PHY 1124 (Winter 2014)

Assignment #1: Solutions

Chapter 1

Q1: #42

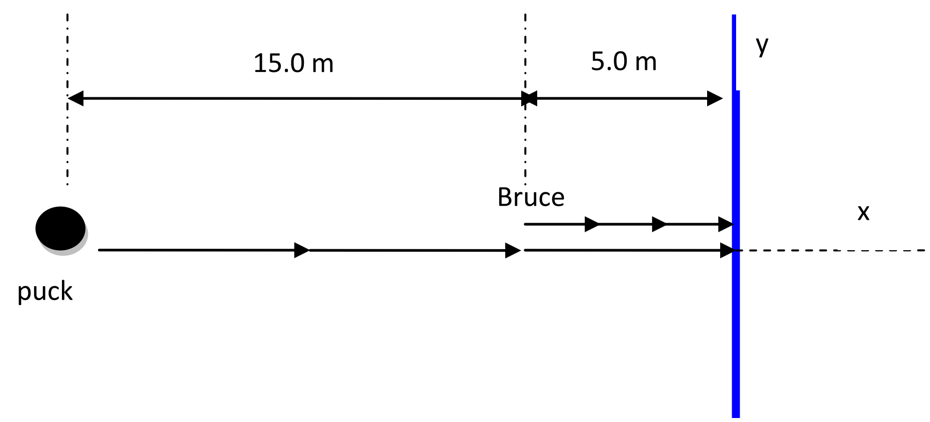
Ice hockey star Bruce Blades is 5.0 m from the blue line and gliding toward it at a speed of 4.0 m/s. You are 20 m from the blue line, directly behind Bruce. You want to pass the puck to Bruce. With what speed should you shoot the puck down the ice so that it reaches Bruce exactly as he crosses the blue line?

Known:

$v_{Bruce} = 4.0\frac{m}{s}$

$\Delta x_{Bruce} = 5.0\,m$

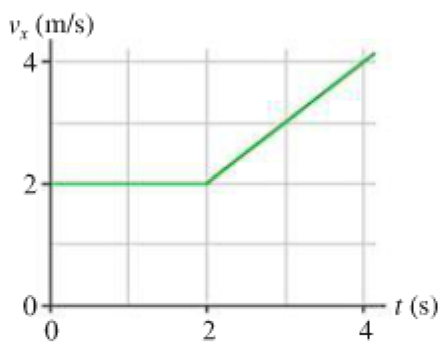
$\Delta x_{Puck} = 20\,m$

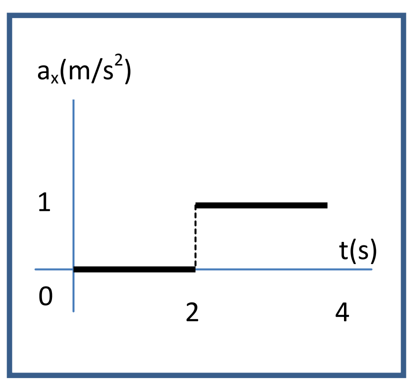


Chapter 2

Q2: #9

Draw the particle's acceleration graph for the interval $0\,s \le t \le 4s$. Give both axes an appropriate numerical scale.

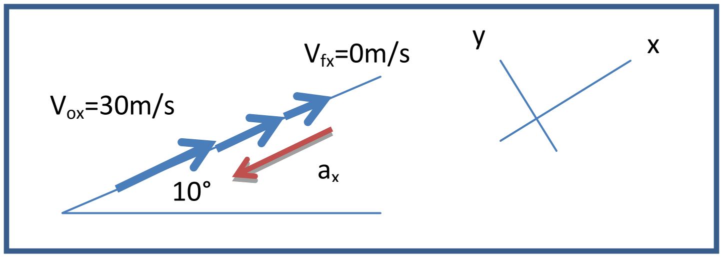




Q3: #22

A car traveling at 30 m/s runs out of gas while traveling up a 10° slope. How far up the hill will it coast before starting to roll back down?

