Workbook for College Physics

Volume One
Classical Mechanics

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by

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ASSIGNMENT ONE

PROBLEMS FOR CHAPTERS ONE THROUGH EIGHT

Problems for Chapter 1

1.) One *inch* is defined as exactly 2.54 *centimeters*. Use that definition in doing the following:

a) The average distance from the Earth to the Sun is called an astronomical unit. The measured value of the astronomical unit is given by

$$1\ AU \equiv 1.49597870691 \times 10^{11}\,m \pm 30\ m\ .$$

Express this value in terms of the *mile*.

b) Our best measurement of the Earth's equatorial radius is

$$R_{\oplus} = 6.378135 \times 10^{6}\,m \pm 5\ m\ .$$

Express this value in terms of the *mile*.

c) The accepted value of the speed of light in vacuum is

$$c = 2.99792458 \times 10^{8}\,m\,/\,s\ (exact)\ .$$

Express this value in terms of *miles per hour*.

2.) In the English system, one *slug* is defined as 14.5939 *kilograms*. Use this definition in doing the following:

a) The mass of the Earth is measured to be

$$M_{\oplus} = 5.9736 \times 10^{24}\, kg\ .$$

Express this value in terms of the *slug*.

b) The ratio of the mass of a proton to a neutron is given by

$$\frac{m_p}{m_n} = \frac{1.672621637 \times 10^{-27}\, kg}{1.674927211 \times 10^{-27}\, kg} = 0.99862\ .$$

Express this ratio in terms of the *slug*.

c) The mass of the electron is measured to be

$$m_{e^-} = 9.10938215 \times 10^{-31}\, kg\ .$$

Express this value in terms of the *slug*.

3.) Use the speed of light in vacuum, given above, to do the following:

a) If we model the universe as a sphere of radius $R_{univ} = ct_{univ}$, where

$$t_{univ} = 13.7 \times 10^9 \ years ,$$

then calculate the amount of time, in *seconds*, it would take a light pulse to cross the universe on a diameter.

b) We can model a star as a sphere of radius

$$R_{star} = n_s R_\odot ,$$

where $R_\odot$ is the radius of the Sun which is measured measured to be

$$R_\odot = 6.955 \times 10^8 m .$$

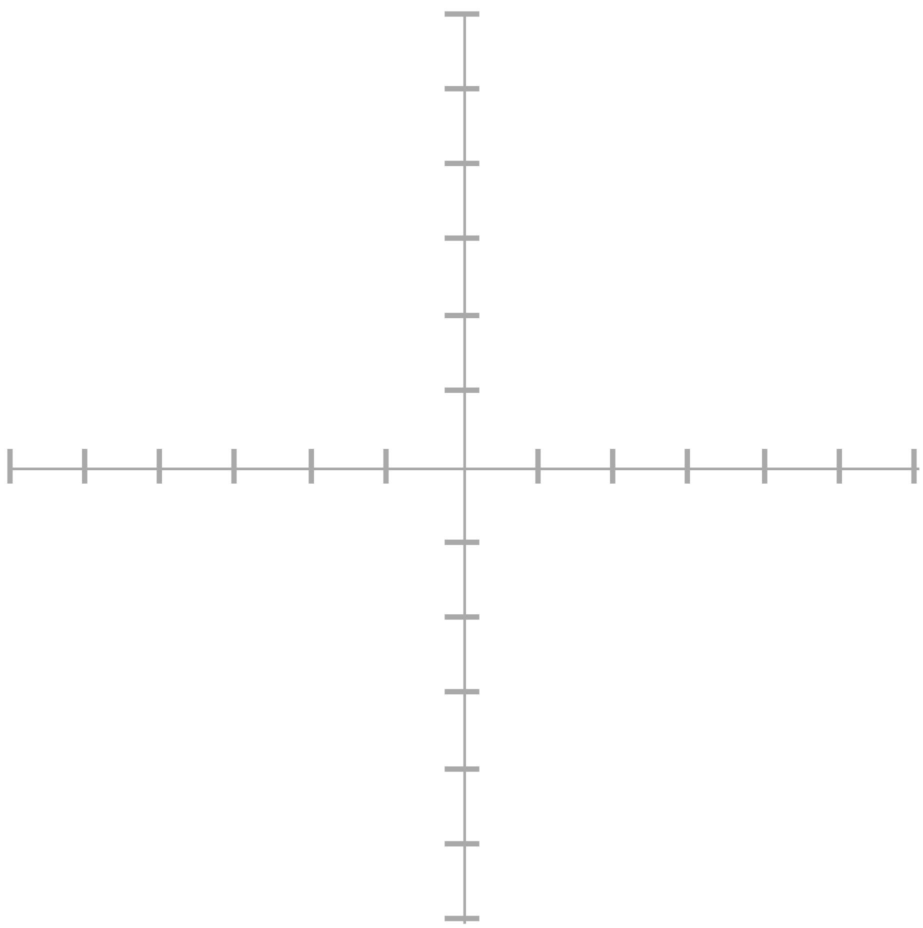
Astrophysicists theorize about the limits on the size of a star. If a star has a mass of one hundred twenty solar masses and a radius where $n_s = 100$, how much time, in *seconds*, would be required for a light signal to cross this star on a diameter.

