E - E_0 = 3m_0 c^2 - m_0 c^2 = 2m_0 c^2$$

So the ratio of kinetic energy to rest energy is

$$K : E_0 = 2 : 1$$

02. What is the mass of an electron having kinetic energy 1.6×10^6 eV?

Answer: 3.75×10^{-30} kg

Explanation:

Use

$$m = \frac{E_k}{c^2} + m_0$$

Convert kinetic energy:

$$E_k = 1.6 \times 10^6 \times 1.6 \times 10^{-19} = 2.56 \times 10^{-13} \text{ J}$$

Now,

$$\frac{E_k}{c^2} = \frac{2.56 \times 10^{-13}}{(3 \times 10^8)^2} = \frac{2.56 \times 10^{-13}}{9 \times 10^{16}} \approx 2.84 \times 10^{-30} \text{ kg}$$

Adding rest mass of electron,

$$m = 2.84 \times 10^{-30} + 9.1 \times 10^{-31} \approx 3.75 \times 10^{-30} \text{ kg}$$

03. When a potential difference of 10 kV is applied, what velocity does an electron attain starting from rest?

Answer: 5.93×10^7 m/s

Explanation:

Electrical energy gained by the electron becomes kinetic energy:

$$eV = \frac{1}{2}mv^2$$

So,

$$v = \sqrt{\frac{2eV}{m}}$$

Substitute values:

$$e = 1.6 \times 10^{-19} \text{ C}, \quad V = 10^4 \text{ V}, \quad m = 9.1 \times 10^{-31} \text{ kg}$$

$$v = \sqrt{\frac{2 \times 1.6 \times 10^{-19} \times 10^4}{9.1 \times 10^{-31}}} \approx 5.93 \times 10^7 \text{ m/s}$$

04. If the work function of sodium is 2.3 eV, what is the maximum kinetic energy of emitted electrons for light of wavelength 2000 Å?

Answer: 3.9 eV

Explanation:

Use Einstein's photoelectric equation:

$$hf = \phi + K_{\max}$$

or

$$K_{\max} = \frac{hc}{\lambda} - \phi$$

Given,

$$\lambda = 2000 \text{ Å} = 2000 \times 10^{-10} \text{ m}$$

Photon energy:

$$E = \frac{hc}{\lambda} = \frac{6.63 \times 10^{-34} \times 3 \times 10^8}{2000 \times 10^{-10}} \approx 9.94 \times 10^{-19} \text{ J}$$

Convert into eV:

$$E \approx \frac{9.94 \times 10^{-19}}{1.6 \times 10^{-19}} \approx 6.2 \text{ eV}$$

So,

$$K_{\max} = 6.2 - 2.3 = 3.9 \text{ eV}$$

05. Using Planck's constant, determine the energy of light having wavelength 2300 Å.

Answer: This one seems mistranscribed from the image.

Explanation:

If the question really is "Find the energy of light of wavelength 2300 Å," then:

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

With

$$\begin{aligned}\lambda &= 2300 \times 10^{-10} = 2.3 \times 10^{-7} \text{ m} \\ E &= \frac{6.63 \times 10^{-34} \times 3 \times 10^8}{2.3 \times 10^{-7}} \approx 8.65 \times 10^{-19} \text{ J}\end{aligned}$$

So the answer should be:

$$\boxed{8.65 \times 10^{-19} \text{ J}}$$

The earlier value $1.8 \times 10^{-7} \text{ J}$ does not match this wording, so this question likely needs a clearer crop.

06. The rest mass of an object is $9.1 \times 10^{-31} \text{ kg}$. If its velocity is 90% of the speed of light, what will be its relativistic mass?

Answer: $2.09 \times 10^{-30} \text{ kg}$

Explanation:

Relativistic mass:

$$m = \frac{m_0}{\sqrt{1 - \frac{v^2}{c^2}}}$$

Given,

$$v = 0.9c$$

So,

$$\begin{aligned}m &= \frac{9.1 \times 10^{-31}}{\sqrt{1 - 0.9^2}} = \frac{9.1 \times 10^{-31}}{\sqrt{1 - 0.81}} = \frac{9.1 \times 10^{-31}}{\sqrt{0.19}} \\ m &\approx 2.09 \times 10^{-30} \text{ kg}\end{aligned}$$

For Practice

01. If the work function of barium is 3.9 eV, determine the threshold frequency.

Answer: 9.41×10^{14} Hz

Explanation:

Threshold frequency is given by:

$$f_0 = \frac{\phi}{h}$$

Convert work function into joules:

$$\phi = 3.9 \times 1.6 \times 10^{-19} = 6.24 \times 10^{-19} \text{ J}$$

Then,

$$f_0 = \frac{6.24 \times 10^{-19}}{6.63 \times 10^{-34}} \approx 9.41 \times 10^{14} \text{ Hz}$$

02. If a 5 kV potential difference is applied, what will be the kinetic energy of an electron?

Answer: 8×10^{-16} J

Explanation:

Kinetic energy gained:

$$K = eV$$

Given,

$$V = 5 \text{ kV} = 5 \times 10^3 \text{ V}$$

So,

$$K = 1.6 \times 10^{-19} \times 5 \times 10^3 = 8 \times 10^{-16} \text{ J}$$

01. If the total energy of a moving particle is 2.5 times its rest energy, what is its velocity?

Answer: 2.75×10^8 m/s

Explanation:

We know:

$$E = \gamma m_0 c^2$$

and rest energy:

$$E_0 = m_0 c^2$$

Given,

$$E = 2.5 E_0 \Rightarrow \gamma = 2.5$$

Now,

$$\gamma = \frac{1}{\sqrt{1 - \frac{v^2}{c^2}}} = 2.5$$

So,

$$\sqrt{1 - \frac{v^2}{c^2}} = \frac{1}{2.5}$$

Squaring:

$$1 - \frac{v^2}{c^2} = \frac{1}{6.25}$$

$$\frac{v^2}{c^2} = 1 - \frac{1}{6.25} = 0.84$$

$$v = c\sqrt{0.84} \approx 3 \times 10^8 \times 0.916 \approx 2.75 \times 10^8 \text{ m/s}$$

02. When light of frequency 4×10^{15} Hz falls on a surface, the emitted electrons have a maximum kinetic energy of 3.6×10^{-19} J. Determine the threshold frequency.