First, draw your motion diagram with an appropriate co-ordinate axis:



Known:

$x_o = 0, v_{ox} = 30\frac{m}{s}, a_x = -9.8\sin 10°\ m/s^2$

$v_{fx} = 0\ m/s, x_f = ?$

Using the kinematic equations for motion with constant acceleration:

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

$$0 = (30\ m/s)^2 + 2(-9.8\sin 10°\ m/s^2)(x_f - x_o)$$

$$\frac{(30\ m/s)^2}{2(9.8\sin 10°\ m/s^2)} = x_f$$

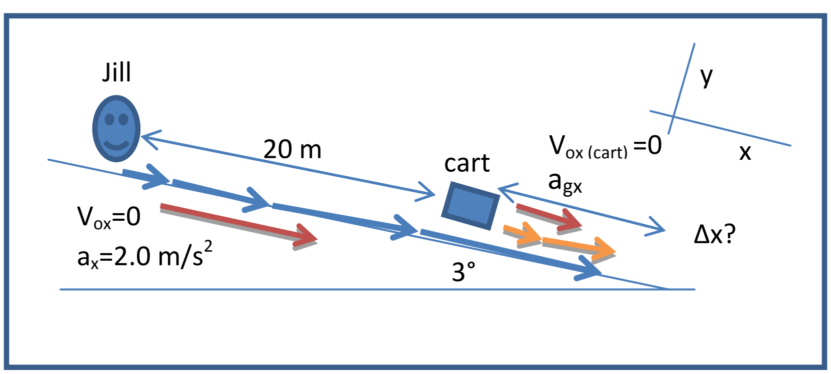
$$x_f = 264.43\ m$$

$$x_f = 2.6 \times 10^2\ m$$

Q4: #67

Jill has just gotten out of her car in the grocery store parking lot. The parking lot is on a hill and is tilted at 3°. Twenty meters downhill from Jill, a little old lady lets go of a fully loaded shopping cart. The cart, with frictionless wheels, starts to roll straight downhill. Jill immediately starts to sprint after the cart with her top acceleration of 2.0 m/s^2. How far has the cart rolled before Jill catches it?

First, draw your motion diagram with an appropriate co-ordinate axis:



We know that the change in time Δt will be the same for the cart rolling to its final position where Jill will catch up with it.

Let's look at what is known for Jill:

$v_{ox(Jill)} = 0\ m/s, x_{o(Jill)} = 0, y_o = y_f = 0\ m, a_x = 2.0\ m/s^2, x_{f(Jill)} = 20 + \Delta x$

We know that the distance the cart moves is in the chosen x direction. Using the kinematic equations for constant acceleration in our x direction:

$$x_{f(Jill)} = x_{o(Jill)} + v_{ox(Jill)}(\Delta t) + \frac{1}{2}a_x(\Delta t)^2$$

$$x_{f(Jill)} - x_{o(Jill)} = \frac{1}{2}a_x(\Delta t)^2$$

$$\frac{2 \times (20 + \Delta x)m}{2.0\ m/s^2} = (\Delta t)^2$$

We still have two unknowns: Δx and Δt.

So we employ the same tactics to the cart:

$v_{ox(cart)} = 0\ m/s, x_o = 0\ m, y_o = y_f = 0\ m, a_{xg} = 9.8 \times \cos 87°\ m/s^2, x_{f(cart)} = \Delta x$

$$x_{f(cart)} = x_{o(cart)} + v_{ox(cart)}(\Delta t) + \frac{1}{2}a_{xg}(\Delta t)^2$$

$$x_{f(cart)} - x_{o(cart)} = \frac{1}{2}a_{xg}(\Delta t)^2$$

$$\frac{2 \times (0 + \Delta x)m}{0.513\ m/s^2} = (\Delta t)^2$$

You should notice that you will have two equations and two unknowns.

