Physics 221 Exam I
Feb. 14, 2008

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1. **For each of the following give your answer with your work and your reasoning clearly shown**

   (a) **A truck moves 70 m east, then moves 120 m west, and finally moves east again a distance of 90 m. If east is chosen as the positive direction, what is the truck's resultant displacement?**
   Since displacement is a vector we have to keep track whether the segements of the movement are to the left or to the right. The first segment is positive, the second is negative, while the third is positive again. The net displacement is then

   $$Displacement = 70 - 120 + 90 = 40\,\text{meters due east}$$

   (b) **An object moves 20 m east in 30 s and then returns to its starting point taking an additional 50 s. If west is chosen as the positive direction, what is the average speed of the object?**
   Speed is a scalar quantity, so we are just concerned with the total distance traveled divided by the elapsed time. The total distance is given by

   $$\text{Distance} = 20 + 20 = 40 \text{ meters}$$

   Total time is given by

   $$t = 30 + 50 = 80 \text{ seconds}$$

   Speed is then given by

   $$Speed = \frac{\text{Distance}}{Time} = \frac{40}{80} = 0.5\,m/s$$

   (c) **A vehicle designed to operate on a drag strip accelerates from zero to 30 m/s while undergoing a straight line path displacement of 45 m. What is the vehicle's acceleration if its value may be assumed to be constant?**
   Since we are not given any information about time the best equaiton to use is the one that directly relates the velocity, initial and final, to the distance and acceleration

   $$v^2 = v_0^2 + 2\,a\,s$$

   Now $v_0 = 0$. So we then have

   $$\begin{aligned} (30)^2 &= (0)^2 + 2(a)(45) \\ 900 &= 90\,a \\ a &= 10\,m/s^2 \end{aligned}$$

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2. **A tennis ball is thrown at a tall, vertical wall 40 meters away. The ball leaves the person's hand with a speed of 25 m/s at an angle of 45^0 above the horizontal.**

   (a) **How long does it take the ball to reach the wall?**
   The time is determined from the distance to the wall and the horizontal component of the velocity.

$$\begin{aligned} d &= t\,v_x = t\,v_0\cos\theta \\ t &= \frac{d}{v_0\cos\theta} = \frac{40}{25\cos 45} = \frac{40}{17.67} \\ &= 2.26\,s \end{aligned}$$

   (b) **How far above the ground does the ball hit the wall?**
   We just need to concern ourselves with just the vertical motion for this step. Since we are not told anything different we assume that the ball is thrown from an initial position of $y_0 = 0$. We use the equation that relates the position, the velocity, the acceleration, and the time.The vertical component of the initial velocity is given $v_{0y} = v_0 \sin\theta$.

$$\begin{aligned} y &= y_0 + v_{0y}\,t + \frac{1}{2}a\,t^2 \\ &= 0 + 25\sin 45(2.26) + (0.50(-9.8)(2.26)^2 \\ &= 0 + 39.95 - 25.03 \\ &= 14.92 \text{ m above the ground} \end{aligned}$$

   (c) **With what velocity does the ball strike the wall?**
   The horizontal component of the velocity does not change.

$$v_x = v_{0x} = v_0\cos\theta = 17.67\,m/s$$

   The vertical component is given by

$$\begin{aligned} v_y &= v_{0y} + a\,t \\ &= 25\sin 45 - (9.8)(2.26) \\ &= 17.68 - 22.15 \\ &= -4.47\,m/s \quad \text{ball is on its way down} \end{aligned}$$

   The magnitude of the velocity is given by

$$\begin{aligned} v &= \sqrt{v_x^2 + v_y^2} = \sqrt{(17.68)^2 + (-4.47)^2} \\ &= \sqrt{329.74} \\ &= 18.16\,m/s \end{aligned}$$

   The direction for this velocity is given by

$$\begin{aligned} \theta &= \tan^{-1}\left(\frac{v_y}{v_x}\right) = \tan^{-1}\left(\frac{-4.47}{17.67}\right) \\ &= \tan^{-1}(-0.25) \\ &= -14.20^0 \end{aligned}$$

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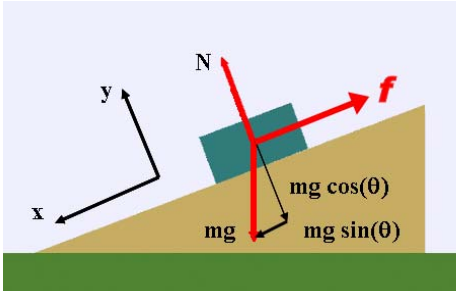
3. **A box of mass 15 kg is released from the top of an inclined plane that is 4.0 m long and makes an angle of 40^0 with the horizontal. A force of 50 N impedes the motion of the box. Find**

   (a) **The net force acting on the box.**
   We need to draw a free body diagram for the box



We resolve the weight as shown

$$W_x = W\cos\theta = (15)(9.8)\sin 40 = 94.49\,Nts$$
$$W_y = W\sin\theta = (15)(9.8)\cos 40 = 112.61\,Nts \text{ in negative y-direction}$$

Since the block is not moving in the y-direction, we must have that the net force in the y-direction is zero.

$$F_y^{net} = N - W_y = 0$$
$$N = W_y$$

The net force in the x-direction is then given by

$$F_x^{net} = W_x - f = 94.90 - 50 = 44.90\,Nts \text{ in the positive x-direction}$$

   (b) **The acceleration of the box.**
   The acceleration is along the x-direction. So we have

$$F_x^{net} = m\,a_x$$
$$44.49 = (15)\,a_x$$
$$a_x = 44.49\,/\,15 = 2.97\,m\,/\,s^2 \text{ in the positive x-direction}$$