Answer: 3.457×10^{15} Hz

Explanation:

Use photoelectric equation:

$$hf = hf_0 + K_{\max}$$

So,

$$f_0 = f - \frac{K_{\max}}{h}$$

Substitute:

$$\begin{aligned} f_0 &= 4 \times 10^{15} - \frac{3.6 \times 10^{-19}}{6.63 \times 10^{-34}} \\ \frac{3.6 \times 10^{-19}}{6.63 \times 10^{-34}} &\approx 5.43 \times 10^{14} \end{aligned}$$

Thus,

$$f_0 = 4 \times 10^{15} - 5.43 \times 10^{14} = 3.457 \times 10^{15} \text{ Hz}$$

03. An electron of total energy 2 MeV has kinetic energy 0.51 MeV. Determine its velocity.

Answer: 2.937×10^8 m/s

Explanation:

Total energy,

$$E = E_0 + K$$

Given,

$$E_0 = 0.51 \text{ MeV}, \quad K = 2 \text{ MeV}$$

Using

$$E = \frac{E_0}{\sqrt{1 - \frac{v^2}{c^2}}}$$

So,

$$\begin{aligned} \frac{E_0}{E} &= \sqrt{1 - \frac{v^2}{c^2}} \\ 1 - \frac{v^2}{c^2} &= \left(\frac{E_0}{E_0 + K} \right)^2 = \left(\frac{0.51}{0.51 + 2} \right)^2 \\ v &= c \sqrt{1 - \left(\frac{0.51}{2.51} \right)^2} \approx 2.937 \times 10^8 \text{ m/s} \end{aligned}$$

04. A rod has a density of 7800 kg/m^3 . If its length becomes half when moving, what will be its new density?

Answer: The earlier extraction seems off.

Explanation:

If mass remains unchanged and only length contracts, then:

$$\rho = \frac{m}{V}$$

If length becomes half, volume becomes half, so density doubles:

$$\rho' = 2\rho = 2 \times 7800 = 15600 \text{ kg/m}^3$$

But the book image seems to involve a different contraction factor, not "half." So this question should also be checked from a clearer crop.

For Practice (Right Side)

01. If the total energy of a moving particle is 2.5 times its rest energy, determine its velocity.

Answer: $2.75 \times 10^8 \text{ m/s}$

Explanation:

Same as Part-2, Question 01:

$$\gamma = 2.5 \Rightarrow v = c\sqrt{1 - \frac{1}{(2.5)^2}} \approx 2.75 \times 10^8 \text{ m/s}$$

01. If the total energy of a moving particle is 2.5 times its rest energy, determine its velocity.

Answer: $2.75 \times 10^8 \text{ m/s}$

Explanation:

Same as Part-2, Question 01:

$$\gamma = 2.5 \Rightarrow v = c\sqrt{1 - \frac{1}{(2.5)^2}} \approx 2.75 \times 10^8 \text{ m/s}$$

02. At what speed will the kinetic energy of a body become equal to its rest energy?

Answer: $2.6 \times 10^8 \text{ m/s}$

Explanation:

If kinetic energy equals rest energy:

$$K = E_0$$

Now,

$$K = (\gamma - 1)m_0c^2$$

So,

$$(\gamma - 1)m_0c^2 = m_0c^2 \Rightarrow \gamma - 1 = 1 \Rightarrow \gamma = 2$$

Thus,

$$\begin{aligned} \frac{1}{\sqrt{1 - \frac{v^2}{c^2}}} &= 2 \\ 1 - \frac{v^2}{c^2} &= \frac{1}{4} \Rightarrow \frac{v^2}{c^2} = \frac{3}{4} \\ v &= \frac{\sqrt{3}}{2}c \approx 0.866c \approx 2.6 \times 10^8 \text{ m/s} \end{aligned}$$

03. A particle of mass 2.4×10^{-28} kg moves with velocity 2.4×10^8 m/s. Determine its kinetic energy and compare it with rest energy.

Answer: 1.44×10^{-11} J; 2.08 : 1

Explanation:

First find relativistic factor:

$$\gamma = \frac{1}{\sqrt{1 - \frac{v^2}{c^2}}} = \frac{1}{\sqrt{1 - (0.8)^2}} = \frac{1}{\sqrt{0.36}} = \frac{1}{0.6} = 1.667$$

Rest energy:

$$E_0 = m_0 c^2 = 2.4 \times 10^{-28} \times (3 \times 10^8)^2 = 2.16 \times 10^{-11} \text{ J}$$

Kinetic energy:

$$K = (\gamma - 1)m_0 c^2 = (1.667 - 1) \times 2.16 \times 10^{-11} \approx 1.44 \times 10^{-11} \text{ J}$$

Comparison:

$$K : E_0 = 1.44 : 2.16 = 2 : 3$$