c) If we model a proton as a sphere of radius $1.2 \times 10^{-15} m$, how much time would be needed for a light signal to cross the proton on a diameter.

Problems for Chapter 2

1.) At time t, a point mass M is observed at a position $\vec{r} = -\,4.00\ m\ \hat{i} + 6.00\ m\ \hat{j}$. Use this information to do the following:

a) Using a straight edge, draw a correct representation of the position vector given.
b) Determine the magnitude of the position vector.
c) Determine the unit vector that represents the direction of the position vector.
d) Determine the magnitude of the angles the position vector makes to each of the co-ordinate axes.



2.) At time t, a point mass M is at a position given by $\vec{r} = 6.00\,m\,\hat{\imath} - 5.00\,m\,\hat{\jmath}$. Use this information to do the following:

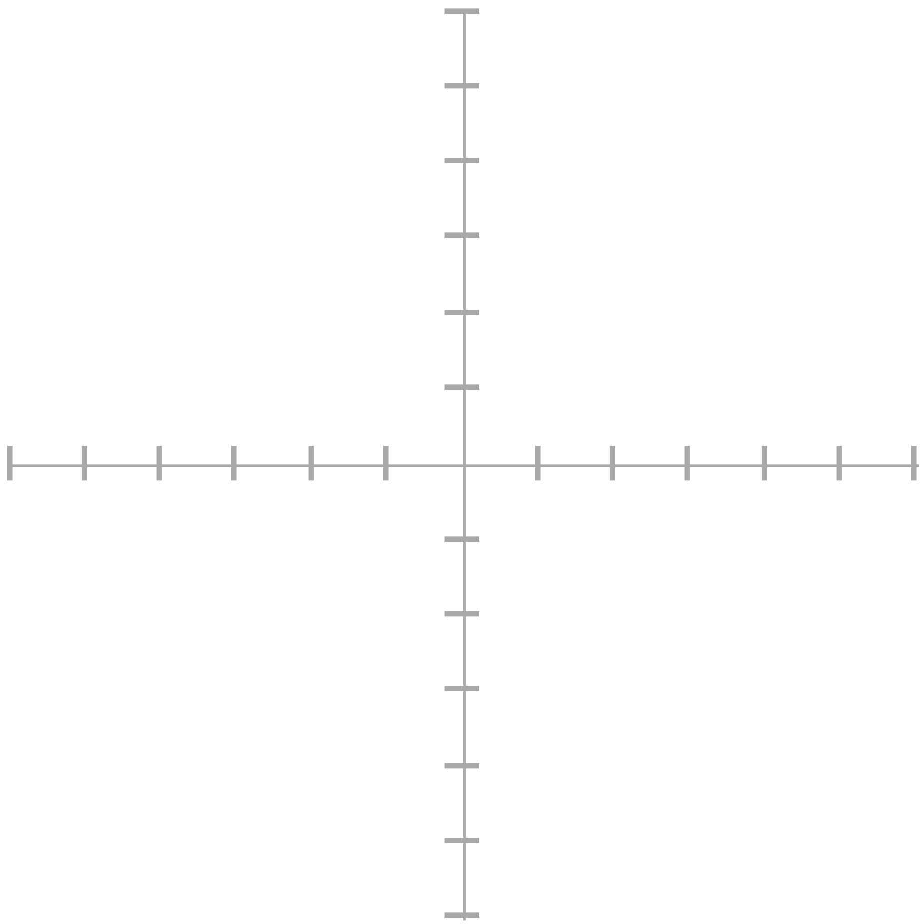
a) Using a straight edge, draw a correct representation of the position vector given.

