Name: ______________________________

You may answer the questions in the space provided here, or if you prefer, on your own notebook paper.

Short Problems

$$
\begin{aligned}
v_f &= v_i + at \\
x_f &= x_i + \frac{1}{2}\left(v_i + v_f\right)t \\
x_f &= x_i + v_i t + \frac{1}{2}at^2 \\
v_f^2 &= v_i^2 + 2a\left(x_f - x_i\right) \\
\sum F &= ma
\end{aligned}
$$

Multiple choice

1. $\boxed{\text{1 point}}$ Which of the following is *not* in the metric system?

   ○ Liters √ **Inches** ○ Seconds ○ Kelvin

2. $\boxed{\text{1 point}}$ How many centimeters are in one meter?

   ○ 0.01 ○ 0.1 ○ 10 √ **100** ○ 1000

3. $\boxed{\text{1 point}}$ Which of the following is not a vector?

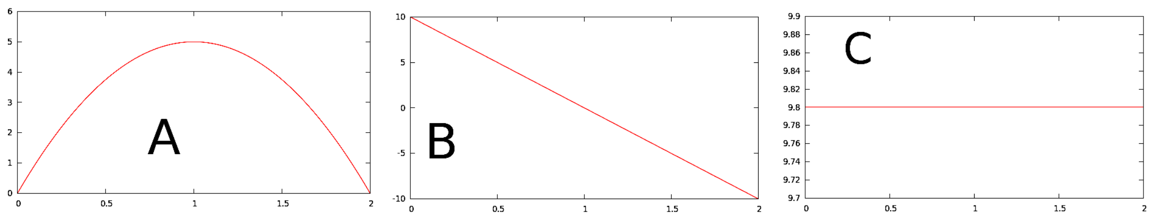
   √ **Temperature** ○ Velocity ○ $300\hat{\imath} + 20\hat{\jmath}$ ○ Gravitational force

4. $\boxed{\text{1 point}}$ Suppose I were driving on a round trip to Wilmington Delaware and back. I travel 30 miles to Wilmington in 0.5 hours, and then I travel back in 1 hour (bad traffic). Assume that I travel on i95, which unlike I-95, travels in a straight line from Philadelphia to Wilmington. What is my average **speed?**

   ○ -30 miles per hour ○ 0 miles per hour ○ 30 miles per hour √ **40**

miles per hour

5. $\boxed{\text{1 point}}$ Which of the following correctly identifies the following graphs of a balling being thrown directly upwards:



√ **A: Position; B: Velocity; C: Acceleration** ◯ A: Velocity; B: Position; C: Acceleration
◯ A: Position; B: Acceleration; C: Velocity ◯ A: Acceleration; B: Velocity; C: Position

6. $\boxed{\text{1 point}}$ Which of Newton's Laws discuss equal and opposite forces?

◯ Newton's First Law √ **Newton's Third Law** ◯ Newton's Second Law

7. $\boxed{\text{1 point}}$ If the net forces acting on an object is equal to zero, then

◯ The object is at rest ◯ There is no friction √ **There is no acceleration**

8. $\boxed{\text{1 point}}$ When we talk about friction forces, we know that

◯ $\mu_s < \mu_k$ ◯ $\mu_s = \mu_k$ √ $\mu_s > \mu_k$

9. $\boxed{\text{1 point}}$ A fictitious force is a force which

√ **Appears to act when $\sum F = 0$.** ◯ Can't be measured ◯ Is seen in inertial frames

10. $\boxed{\text{1 point}}$ In an inertial frame of reference,

◯ there are fictitious force √ $\sum F = 0$ **implies no acceleration** ◯ acceleration is zero

11. $\boxed{\text{1 point}}$ Normal forces

√ **act perpendicular to the surface of contact** ◯ act in the same direction as gravity

12. $\boxed{\text{1 point}}$ Suppose you are standing on a scale to weight yourself on an elevator accelerating upwards. A scale measures your normal force. You will appear to

◯ weigh less √ **weigh more** ◯ weigh the same

13. $\boxed{\text{1 point}}$ On and off ramps for major highways are banked at an angle. This is to counterbalance

◯ Normal Force ◯ Gravitational Force √ **Centripetal Force**

14. $\boxed{\text{1 point}}$ Parachutes are used in order for sky jumpers to have a slower

√ **Terminal Velocity** ◯ Drag Coefficient ◯ Inertial Frame

Conversions

1. $\boxed{\text{5 points}}$ Water is being pumped out of a pool at **32 liters per second**. How many **gallons per minute** will this be?

