Chapter 2 (Mass Energy Equivalence)

PYQ [IIT-JAM]

Q1. The amount of work done to increases the speed of an electron nom $c/3$ to $2c/3$ is ($c = 3\times10^8$ m/s and rest mass of electron is $0..511$ MeV)

(a) $56.50\,\text{keV}$ (b) 143.58 keV (c) $168.20\,\text{keV}$ (d) 511.00 keV

IIT-JAM 2019

Q2. Two relativistic particles with opposite velocities collide head-on and come to rest by sticking with each other. Which of the following quantities is/are conserved in the collision?

(a) Total momentum (b) Total energy

(c) Total kinetic energy (d) Total rest mass

IIT-JAM 2020

Q3. A particle is moving with a velocity $0.8c\hat{j}$ (c is the speed of light) in an inertial frame S_1. Frame S_2 is moving with a velocity $0.8c\hat{i}$ with respect to S_1. Let E_1 and E_2 be the respective energies of the particle in the two frames. Then, $\frac{E_2}{E_1}$ is _____ (Round off to two decimal places).

IIT-JAM 2021

PYQ [GATE]

Q1. Two particles each of rest mass m collide head-on and stick together. Before collision, the speed of each mass was 0.6 times the speed of light in free space. The mass of the final entity is

(a) $5m/4$ (b) $2m$ (c) $5m/2$ (d) $25m/8$

GATE- 2011

Q2. A particle with rest mass M is at rest and decays into two particles of equal rest masses $\frac{3}{10}M$ which move along the z axis. Their velocities are given by

(a) $\vec{v}_1 = \vec{v}_2 = (0.8c)\hat{z}$ (b) $\vec{v}_1 = -\vec{v}_2 = (0.8c)\hat{z}$

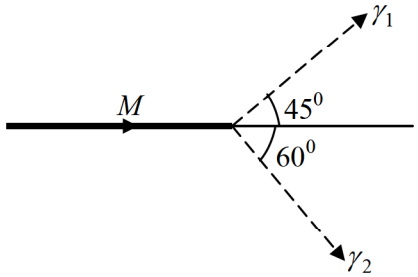
(c) $\vec{v}_1 = -\vec{v}_2 = (0.6c)\hat{z}$ (d) $\vec{v}_1 = (0.6c)\hat{z};\ \vec{v}_2 = (-0.8c)\hat{z}$

GATE- 2015

Q3. The kinetic energy of a particle of rest mass m_0 is equal to its rest mass energy. Its momentum in units of $m_0 c$, where c is the speed of light in vacuum, is _____. (Give your answer upto two decimal places)

GATE- 2016

Q4. A particle of rest mass M is moving along the positive x-direction. It decays into two photons γ_1 and γ_2 as shown in the figure. The energy of γ_1 is $1\ GeV$ and the energy of γ_2 is $0.82\ GeV$. The value of M (in units of $\frac{GeV}{c^2}$) is _____. (Give your answer upto two decimal places)



GATE- 2016

Q5. The relativistic form of Newton's second law of motion is

(a) $F = \frac{mc}{\sqrt{c^2 - v^2}}\frac{dv}{dt}$ (b) $F = \frac{m\sqrt{c^2 - v^2}}{c}\frac{dv}{dt}$

(c) $F = \frac{mc^2}{c^2 - v^2}\frac{dv}{dt}$ (d) $F = m\frac{c^2}{c^2}\frac{v^2}{}\frac{dv}{dt}$

GATE- 2013

PYQ [NET-JRF]

Q1. According to the special theory of relativity, the speed v of a free particle of mass m and total energy E is:

(a) $v = c\sqrt{1-\frac{mc^2}{E}}$ (b) $v = \sqrt{\frac{2E}{m}}\left(1+\frac{mc^2}{E}\right)$

(c) $v = c\sqrt{1-\left(\frac{mc^2}{E}\right)^2}$ (d) $v = c\left(1+\frac{mc^2}{E}\right)$

NET/JRF (DEC-2014)

Q2. Let *v*, *p* and *E* denote the speed, the magnitude of the momentum, and the energy of a free particle of rest mass *m*. Then

(a) $\frac{dE}{dP} = c$ constant (b) $p = mv$ (c) $v = \frac{cp}{\sqrt{p^2+m^2c^2}}$ (d) $E = mc^2$

NET/JRF (DEC-2012)

Q3. Consider a particle of mass m moving with a speed v. If T_R denotes the relativistic kinetic energy and T_N its non-relativistic approximation, then the value of $\frac{(T_R - T_N)}{T_R}$ for $v = 0.01\,c$, is

(a) 1.25×10^{-5} (b) 5.0×10^{-5} (c) 7.5×10^{-5} (d) 1.0×10^{-4}

NET/JRF (DEC-2015)

Q4. Consider the decay process $\tau^- \to \pi^- + \nu_\tau$ in the rest frame of the τ^-. The masses of the τ^-, π^- and ν_τ are M_τ, M_π and zero respectively.