b) Determine the magnitude r of the position vector.

c) Determine the unit vector $\hat{r}$ which represents the direction of the position vector.

d) Determine the angle θ_x that the position vector makes to the positive branch of the x-axis.

e) Determine the angle θ_y that the position vector makes to the positive branch of the y-axis.



3.) A point mass $M = 1.50\ kg$ is observed at time t_o at a position given by $\vec{r}_o = 2.00\,m\,\hat{i} + 4.00\,m\,\hat{j}$. Use this information to do the following:

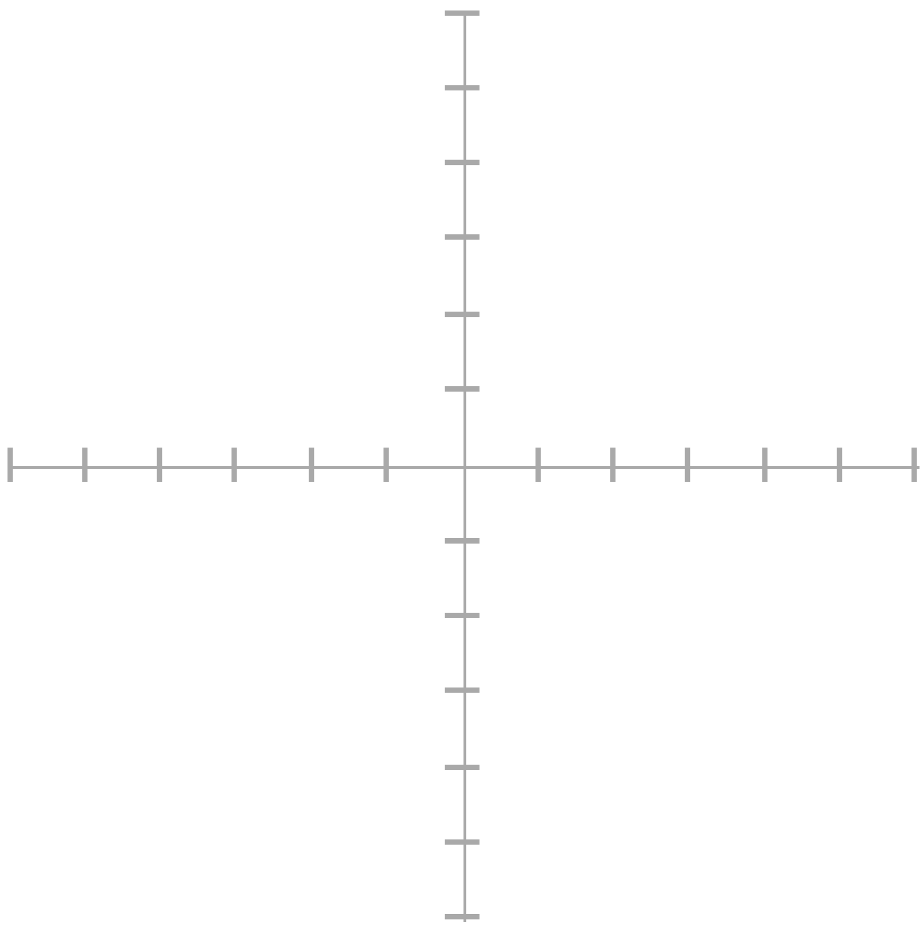
a) Using a straight edge, draw a correct representation of the position vector given.

b) Determine the magnitude, r_o , of this vector.

c) Determine the unit vector, $\hat{r}_o$, that represents the direction of this vector.

d) Determine the angle, θ_x , this vector makes to the positive branch of the x-axis.

e) Determine the angle, θ_y , this vector makes to the positive branch of the y-axis.