1 L = 0.2642 gal

Solution:

We begin by converting liters to gallons:

$$\frac{32\cancel{L}}{\text{s}}\left(\frac{0.2642\text{ gal}}{1\cancel{L}}\right) = \frac{8.45\text{ gal}}{\text{s}}$$

Take a few digits, we won't worry about sig figs here, though technically we should only have two. Next convert hours to minutes.

$$\frac{8.45\text{ gal}}{\cancel{s}}\left(\frac{60\cancel{s}}{\text{minute}}\right) = \frac{507.28\text{ gal}}{\text{minute}}$$

Notice that the the conversion fraction is always selected so as to cancel out that unit that we are converting **from**. Your answers may vary depending on rounding, but please don't worry about this. Introductory physics is about ball-park figures.

How many **gallons per hour** will this be?

Solution: *This is one step further,*

$$\frac{507.28 \text{ gal}}{\cancel{\text{minute}}}\left(\frac{60 \cancel{\text{ minute}}}{\text{hour}}\right) = \frac{30{,}435.84 \text{ gal}}{\text{hour}}$$

Bonus question: If we originally have **73239 gallons** of water, in how many seconds will the water be gone?

Solution: *If we are pumping at* 8.45*gallons per second, and we start with 73239 gallons, then we will run out of water at,*

$$\frac{73239 \cancel{\text{ gal}}}{\frac{8.45 \cancel{\text{ gal}}}{\text{s}}} = 8{,}662.9 \text{ sec}$$

2. $\boxed{\text{1 point}}$ How many milligrams are in one kilogram?

Solution: There are 1000 mg in 1 g, and 1000 g in 1 kg, so there are 1,000,000 mg in 1 kg.

3. $\boxed{\text{1 point}}$ How many meters are in one 35.25 kilometers?

Solution: There are 1000 m in 1 km, so there are 35,250 meters in 35.25 kilometers.

4. $\boxed{\text{5 points}}$ It takes two hours to fill a 252.0 gallon gasoline tank. What is the rate it is being filled in cubic meters per seconds? (Given: 1 m^3 = 264.172 gal).

Solution:

$$\frac{250 \cancel{\text{ gal}}}{2 \text{ hour}}\left(\frac{1\ m^3}{264.172 \cancel{\text{ gal}}}\right) = \frac{0.47\ m^3}{\text{hour}}$$

$$\frac{0.47\ m^3}{\cancel{\text{hour}}}\left(\frac{\cancel{\text{hour}}}{3600 \text{ s}}\right) = \frac{1.31 \cdot 10^{-4}\ m^3}{\text{sec}}$$

Motion in One Dimension

Kinematic Equations for Motion of a Particle Under Constant Acceleration

$$
\begin{aligned}
v_f &= v_i + a_x t \\
x_f &= x_i + \frac{1}{2}(v_i + v_f)t \\
x_f &= x_i + v_i t + \frac{1}{2}at^2 \\
v_f^2 &= v_i^2 + 2a(x_f - x_i)
\end{aligned}
$$

Bonus: Equation for particle with no acceleration but constant velocity

$$x_f = x_i + vt \tag{0.1}$$

Extra equation:

$$x = \frac{-b \pm \sqrt{b^2 - 4ac}}{2a}$$

1. 20 points Two race cars are racing towards the finish line along a straight track. Red car is traveling at a constant velocity of 125 m/s. Blue car is ahead of Red car, but is having motor trouble and is slowing down. When the cars pass each other, Blue car has a velocity of 110 m/s and is slowing at a rate of -2 m/s^2. The Red car makes it to the finish line in 10 seconds. How long will it take for the Blue car to make it to the finish line?

