Phys.115 Exam I
26 September 2007

Please do not turn the page until you are told to do so. Make sure that you have all three problems on your copy of the test. In order to get credit on a problem, you must show your work. If you only write down an answer without the work leading up to it, you will get no credit for it, even if it is the right answer.
1) A hot-air balloon carrying a basket is descending at a constant velocity of 20.0 m/s. A person in the basket throws a stone with an initial velocity of 15.0 m/s horizontally, perpendicular to the path of the descending balloon. 4.00 s later, this person sees the rock strike the ground.

(a) (7 points) How high was the balloon when the rock was thrown out?

\[ \gamma_{\text{balloon}} = \gamma_{\text{rock}} \]
\[ \gamma_{\text{air}}: \quad \gamma = \gamma_{\text{rock}} + v_{0y} t + \frac{1}{2} a_y t^2 \]
\[ 0 = \gamma_{\text{rock}} + (-20.0 \text{ m/s})(4.00 \text{ s}) + \frac{1}{2}(-9.8 \text{ m/s}^2)(4.00 \text{ s})^2 \]
\[ \gamma_{\text{rock}} = 15.8 \text{ m} \]
\[ \Rightarrow \gamma_{\text{balloon}} = 15.8 \text{ m} \]

(b) (6 points) How far horizontally does the rock travel before it hits the ground?

\[ x_{\text{air}}: \quad a_x = 0 \]
\[ \Rightarrow x = v_{0x} t = (15.0 \text{ m/s})(4.00 \text{ s}) = 60.0 \text{ m} \]

(c) (7 points) At the instant the rock hits the ground, what is the total distance between the rock and the basket?

What distance did the balloon travel (at const. speed) in 4.00 s?

\[ \Delta y = v_{0y} t = (20.0 \text{ m/s})(4.00 \text{ s}) = 80.0 \text{ m} \]
\[ \Rightarrow \text{the balloon is at a height of } 15.8 - 80.0 \text{ m} = 78.0 \text{ m} \text{ off the ground where the rock hits the ground.} \]

\[ r = \sqrt{x^2 + y^2} = \sqrt{(60.0 \text{ m})^2 + (78.0 \text{ m})^2} \]
\[ r = 98.4 \text{ m} \]
2) While a fractured tibia (the larger of the two major lower leg bones in mammals) is healing, it must be held horizontally and kept under some tension, so that the bones heal properly. One way to do this is to support the leg by using a variation of the Russell traction apparatus. The lower leg, including the foot, of a particular patient weighs 51.5 N, all of which must be supported by the traction apparatus.

(a) (10 points) What must be the mass of W, shown in the figure? Assume that the sling around the leg is slack, so it does not provide any force.

\[ \sum F_y = 0 \]
\[ T \sin 46 - mg - T \sin 37 = 0 \]
\[ T = \frac{mg}{\sin 46 - \sin 37} = \frac{51.5 \text{ N}}{\sin 46 - \sin 37} \]
\[ T = W = 438 \text{ N} \]
\[ M = \frac{W}{g} = \frac{438 \text{ N}}{9.2 \text{ m/s}^2} = 44.7 \text{ kg} \]

(b) (10 points) What traction force does the apparatus provide along the direction of the leg?

\[ \sum F_x = T \cos 37 + T \cos 46 = 438 \text{ N} (\cos 37 + \cos 46) \]
\[ \sum F_x = 654 \text{ N} \]
3) The 4.00 kg block in the figure is attached to a vertical rod by means of two strings. When the system rotates about the axis of the rod, the strings are extended as shown in the figure. The tension in the upper string is 80.0 N. (a) (6 points) Draw a free-body diagram of the block.

(b) (7 points) What is the tension in the lower string?

\[ \sum F_y = 0 \]
\[ T_u \sin \theta - mg - T_l \sin \theta = 0 \]
\[ T_l = \frac{T_u \sin \theta - mg}{\sin \theta} = 80.0 \text{N} - \frac{(4.00 \text{kg})(9.8 \text{m/s}^2)}{\sin 53.1^\circ} = 31.0 \text{N} \]

(c) (7 points) What is the speed of the block?

\[ \sum F_x = m \frac{v_x}{\ell} \]
\[ \ell = \sqrt{(1.25 \text{m})^2 - (1.00 \text{m})^2} = 0.750 \text{m} \]
\[ T_l \cos \theta + T_u \cos \theta = m \frac{v_x}{\ell} \]
\[ v = \sqrt{\frac{\ell}{m} (T_l + T_u) \cos \theta} = \sqrt{\frac{0.750 \text{m}}{4.00 \text{kg}} \left(80.0 \text{N} + 31.0 \text{N}\right) \cos 53.1^\circ} = 3.54 \text{m/s} \]
\[ |\vec{A}| = \sqrt{A_x^2 + A_y^2 + A_z^2} \]

\[ \theta = \tan^{-1} \frac{A_y}{A_x} \]

\[ \vec{v} = \frac{\Delta \vec{r}}{\Delta t} \]

\[ \vec{a} = \frac{\Delta \vec{v}}{\Delta t} \]

\[ x = x_0 + v_0 t + \frac{1}{2} a t^2 \]

\[ v = v_0 + at \]

\[ v^2 = v_0^2 + 2a \Delta x \]

\[ \Sigma \vec{F} = m \vec{a} \]

\[ F = G \frac{m_1 m_2}{R^2} \]

\[ f_k = \mu_k F_N \]

\[ a_e = \frac{v^2}{r} \]

\[ T = \frac{2\pi r}{v} \]

\[ F_c = \frac{mv^2}{r} \]

..... constants ..... 

\[ g = 9.8 \text{ m/s}^2 \]

\[ G = 6.67 \times 10^{-11} \text{ Nm}^2 / \text{kg}^2 \]