4.) At time $t_o = 0$, a point-like object of mass $M = 2.55\ kg$ is observed to have a position in a Cartesian coordinate system given by $\vec{\boldsymbol{r}}_o = -5\,m\ \hat{\boldsymbol{i}} - 3m\ \hat{\boldsymbol{j}}$. Use this information to find the following:

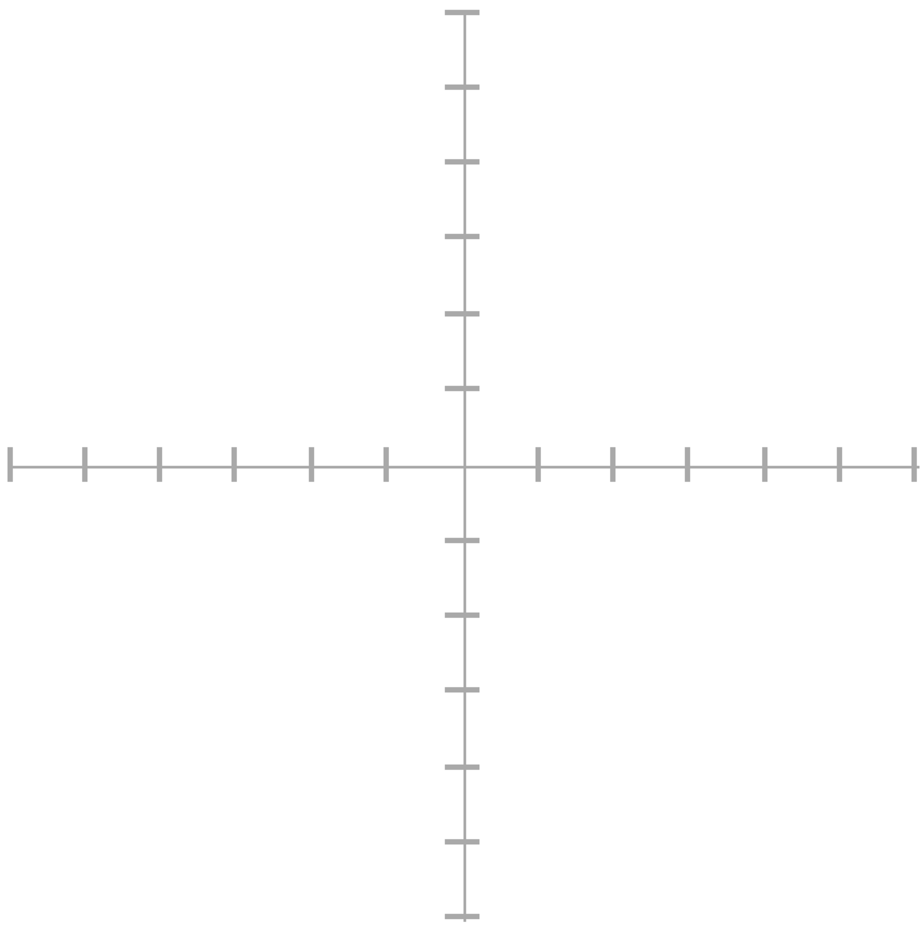
a) Using a straight edge, draw a correct representation of the position vector given.

b) The magnitude, r_o, of this position vector.

c) The unit vector, $\hat{\boldsymbol{r}}_o$, which represents the direction of this position vector.