Solution: *The problem starts when the cars pass each other, so then this is when $t = 0$. We can also set that point as being our initial starting position, $x_i = 0$. We begin with writing the kinematic equation for position for the car without acceleration. The cars are heading along a straight line, so call that the x direction. The position of this red car will be written as x and is given by $x_f = x_i + vt$.*

Next, we want to write the equation for the position of the blue. Since the blue car is under acceleration, we select the kinematic equation for position that involves acceleration. To differentiate the two equations, we will write the blue car's equation with an X, V, and T: $X_f = X_i + VT + \frac{1}{2}AT^2$.

So what do we know?

Red car: **Blue Car:**

$$\begin{aligned} x_i &= 0 \text{ m} \\ x_f &= \ ?\text{ m} \\ v &= \frac{125 \text{ m}}{\text{s}} \\ t &= 10 \\ a &= 0 \end{aligned} \qquad \begin{aligned} X_i &= 0 \text{ m} \\ X_f &= \ ?\text{ m} \\ V_i &= \frac{110 \text{ m}}{\text{s}} \\ t &= \ ? \\ A &= \frac{-2 \text{ m}}{\text{s}^2} \end{aligned}$$

We can first solve for how far away the finish line is when the cars just pass each other:

$$x_f = 0 + \left(125\frac{\text{m}}{\text{s}}\right) 10 \text{ s} = 1250.0 \text{ m}$$

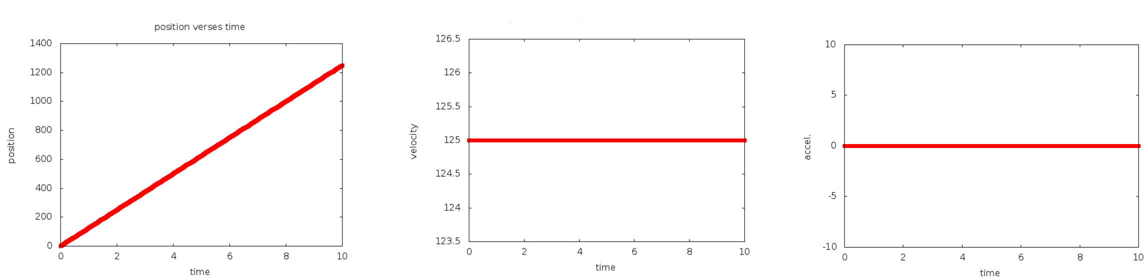
This will also be X_f since they are heading towards the same finish line:

$$1250.0 \text{ m} = 0 + \left(110\frac{\text{m}}{\text{s}}\right) t + \frac{1}{2}\left(-2\frac{\text{m}}{\text{s}^2}\right) t^2$$

To solve the quadratic we used the quadratic formula. The solutiosn for t are 12.86925 s and 97.13074 s. One solution corresponds to the car passing the finish line (the smaller solution) and the other corresponds to the car passing the finish line, continuing to accelerate backwards until eventually it is reversing back to the finish line. The smaller number is the realistic one.

2. $\boxed{\text{3 points}}$ Sketch the position, velocity, and acceleration graph (verses time) for the Red car in the previous problem.

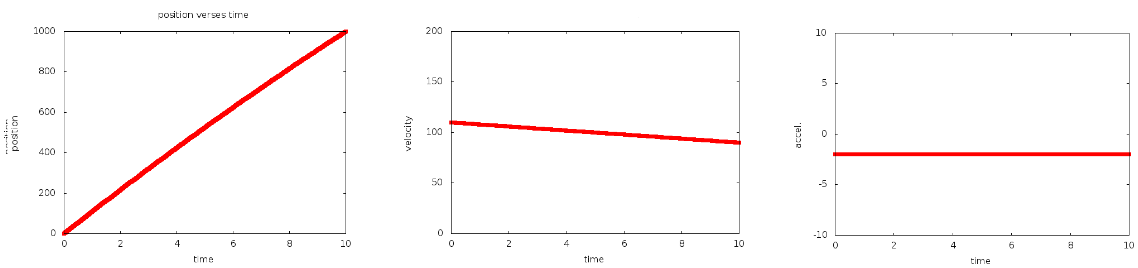
Solution:



3. $\boxed{\text{3 points}}$ Sketch the position, velocity, and acceleration graph (verses time) for the Blue

car in the previous problem.