   (c) **The time required for it to reach the bottom of the incline.**
   The appropriate equation is

$$x = x_0 + v_{0x}\,t + \frac{1}{2}a_x\,t^2$$

We can take $x_0 = 0,\ v_{0x} = 0$. We then have

$$x = \frac{1}{2}a_x\,t^2$$
$$4 = (0.5)(2.97)\,t^2$$
$$t^2 = 8/2.97 = 2.693$$
$$t = 1.64\,s$$

   (d) **The coefficient of friction between the box and the incline.**
   The frictional force is given by

$$f = \mu\,N$$
$$50 = \mu(112.61)$$
$$\mu = \frac{50}{112.61} = 0.44$$

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4. **A ball is rolled horizontally off a table with an initial speed of 0.24 m/s. A stopwatch measures the ball's trajectory time from table to the floor to be 0.30 s.**

   (a) **How far from the table does the ball land?**
   This distance is given only by the horizontal velocity.

$$\begin{aligned} x &= v_{0x}t \\ &= (0.24)(0.3) \\ &= 0.072\,m \end{aligned}$$

   (b) **What is the height of the table? (g = 9.8 m/s^2 and air resistance is negligible)**
   We use the distance equation with $y = 0$, and $v_{0y} = 0$.

$$\begin{aligned} y &= y_0 + v_{0y}\,t + \frac{1}{2}a\,t^2 \\ 0 &= y_0 + (0)(0.3) + (0.50)(-9.8)(0.3)^2 \\ 0 &= y_0 - 0.441 \\ y_0 &= 0.441\,m \end{aligned}$$

   (c) **What is the ball's velocity?**
   The y-component of the ball's velocity is given by

$$\begin{aligned} v_y &= v_{0y} + a\,t \\ &= 0 + (-9.8)(0.3) \\ &= -2.94\,m/s \end{aligned}$$

   The horizontal component of the velocity remains unchanged

$$v_x = v_{0x} = 0.24\,m/s$$

   The ball's velocity is given by

$$\begin{aligned} v &= \sqrt{v_x^2 + v_y^2} = \sqrt{(0.24)^2 + (2.94)^2} = \sqrt{8.7012} \\ &= 2.95\,m/s \end{aligned}$$

5. **A boat travels upstream and after one hour has gone 10 km. The boat next travels downstream and after one hour has gone 14 km. If the boat's speed relative to the water is constant, what is the speed of the current in the river?**
In general the the velocity of the boat with regards to the ground is given by

$$v_{boat,ground} = v_{boat,water} + v_{water,ground}$$

We take the direction of the current as being positive. For the first part of the journey the velocity of the boat with respect to the water is negative, while in the second part of the journey the velocity of the boat with respect to the water is positive. So for the first part of the journey we have

$$\begin{aligned} d_1 &= (-v_{boat,water} + v_{water,ground})t_1 \\ -10 &= -v_{boat,water} + v_{water,ground} \qquad (1) \end{aligned}$$

For the second part of the journey we have

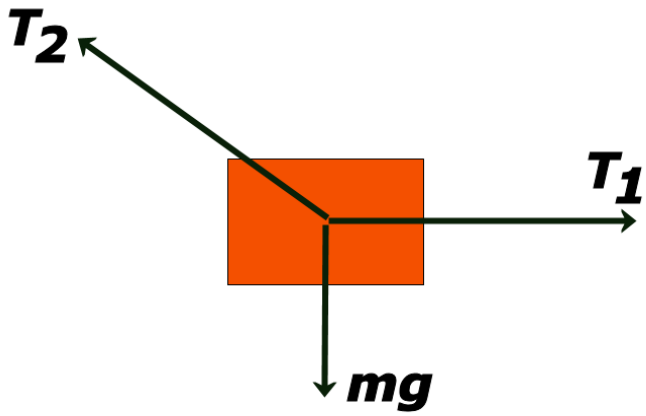
$$\begin{aligned} d_2 &= (v_{boat,water} + v_{water,ground})t_2 \\ 14 &= v_{boat,water} + v_{water,ground} \qquad (2) \end{aligned}$$

We now add Equation 1 and Equation 2 to obtain

$$\begin{aligned} 4 &= 2(v_{water,ground}) \\ v_{water,ground} &= 2\,km/hr \end{aligned}$$

6. **A 5 000-N weight is held suspended in equilibrium by two cables. Cable 1 applies a horizontal force to the right of the object and has a tension, $\mathbf{T}_1$. Cable 2 applies a force upward and to the left at an angle of 37.0 to the negative x axis and has a tension, $\mathbf{T}_2$. What is the tension, $\mathbf{T}_1$?**

We need to draw a free body diagram for the weight.



Since the weight is not moving, the sum of the forces in the x- and y-directions are equal to zero seperately. In the x-direction we have

$$T_1 - T_2 \cos 37 = 0 \tag{3}$$

In the y-direction we have

$$\begin{aligned} T_2 \sin 37 - mg &= 0 \quad (4) \\ T_2 &= \frac{mg}{\sin 37} \quad (5) \end{aligned}$$

We now insert Equation 5 into Equation 3 to obtain

$$\begin{aligned} T_1 - \frac{mg}{\sin 37} \cos 37 &= 0 \\ T_1 - \frac{mg}{\tan 37} &= 0 \\ T_1 &= \frac{mg}{\tan 37} = \frac{5000}{0.75} \\ T_1 &= 6635\, Nts \end{aligned}$$