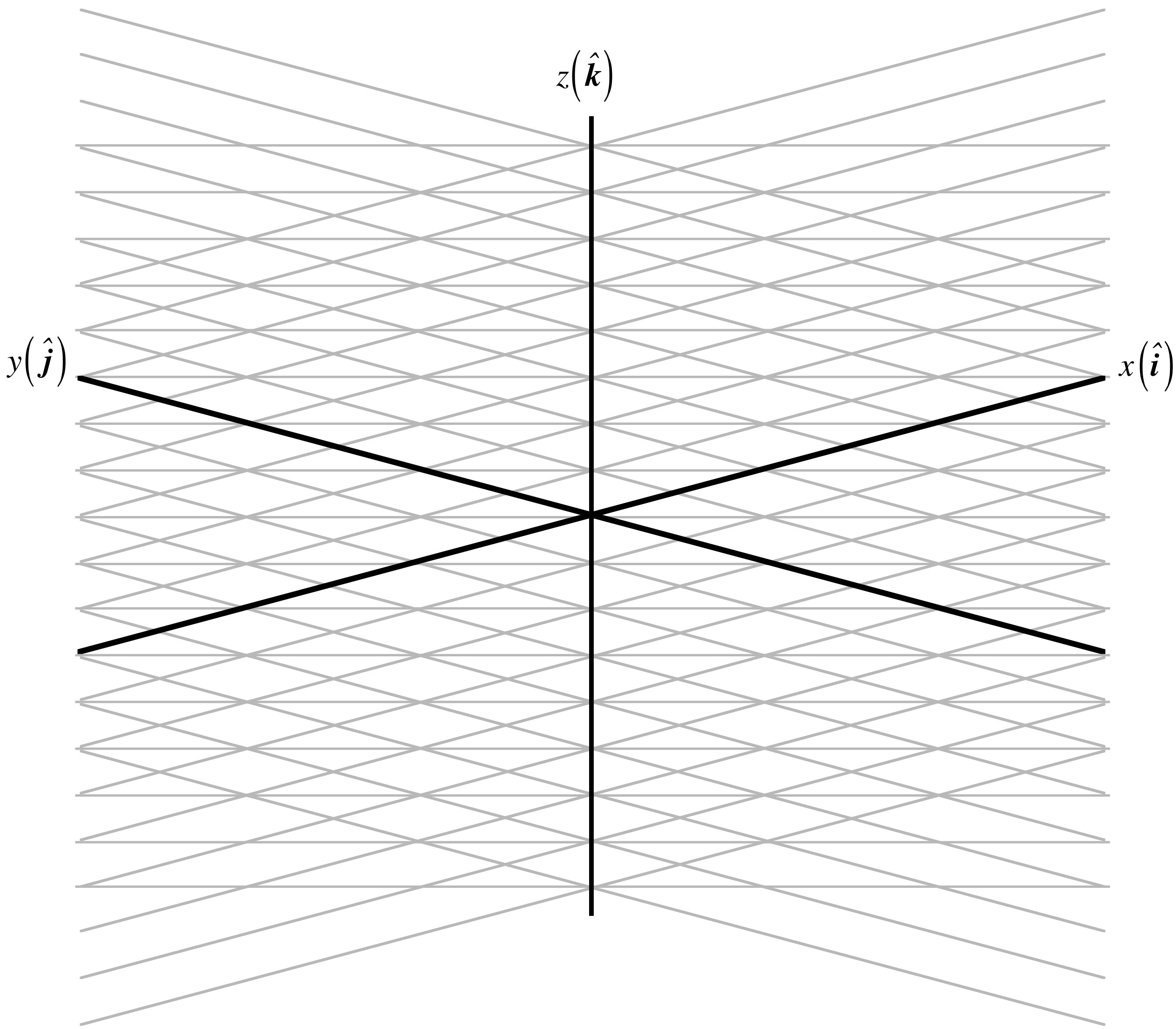
d) The angle, θ_x, between the vector $\vec{\boldsymbol{r}}_o$ and the positive branch of the x-axis.

e) The angle, θ_y, between the vector $\vec{\boldsymbol{r}}_o$ and the positive branch of the y-axis.