The energy of π^- is

(a) $\frac{(M_\tau^2 - M_\pi^2)c^2}{2M_\tau}$ (b) $\frac{(M_\tau^2 + M_\pi^2)c^2}{2M_\tau}$ (c) $(M_\tau - M_\pi)c^2$ (d) $\sqrt{M_\tau M_\pi}c^2$

NET/JRF (JUNE-2011)

Q5. The recently-discovered Higgs boson at the LHC experiment has a decay mode into a photon and a Z boson. If the rest masses of the Higgs and Z boson are $125\ \text{GeV/c}^2$ and $90\ \text{GeV/c}^2$ respectively, and the decaying Higgs particle is at rest, the energy of the photon will approximately be

(a) $35\sqrt{3}\,GeV$ (b) $35\,GeV$ (c) $30\,GeV$ (d) $15\,GeV$

NET/JRF (JUNE-2014)

Q6. The muon has mass $105\,MeV/c^2$ and mean life time $2.2\,\mu s$ in its rest frame. The mean distance traversed by a muon of energy $315\,MeV$ before decaying is approximately,

(a) $3\times10^5\,km$ (b) $2.2\,cm$ (c) $6.6\,\mu m$ (d) $1.98\,km$

NET/JRF (DEC-2012)

Q7. The energy of a free relativistic particle is $E=\sqrt{|\vec{p}|^2c^2+m^2c^4}$, where m is its rest mass, $\vec{p}$ is its momentum and c is the speed of light in vacuum. The ratio v_g/v_p of the group velocity v_g of a quantum mechanical wave packet (describing this particle) to the phase velocity v_p is

(a) $|\vec{p}|c/E$ (b) $|\vec{p}|mc^3/E^2$ (c) $|\vec{p}|^2c^3/E^2$ (d) $|\vec{p}|c/2E$

NET/JRF (JUNE-2018)

Q8. A constant force *F* is applied to a relativistic particle of rest mass *m*. If the particle starts from rest at *t* = 0, its speed after a time *t* is

(a) Ft/m (b) $c\tanh\left(\frac{Ft}{mc}\right)$ (c) $c\left(1-e^{-Ft/mc}\right)$ (d) $\frac{Fct}{\sqrt{F^2t^2+m^2c^2}}$

NET/JRF (DEC-2011)

Q9. A relativistic particle of mass m and charge e is moving in a uniform electric field of strength ε. Starting from rest at $t=0$, how much time will it take to reach the speed $\frac{c}{2}$?

(a) $\frac{1}{\sqrt{3}}\frac{mc}{e\varepsilon}$ (b) $\frac{mc}{e\varepsilon}$ (c) $\sqrt{2}\frac{mc}{e\varepsilon}$ (d) $\sqrt{\frac{3}{2}}\frac{mc}{e\varepsilon}$

Q10. For a particle of energy E and momentum p (in a frame F), the rapidity y is defined as $y=\frac{1}{2}\ln\left(\frac{E+p_3c}{E-p_3c}\right)$. In a frame F' moving with velocity $v=(0,0,\beta c)$ with respect to F, the rapidity y' will be

(a) $y'=y+\frac{1}{2}\ln\left(1-\beta^2\right)$ (b) $y'=y-\frac{1}{2}\ln\left(\frac{1+\beta}{1-\beta}\right)$

(c) $y'=y+\ln\left(\frac{1+\beta}{1-\beta}\right)$ (d) $y'=y+2\ln\left(\frac{1+\beta}{1-\beta}\right)$

NET/JRF (June-2016)

Q11. A heavy particle of rest mass M while moving along the positive z - direction, decays into two identical light particles with rest mass m (where $M>2m$). The maximum value of the momentum that any one of the lighter particles can have in a direction perpendicular to the z - direction, is

(a) $\frac{1}{2}C\sqrt{M^2-4m^2}$ (b) $\frac{1}{2}C\sqrt{M^2-2m^2}$ (c) $C\sqrt{M^2-4m^2}$ (d) $\frac{1}{2}MC$

NET/JRF (JUNE-2020)

PYQ [JEST]

Q1. In an observer's rest frame, a particle is moving towards the observer with an energy E and momentum P. If c denotes the velocity of light in vacuum, the energy of the particle in another frame moving in the same direction as particle with a constant velocity v is

(a) $\frac{(E+vP)}{\sqrt{1-(v/c)^2}}$ (b) $\frac{(E-vP)}{\sqrt{1-(v/c)^2}}$ (c) $\frac{(E+vP)}{\left[1-(v/c)^2\right]^2}$ (d) $\frac{(E-vP)}{\left[1-(v/c)^2\right]^2}$

JEST-2013

Q2. A K meson (with a rest mass of 494 MeV) at rest decays into a muon (with a rest mass of 106 MeV) and a neutrino. The energy of the neutrino, which can be massless, is approximately

(a) 120 MeV (b) 236 MeV (c) 300 MeV (d) 388 MeV

JEST-2013

Q3. The velocity of a particle at which the kinetic energy is equal to its rest energy is (in terms of c, the speed of light in vacuum)

(a) $\sqrt{3}c/2$ (b) $3c/4$ (c) $\sqrt{3/5}c$ (d) $c/\sqrt{2}$

JEST-2013