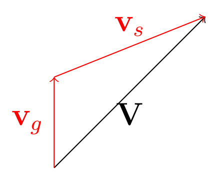
Solution: *Since the acceleration is constant, it should be a straight line. The kinematic equation for velocity under constant acceleration is linear, and the kinematic equation for position under the condition of constant acceleration is quadratic (parabola shape).*



Motion in Two Dimensions

The kinematic equations from the previous page will be useful on some of these problems.

1. $\boxed{\text{10 points}}$ A ship is traveling in a calm sea 23 miles per hour at 17 ° North of East with a constant velocity when it suddenly hits the Gulf Stream which is an area in the ocean where the water flows rapidly in one direction. The stream is directed Northward at 5.6 miles per hour. Ignoring drag, what is the new velocity of the ship? Please put your answer in vector notation (example: $v = 100$ mph $\hat{i} + 200$ mph $\hat{j}$, 223.6 mph, 63° North of East.).



Solution:

This is an idealized problem in which we assume that the additional speed of the Gulf Stream adds directly to the speed of the ship. We write the initial speed of the ship as:

$$\mathbf{v_s} = 23 \text{ mph } \cos(17°)\hat{\mathbf{i}} + 23 \text{ mph } \sin(17°)\hat{\mathbf{j}} = 22 \text{ mph } \hat{\mathbf{i}} + 6.7 \text{ mph } \hat{\mathbf{j}}$$

We can write the Gulf Stream velocity as $\mathbf{v_g} = 0$ mph $\hat{\mathbf{i}} + 5.6$ mph $\hat{\mathbf{j}}$, *so that the net resulting velocity is:*

$$\mathbf{V} = \mathbf{v_s} + \mathbf{v_g} = 22 \text{ mph } \hat{\mathbf{i}} + 12.3 \text{ mph } \hat{\mathbf{j}}$$

2. $\boxed{\text{10 points}}$ Regarding the previous problem, the ship wants to get back on course with the same speed as before it hit the Gulf Stream. What change in speed should the captain order? Hint: What is the vector difference between its original speed and its speed after passing into the Gulf Stream? Your can answer this in $\hat{i} + \hat{j}$ notation.

Solution: *The ship should increase speed in the opposite direction of the Gulf Stream with the same magnitude as the Gulf Stream: 5.6 mph south, or* -5.6 mph $\hat{\mathbf{j}}$.

3. $\boxed{\text{10 points}}$ NASA has lost contact with a flying drone. The drone is flying along a straight line at 113.101 meters per second, holding at a constant altitude of 6096 meters. NASA positions a cannon to shoot it down. The drone passes over the cannon at the same instance the cannon is fired. If the cannon's projectile hits the drone 30 seconds later, how far has the drone traveled in the horizontal direction?

> **Solution:** *The drone is traveling in a straight line at a constant velocity so that its position will be described by the equation:*
>
> $$x_f = x_i + v_i t = 0 + \frac{113.101 \text{ m}}{\text{s}} 30\text{s} = 3393.02994 \text{ m}$$
>
> *Where we have taken x_i to be zero at the instant the cannon is fired (overhead of the cannon).*

4. $\boxed{\text{25 points}}$ Find the velocity and angle combination for the cannon that would enable the projectile from the previous problem to hit the flying drone? Use all of the information from the previous problem and the kinematic equations. The acceleration due to gravity is $-9.8 m/s^2$. Ignore air drag and assume that the projectile starts at position $x_i = 0$, $y_i = 0$.

