Chapter 2 (Mass Energy Equivalence)
Worksheet

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

Q2. 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) $c/\sqrt{2}$

Q3. The energy of the particle P in the rest frame of the particle Q is

(a) $\frac{1}{2}m_0c^2$ (b) $\frac{5}{4}m_0c^2$ (c) $\frac{19}{13}m_0c^2$ (d) $\frac{11}{9}m_0c^2$

Q4. The momentum of an electron (mass m) which has the same kinetic energy as its rest mass energy is (c is velocity of light)

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

Q5. A particle of rest mass m_0 is moving with speed $\frac{4}{5}c$. Then the kinetic energy of the particle is given by

(a) $\frac{5}{3}m_0c^2$ (b) $\frac{2}{3}m_0c^2$ (c) $\frac{3}{5}m_0c^2$ (d) $\frac{8}{3}m_0c^2$

Q6. If E is relativistic energy and P is relativistic momentum then the value of $\frac{dE}{dp}$ is equivalent to

(a) $\frac{dE}{dP} = \frac{pc^2}{E}$ (b) $\frac{dE}{dP} = \frac{2pc^2}{E}$ (c) $\frac{dE}{dP} = \frac{pc^2}{2E}$ (d) c

Q7. The kinetic energy of a particle of rest mass m_0 is equal to its rest mass energy. Its momentum in units of m_0c, where c is the speed of light in vacuum, is given by.

(a) $2m_0c$ (b) $\sqrt{2}m_0c$ (c) $3m_0c$ (d) $\sqrt{3}m_0c$

Q8. A Particle has rest mass m_0, relativistic energy E and kinetic energy T. If P is relativistic momentum then the value of $\frac{dE}{dp}$ is equivalent to

(a) $\frac{dE}{dP}=\frac{pc^2}{T+m_0c^2}$
(b) $\frac{dE}{dP}=\frac{2pc^2}{E-m_0c^2}$
(c) $\frac{dE}{dP}=\frac{pc^2}{2\left(T+m_0c^2\right)}$
(d) $\frac{dE}{dP}=\frac{pc^2}{2\left(E-m_0c^2\right)}$

Q9. 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) $F=\frac{mc^3}{\left(c^2-v^2\right)^{3/2}}\frac{dv}{dt}$
(d) $F=m\frac{c^2-v^2}{c^2}\frac{dv}{dt}$

Q10. Consider a beam of relativistic particles of kinetic energy K at normal incidence upon a perfectly absorbing surface. The particle flux (number of particles per unit area per unit time) is J and each particle has rest mass m_0. The pressure on the surface is

(a) $\frac{JK}{c}$
(b) $\frac{J\sqrt{K\left(K+m_0c^2\right)}}{c}$
(c) $\frac{J\left(K+m_0c^2\right)}{c}$
(d) $\frac{J\sqrt{K\left(K+2m_0c^2\right)}}{c}$

Q11. The muon has rest mass $105MeV/c^2$ and mean life time $2\mu s$ in its rest frame. The mean time traversed by a muon of energy $210MeV$ before decaying is approximately:

(a) $2\mu s$ (b) $3\mu s$ (c) $4\mu s$ (d) $6\mu s$

Q12. The kinetic energy of a particle of rest mass m_0 is equal to twice to its rest mass energy. Its momentum in units of m_0c, where c is the speed of light in vacuum, is given by

(a) $2m_0c$ (b) $\sqrt{2}m_0c$ (c) $p=2\sqrt{2}m_0c$ (d) $\sqrt{3}m_0c$

Q13. 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 is massless, is approximately

(a) $120\,MeV$ (b) $236\,MeV$ (c) $300\,MeV$ (d) $388\,MeV$

Q14. The π^+ decays at rest to μ^+ and ν_μ. Assuming the neutrino to be massless, the momentum of the neutrino is (in MeV/c). ($m_\pi = 139\,MeV/c^2, m_\mu = 105\,MeV/c^2$)

(a) 25 (b) 30 (c) 35 (d) 40

Q15. 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) $25m/8$

Q16. A particle of mass M decays at rest into a massless particle and another particle of mass m. The magnitude of the momentum of each of these relativistic particles is:

(a) $\frac{c}{2}\sqrt{M^2 - 4m^2}$ (b) $\frac{c}{2}\sqrt{M^2 + 4m^2}$

(c) $\frac{c}{2M}\left(M^2 - m^2\right)$ (d) $\frac{c}{2M}\left(M^2 + m^2\right)$

Q17. A body of rest mass m_0 moving at speed v collide and stick to an identical body at rest. The rest mass of mass M of the final clump is (take $\gamma = \frac{1}{\sqrt{1-\frac{v^2}{c^2}}}$)

(a) $M = m_0\sqrt{2+\gamma}$ (b) $M = m_0\sqrt{2-\gamma}$

(c) $M = m_0\sqrt{2(1+\gamma)}$ (d) $M = m_0\sqrt{2(1-\gamma)}$

Q18. A particle with rest mass M is at rest and decays into two particles of equal rest masses $\frac{2}{5}M$ 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) $\vec{v}_1 = (0.6c)\hat{z},\ \vec{v}_2 = (-0.8c)\hat{z}$

Q19. A neutral pion of (rest) mass m_0 and energy $E = \frac{5}{4}m_0c^2$ decays into two photon, one of the photon emitted in the same direction as the original pion and other in opposite direction. Energy of the each photon is given by

(a) $E_1 = m_0c^2, E_2 = \frac{m_0c^2}{4}$ (b) $E_1 = \frac{5m_0c^2}{8}, E_2 = \frac{5m_0c^2}{8}$

(c) $E_1 = \frac{3m_0c^2}{4}, E_2 = \frac{m_0c^2}{2}$ (d) $E_1 = \frac{11}{12}m_0c^2, E_2 = \frac{m_0c^2}{3}$

Q20. A particle of rest mass m_0 whose total energy is twice the rest mass energy collide with identical particle at rest. If the stick together and make a composite mass. Then which one are correct statements?

1. the momentum of composite mass is $\sqrt{3}\, m_0 c$

2. the total energy is given by is $3m_0c^2$

3. the rest mass of composite mass is $\sqrt{6}\, m_0$

(a) 1 and 2 are correct
(b) 2 and 3 are correct
(c) 1 and 3 are correct
(d) 1, 2 and 3 are correct

Q21. K meson of rest energy $494\, MeV$ decays into a μ meson of rest energy $106\, MeV$ and a neutrino of zero rest energy. Then which of the following statement is correct

(a) The kinetic energy of the neutrino is $235.6\, MeV$, and that of the muon is $152.4\, MeV$.

(b) The kinetic energy of the neutrino is $152.4\, MeV$, and that of the muon is $235.6\, MeV$

(c) The kinetic energy of the neutrino and that of the muon is $235.6\, MeV$

(d) The kinetic energy of the neutrino and that of the muon is $152.4\, MeV$

Q22. An electron of mass $m = 0.511\, MeV/c^2$ and a photon of mass $m = 0$ both have momenta of $2.000\, MeV/c$. The corresponding energy for electron and photon are respectively:

(a) $2.064\, MeV$ and $2.000\, MeV$
(b) $2.000\, MeV$ and $2.064\, MeV$
(c) $20.64\, MeV$ and $2.000\, MeV$
(d) $20.00\, MeV$ and $2.064\, MeV$