Name____________________________________

Physics 120 Quiz #5, February 23, 2007

Please circle the best choice to question 1. For the problems, the parts have the points shown.

1. Two children ride on a merry-go-round, with child 1 at a greater distance from the axis of rotation than child 2. The angular speed of child 1 is
   a. greater than child 2.
   b. less than child 2.
   [✓ c.] the same as the angular speed of child 2.
   d. unable to be determined.

2. Consider a relativistic proton moving through a region of space.

2a. What is the proton's rest energy in MeV? (Hint: *MeV* stands for millions of electron volts, where $1\ eV = 1.6x10^{-19}\ J$ and the mass of the proton is $1.67x10^{-27} kg$.) (2 points)

$$E_r = m_p c^2 = 1.67\times10^{-27}\,kg\times\left(3\times10^8\,\tfrac{m}{s}\right)^2\times\frac{1eV}{1.6\times10^{-19}\,J}\times\frac{1MeV}{1\times10^6\,eV} = 939.4MeV$$

2b. Suppose that the total energy of the proton is three times its rest energy, what speed is the proton moving. Express your answer as a *fraction of the speed of light, c*. (3 points)

$$E_{total} = KE + E_r \rightarrow KE = E_{total} - E_r = 3E_r - E_r = 2E_r$$

$$KE = (\gamma - 1)m_p c^2 = 2m_p c^2 \rightarrow \gamma = 3$$

$$\therefore \gamma = 3 = \frac{1}{\sqrt{1-\frac{v^2}{c^2}}} \rightarrow v = 0.943c$$

2c. What is the kinetic energy (in *eV*) of the proton in part b? (1 point)

$$KE = (\gamma - 1)m_p c^2 = 2m_p c^2 = 2\times939.4MeV = 1878.8MeV = 1.8788\times10^9\,eV$$

2d. What is the proton's momentum? (2 points)

$$E_{total}^2 = p^2c^2 + m_p^2c^4 \rightarrow p^2c^2 = \left(3m_pc^2\right)^2 - \left(m_pc^2\right)^2 = 8\left(m_pc^2\right)^2 = 8(939.4MeV)^2 = 7.0598\times10^6\,MeV^2$$

$$\therefore p = \sqrt{\frac{7.0598\times10^6\,MeV^2}{c^2}} = \frac{2657MeV}{c} = 1.42\times10^{-18}\,kg\,\tfrac{m}{s}$$

Motion in the x-direction

$$x_f = x_i + v_{ix}t + \tfrac{1}{2}a_x t^2$$

$$v_{fx} = v_{ix} + a_x t$$

$$v_{fx}{}^2 = v_{ix}{}^2 + 2a_x \Delta x$$

$$F_x = ma_x$$

Vectors

$$\text{magnitude of a vector} = \sqrt{v_x{}^2 + v^2{}_y}$$

$$\text{direction of a vector} \rightarrow \phi = \tan^{-1}\left(\frac{v_y}{v_x}\right)$$

Forces

$$\vec{F} = m\vec{a} = \frac{d\vec{p}}{dt}$$

$$\vec{F}_s = -k\Delta\vec{x}$$

$$F_c = m\frac{v^2}{r}$$

Relativity

$$L = \frac{L_p}{\gamma}$$

$$\Delta t = \gamma \Delta t_p$$

$$p = \gamma m v$$

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

$$E_r = mc^2$$

$$E^2 = p^2c^2 + m^2c^4 = \gamma mc^2$$

$$KE = (\gamma - 1)mc^2$$

Motion in the y-direction

$$y_f = y_i + v_{iy}t + \tfrac{1}{2}a_y t^2$$

$$v_{fy} = v_{iy} + a_y t$$

$$v_{fy}{}^2 = v_{iy}{}^2 + 2a_y \Delta y$$

$$F_y = ma_y$$

Useful Constants

$$g = 9.8\,\tfrac{m}{s^2}$$

$$\text{Quadratic Equation}: ax^2 + bx + c = 0; \quad \text{solutions}: x = \frac{-b \pm \sqrt{b^2 - 4ac}}{2a}$$

Work – Energy-Momentum

$$W = \int_{r_1}^{r_2} \vec{F} \cdot d\vec{r} = \Delta KE$$

$$KE = \tfrac{1}{2}mv^2$$

$$PE_g = mgy$$

$$PE_s = \tfrac{1}{2}kx^2$$

$$\vec{p} = m\vec{v}$$

$$\vec{I} = \int \vec{F}dt = \Delta\vec{p}$$

Rotational Motion

$$s = r\theta; \quad v = r\omega; \quad a_t = r\alpha$$

$$\theta_f = \theta_i + \omega_i t + \tfrac{1}{2}\alpha t^2$$

$$\omega_f = \omega_i + \alpha t$$

$$\omega_f^2 = \omega_{\mathbf{i}}^2 + 2\alpha\Delta\theta$$

$$\tau = I\alpha = rF\sin\theta = \frac{dL}{dt}$$

$$L = I\omega$$

$$KE_{rot} = \tfrac{1}{2}I\omega^2$$