Massachusetts Institute of Technology
Physics Department

Physics 8.01x Fall term 2002

Solutions to Problem Set# 3

The solution is given for $g = 10.0 m/s^2$. Of course you can use $9.8 m/s^2$ and get the same credit.

Problem 1) Y&F 3-50, p88

a) If we choose the edge of the roof as the origin, the upward direction as the positive y axis and the x axis to the right, the equation of motion for projectile motion of the snowball is

$$\vec{r}(t) = \hat{v}_0 t + \frac{1}{2}\vec{g}t^2 = (v_0 t\cos\theta, -v_0 t\sin\theta - \frac{1}{2}gt^2),$$

so that when the snowball reaches the ground, ie.

$$r_y = -v_0 t\sin\theta - \frac{1}{2}gt^2 = -H = -14.0\text{m},$$

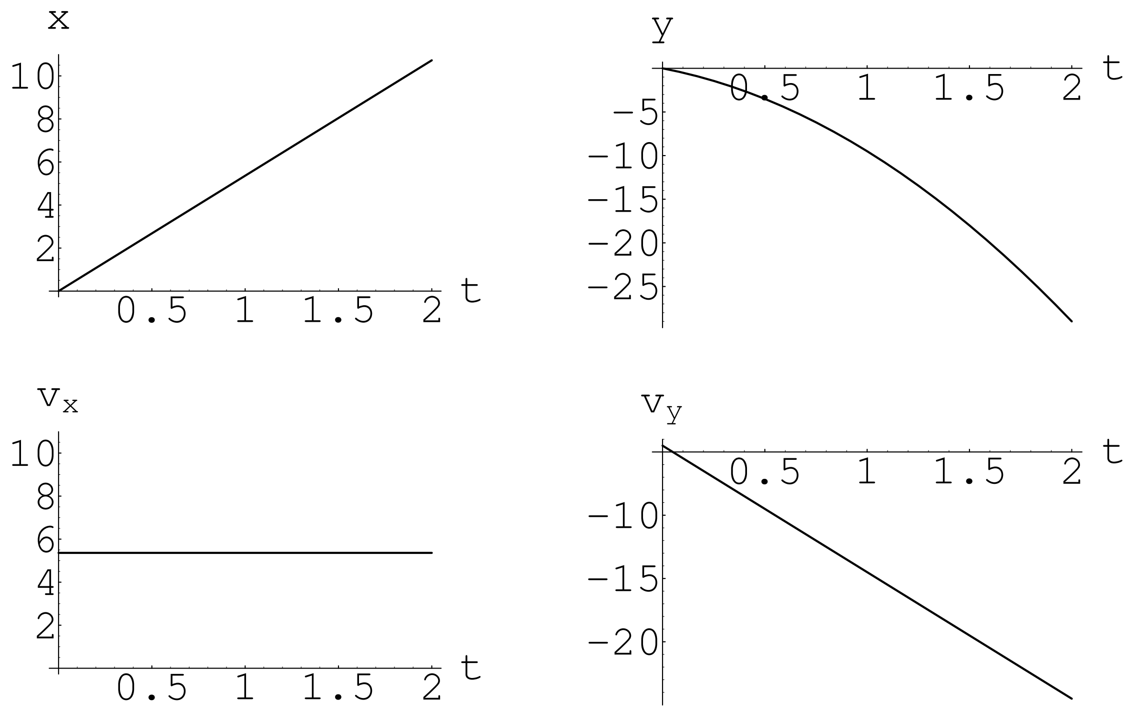
the solution is $t = 1.28$sec. (The other solution, which is negative, is ignored because the reasonable solution is positive.) The distance from the edge of the barn to where the snowball hits the ground is

$$x(t = 1.28s) = v_0 t\cos\theta = 6.88m.$$

b) Expressions for the velocity as a function of time is

$$\begin{aligned} v_x(t) &= \frac{d}{dt}(v_0 t\cos\theta) = v_0\cos\theta \\ v_y(t) &= \frac{d}{dt}(-v_0 t\sin\theta - \frac{1}{2}gt^2) = -v_0\sin\theta - gt. \end{aligned}$$