$$\frac{2 \times (20 + \Delta x)m}{2.0\ m/s^2} = (\Delta t)^2 = \frac{2 \times (0 + \Delta x)m}{0.513\ m/s^2}$$

Rearranging to find Δx:

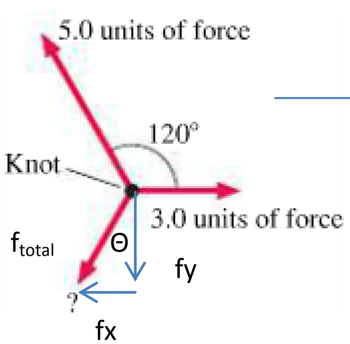
$$20 = \left(\frac{2}{0.513} - 1\right)(\Delta x)$$

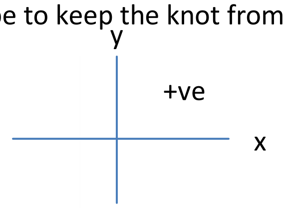
$$\Delta x = 6.9\ m$$

Chapter 3

Q5: #42

The figure shows three ropes tied together in a knot. One of your friends pulls on a rope with 3.0 units of force and another pulls on a second rope with 5.0 units of force. How hard and in what direction must you pull on the third rope to keep the knot from moving?





For this type of question we are looking at equilibrium equations. We do not want the knot to move and so the sum of forces in the x and y directions must equal zero.

Sum in x:

$$\sum F_x = 0 = 3 - f_x - 5.0\cos 60°$$

$$f_x = 3 - 5.0\cos 60° = 0.5\ units\ of\ force$$

Sum in y:

$$\sum F_y = 0 = -f_y + 5.0\sin 60°$$

$$f_y = 5.0\sin 60° = 4.33\ units\ of\ force$$

Total force magnitude:

$$f_{total} = \sqrt{f_x^2 + f_y^2} = \sqrt{(0.5)^2 + (4.33)^2} = 4.4\ units\ of\ force$$

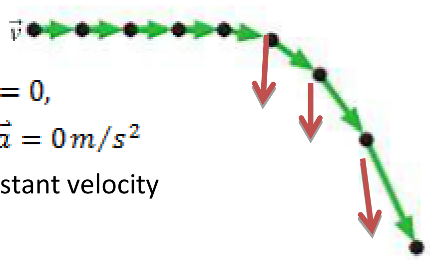
And direction:

$$\tan\theta = \frac{0.5}{4.33}, \theta = 6.59°, \therefore angle\ from\ x\ axis\ is: (90 + 6.59)° = -96°$$

Chapter 4

Q6: #2

The figure shows a partial motion diagram. Complete the motion diagram by adding acceleration vectors. Write a physics problem for which this is the correct diagram.



$\Delta v = 0,$

$\therefore\ \vec{a} = 0\,m/s^2$

constant velocity

$\vec{a}$ around the corner has a tangential (increase in speed) and a perpendicular component (change in direction) total vector direction shown here

$\vec{a}$ is +ve – velocity is increasing

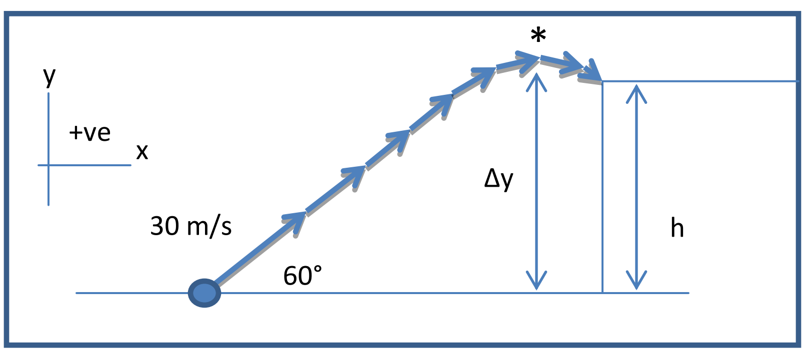
The physics problem could involve a car driving at a constant velocity until if falls off of a cliff – which where it would accelerate downward and be changing direction.