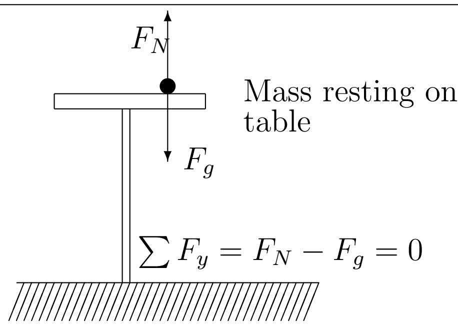
> **Solution:** *Since there is no acceleration of the projectile or drone in the x horizontal direction, and since the cannon launches at the same time as the drone is overhead, we can assume that for the projectile, $v_x = 113.101$ meters per second–the same speed as the drone in the x direction. You could also have solved this just by using the right kinematic equation and knowing that the final distance in the horizontal direction will be how far the drone traveled before it was destroyed, 3393.03 meters from the previous problem.*
>
> *For the y direction, we will use the equation:*
>
> $$y_{x,f} = y_{x,i} + v_{y,i} t + \frac{1}{2} a_y t^2 = 0 + v_y (30 \text{ s}) - \frac{9.8 \text{ m/s}^2}{2} (30 \text{ s})^2$$
>
> *But we also know $y_{x,f}$, for if the projectile is to hit the drone, and the drone is 6096 meters high, then,*
>
> $$6096 \text{ m} = 0 + v_y (30 \text{ s}) - \frac{9.8 \text{ m/s}^2}{2} (30 \text{ s})^2 \implies v_{y,i} = 350.19981 \frac{\text{m}}{\text{s}}$$
>
> *The initial velocity is:*
>
> $$v = \sqrt{v_x^2 + v_{y,i}^2} = 367.98 \frac{\text{m}}{\text{s}}$$
>
> *at an angle of:*
>
> $$\tan^{-1}\left(\frac{v_{y,i}}{v_x}\right) = 72.1^\circ$$

Free Body Diagrams

For each of the objects below, draw corresponding free body diagrams, label all forces, and write the corresponding net force equation(s).

1. 5 points A ball resting on a table.

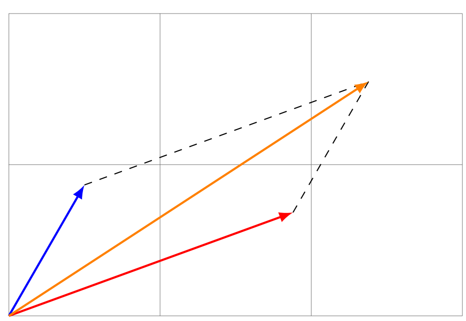
Solution:



$\sum F_y = F_N - F_g = 0$

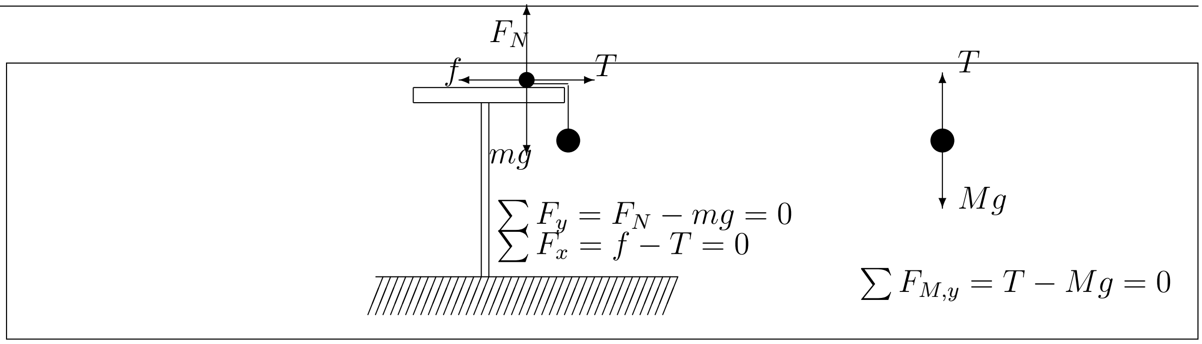
2. 5 points A hockey puck is struck with a force of one Newton at 60 degrees from the x axis and two Newtons at 20 degrees from the x axis. Draw graphically (but don't find numerically) the net resulting force. You can guess what the angles 60 and 20 would be, no need for a protractor. Assume no friction.