From the expressions for x(t), y(t), $v_x(t)$ and $v_y(t)$, we get the diagrams



c) To find if the man will be hit, we calculate the snowball's height when it is 4.0 meters away from the edge of the barn(let this time be t).

$$x(t) = v_0 t \cos\theta = 4.0\text{m} \Longrightarrow t = \frac{4.0m}{v_0 \cos\theta} = 0.76\text{s}.$$

At this moment the height of snowball is

$$y(t = 0.76s) = -6.14m > y_{man} = 1.9m - 14.0m = -12.1m,$$

which means the snowball will not hit the man.

Problem 2) Y&F 4-22, p117

According to Newton's Law, reaction force is -1 times action force(as vector!). So the reaction force to the floor's normal force is 620N downward, exterted by the passenger on the floor. The reaction force to the passenger's gravitational force is exterted by the passenger to the earth(it is the whole earth that attracts the passenger), upward 650N.
Because the mass of the passenger is $m = mg/g = 65kg$, his acceleration is

$$a = (650N - 620N)/m = 0.46m/s^2.$$

As the gravitational force is greater, the direction of $\vec{a}$ is downward.

Problem 3 Y&F 5-86, p159

a) Since the lower block has smaller coefficient of friction with the inclined plane, it tends to slip down with a greater acceleration than the upper block. So the string will constrain the lower block and both will slip down with the same acceleration. If we take the two blocks as a system, we can apply Newton's Law on it without considering the internal interaction(tesion in the string).
In this kind of inclied-plane problem, gravitational force has a well known downward component along the direction of the inclied plane $Mg\sin\theta$. The total frictional force upward along the plane is

$$f = m_1 g \cos\theta \mu_1 + m_2 g \cos\theta \mu_2 = (4.0kg \times 0.25 + 8.0kg \times 0.35) \times 10m/s^2 \times \cos(30^o) = 32.9N$$

so the acceleration is

$$a = \frac{(m1 + m2) g \sin\theta - f}{m1 + m2} = 2.26m/s^2$$

b) Now we only look at m_1. The total force along the direction of the inclined plane is $m_1 g \sin\theta - m_1 g \cos\theta \mu_1 - T$, where T denotes the tension in the string. Application of Newton's Law in this direction gives

$$m_1 a = m_1 g \sin\theta - m_1 g \cos\theta \mu_1 - T \Longrightarrow T = 2.30N,$$

where we have calculated the acceleration in a).

c) Now that the upper block tends to slip down with greater acceleration, the string will be loose and there is no tension in it(T=0). The acceleration of each block is

$$\begin{aligned} a_1 &= \frac{m_1 g \sin\theta - m_1 g \cos\theta \mu_1}{m} = g(\sin\theta - \mu_1 \cos\theta) = 2.83m/s^2 \\ a_2 &= \frac{m_2 g \sin\theta - m_2 g \cos\theta \mu_2}{m} = g(\sin\theta - \mu_2 \cos\theta) = 1.97m/s^2 \end{aligned}$$

Problem 4 Y&F 5-93, p160

Hint: the tension in both sides of the string will be the same since the pulley is frictionless. This means at any moment the total forces on the banana and the monkey are the same in magnitude AND direction, given that they also have the same mass. It follows that they will have the same velocity any time.

a) The monkey starts from rest to upward motion, which means she has an upward acceleration. From the argument above the banana also has a upward velocity so it moves upward.

b) Since the monkey and the banana have the same acceleration and velocity any time, their equations of motion only differ in the initial position. Hence their relative distance will remain the initial value.

c) Same reason, constant.

d) The length of the part of the string between monkey and banana will change if there is relative motion between monkey and string. Now if the monkey grabs the string and try to stop, the lenth does not change. This means both stop.