Q7: #44

A ball is thrown toward a cliff of height h with a speed of 30 m/s and an angle of 60° above horizontal. It lands on the edge of the cliff 4.0 s later.

a. How high is the cliff?
b. What was the maximum height of the ball?
c. What is the ball's impact speed?

This is a projectile motion question. Again, first draw your diagram.



Known:

$y_o = 0\,m,\ \ y_f = h\,m, \Delta t = 4.0s, a_y = -9.8\ m/s^2, v_{0y} = 30\sin 60°\ m/s,$

We can find the height of the cliff by using our kinematic equations:

$$y_f = y_o + v_{oy}(\Delta t) + \frac{1}{2}a_y(\Delta t)^2$$

$$y_f - y_o = h = v_{oy}(\Delta t) + \frac{1}{2}a_y(\Delta t)^2$$

$$h = 30\sin 60°\ m/s\,(4.0\ s) - \frac{1}{2}(9.8\ m/s^2)(4.0\ s)^2 = 25.52\ m = 2.5\times 10^1\ m$$

Now we can find the maximum height of the ball:

$$v_{*y}{}^2 = v_{oy}{}^2 + 2a_y(\Delta y)$$

$$0 = (30\sin 60^\circ\ m/s)^2 + 2\left(9.8\frac{m}{s^2}\right)(\Delta y)$$

$$\Delta \text{y} = 34.44 = 3.4 \times 10^1\ m$$

To solve for the impact speed, we already know the velocity in x (since it doesn't change), so we just find the final velocity in y.

$$v_{fy} = v_{0y} + a_y(\Delta t)$$

$$v_{fy} = 30\sin 60^\circ\ m/s - 9.8\ m/s^2\,(4.0\,s) = -13.23\ m/s\ (downward)$$

So the total velocity:

$$v_f = \sqrt{v_{fy}^2 + v_{fx}^2} = \sqrt{(13.23)^2 + (30\cos 60^\circ)^2} = 20.00 = 2.0\ \times 10^1\, m/s$$

At an angle of:

$$\tan\theta = \frac{v_{fy}}{v_{fx}} = \frac{-13.23}{15}$$

$$\therefore\ \theta = 41.41^\circ = -4.1 \times 10^{1\circ}\ from\,the\ horizontal$$

Q8: #58

A typical laboratory centrifuge rotates at 4000rpm. Test tubes have to be placed into a centrifuge very carefully because of the very large accelerations.

a. What is the acceleration at the end of a test tube that is 10 cm from the axis of rotation?
b. For comparison, what is the magnitude of the acceleration a test tube would experience if dropped from a height of 1.0m and stopped in a 1.0-ms-long encounter with a hard floor?

For part (a). First let's convert our angular velocity of 4000 rpm to rad/s.

$$\omega = 4000\,\frac{1\,rev}{1\,min} \times \frac{2\pi\,rad}{1\,rev} \times \frac{1\,min}{60\,s} = 418.88\,rad/s$$

If we assume the test tube length is small, then we can use our equation for centripetal acceleration (since we have uniform angular velocity):

$$a = \omega^2 r = (418.88\,rad/s)^2(0.10\,m) = 17{,}545.96 = 1.7 \times 10^4\,m/s^2$$

Now for part (b). We need to find the velocity of the test tube just as it hits the floor.

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

$$v_{fy}{}^2 = 0 + 2\left(9.8\frac{m}{s^2}\right)(1.0\,m)$$

$$v_{fy} = 4.43\ m/s$$

This is our initial velocity for the time it takes to decelerate and stop completely on the ground. Giving us the deceleration as it slides along the floor to be:

$$a = \frac{\Delta v}{\Delta t} = \frac{v_f - v_i}{0.001\,s} = \frac{0 - 4.43\,m/s}{0.001\,s} = -4{,}430 = -4.4\ \times 10^3\,m/s^2$$