Solution:



3. 10 points A ball of mass m on a table is connected by string to a ball of mass M hanging on the side of the table, such that the friction between the ball on the table and the table is enough to keep the system in equilibrium and at rest.

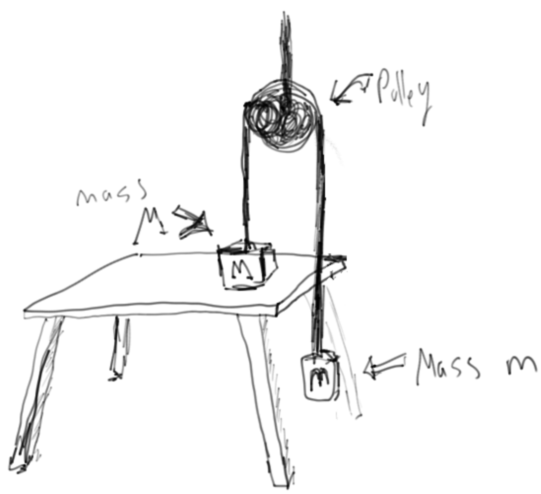
Solution:



Problems

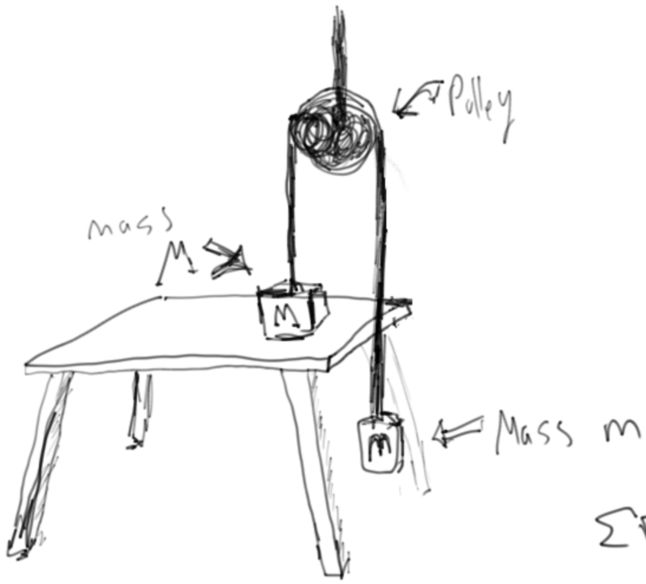
For each problem, draw corresponding free body diagrams, label all forces, and write the corresponding net force equation(s) to solve for stated unknown quantity.

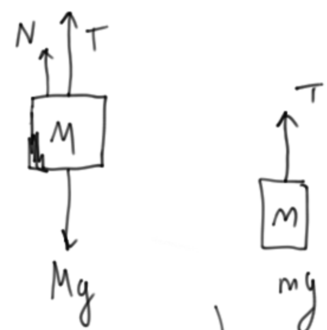
1. $\boxed{\text{15 points}}$ A weight of mass M is resting on a table and attached, via pulley, to another weight of mass m ($M > m$). The entire system is at rest. What is the normal force, as



a function of M, m, and g?

Solution:





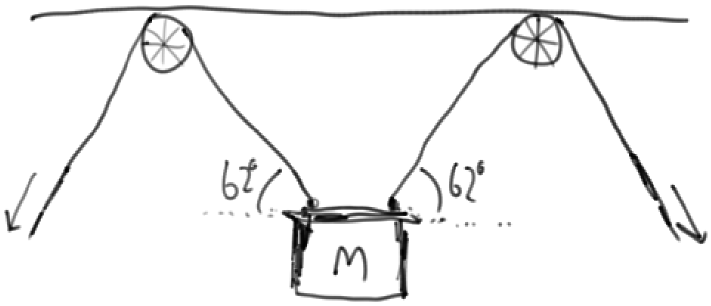
$$\sum F_{y,m} = T - mg = 0$$

$$T = mg$$

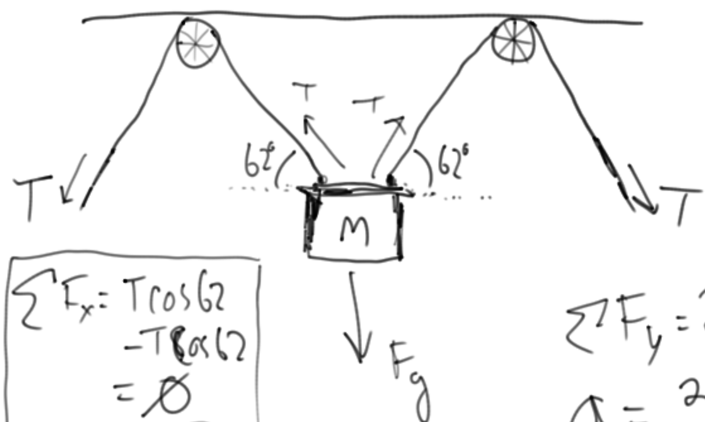
$$\sum F_{y,M} = N + T - Mg = 0$$

$$N + mg - Mg = 0 \rightarrow N = (M-m)g$$

2. $\boxed{\text{15 points}}$ A load of mass 325 kg is being lifted up by two ropes looped through a pulley. The ropes each have a tension of 2850 N, and they attach to the load at an angle of 62° (see drawing). Find the net acceleration of the load.



Solution:



$$\sum F_x = T\cos 62 - T\cos 62 = 0$$

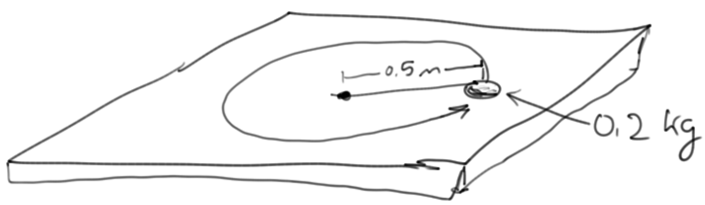
$$\sum F_y = 2(\overset{2850\,N}{T}\sin(62)) - \overset{325\,kg}{m}\overset{9.8\,m/s^2}{g} = ma$$

$$a = \frac{2T\sin(62) - mg}{m}$$

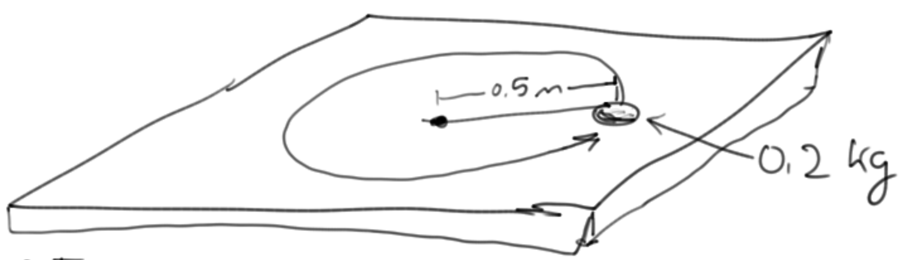
$$= 5.7\ \frac{m}{s^2}$$

3. $\boxed{\text{15 points}}$ Imagine a puck on a table with friction. The puck is attached to the center of the table by a string which is 0.5 m long. The puck has a mass of 0.2 kg and is set in motion at an initial velocity of 10 m/s, thus setting it in a circular motion. The centripetal force will result in a tension in the string. Furthermore, the table has a coefficient of kinetic friction $\mu_k = 0.2$. What is the initial tension in the string and what is the rate at which the puck will deaccelerate due to friction as it loops around the circular path? Recall from lecture that the centripetal force is

$$F_c = \frac{mv^2}{R}$$

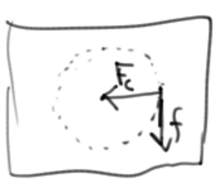


Solution:



$F_N - mg = 0$

$F_N = mg = 0.2\,kg\,(9.8\,m/s^2) = 1.96\,N$



$\leftarrow f = \mu F_N = 0.2\,(1.96N) = 0.392\,N = ma = 0.2kg\,a$

$a = 1.96\,m/s^2$

$V_i = 10\,m/s \longrightarrow F_{c,i} = \frac{mv^2}{R} = 40N$