5.) A point-like physical thing of mass $M = 1.00\,kg$ is observed at a position given by $\vec{\boldsymbol{r}} = r\,\hat{\boldsymbol{r}} = 3m\ \hat{\boldsymbol{i}} - 2m\ \hat{\boldsymbol{j}} + 6m\ \hat{\boldsymbol{k}}$. Use this information, and do the following:

a) Using a straight edge, draw a correct representation of the position vectors $\vec{\boldsymbol{r}}$.
b) The magnitude, r , of the position vector.
c) The unit vector, $\hat{\boldsymbol{r}}$, that represents the direction of the position .
d) The angle, θ_x, the position vector makes with the positive branch of the x-axis.
e) The angle, θ_y, the position vector makes with the positive branch of the y-axis.
f) The angle, θ_z , the position vector makes with the positive branch of the z-axis.



Problems for Chapter 3

1.) A point-like physical thing of mass $M = 3.00\,kg$ is initially observed to be a distance $r = 7.50\ m$ from the origin of a Cartesian coordinate system. The vector that represents this position lies in the x-y plane and makes an angle of $\theta = 125.00°$ in a counterclockwise sense to the positive branch of the x-axis. Use this information to do the following:

a) Using a protractor and a straight edge, draw an appropriate coordinate system and a vector to represent this position. Also, draw the x and y components of the vector.

b) Determine the magnitude and the direction of the x-component of this position vector.

c) Determine the magnitude and the direction of the y-component of this position vector.

2.) A point-like physical thing of mass $M = 2.50\ kg$ is initially observed to be a distance $r = 9.75\ m$ from the origin of a Cartesian coordinate system. The vector that represents this position lies in the x-y plane and makes an angle of $\theta = 145.00°$ in a clockwise sense to the positive branch of the x-axis. Use this information to do the following:

a) Using a protractor and a straight edge, draw an appropriate coordinate system and a vector to represent this position. Also, draw the x and y components of the vector.

b) Determine the magnitude and the direction of the x-component of this position vector.

c) Determine the magnitude and the direction of the y-component of this position vector.

3.) A point-like physical thing of mass $M = 8.25\ kg$ is initially observed to be a distance $r = 15.25\ m$ from the origin of a Cartesian coordinate system. The vector that represents this position lies in the x-y plane and makes an angle of $\theta = 57.00°$ in a counterclockwise sense to the positive branch of the x-axis. Use this information to do the following:

a) Using a protractor and a straight edge, draw an appropriate coordinate system and a vector to represent this position. Also, draw the x and y components of the vector.

b) Determine the magnitude and the direction of the x-component of this position vector.

c) Determine the magnitude and the direction of the y-component of this position vector.

4.) A point-like physical thing of mass $M = 5.65\ kg$ is initially observed to be a distance $r = 7.50\ m$ from the origin of a Cartesian coordinate system. The vector that represents this position lies in the x-y plane and makes an angle of $\theta = 37.00°$ in a clockwise sense to the positive branch of the x-axis. Use this information to do the following:

a) Using a protractor and a straight edge, draw an appropriate coordinate system and a vector to represent this position. Also, draw the x and y components of the vector.

b) Determine the magnitude and the direction of the x-component of this position vector.

c) Determine the magnitude and the direction of the y-component of this position vector.

5.) A block of mass $M = 2.25\,kg$ is moving with an instantaneous speed of $v = 15.75\ m/s$ on a level surface in a direction of $25°$ north of east. Use this information to do the following:

a) Using a protractor and a straight edge, draw an appropriate coordinate system and a vector to represent the instantaneous velocity.

b) Write a correct vector for the component of the velocity directed east.

c) Write a correct vector for the component of the velocity directed north.

6.) An auto of mass $M = 1.25 \times 10^3\ kg$ is accelerating with an instantaneous acceleration of $a = 6.25\ m/s^2$ on a level road in a direction of $35°$ south of west. Use this information to do the following:

a) Using a protractor and a straight edge, draw an appropriate coordinate system and a vector to represent the instantaneous acceleration.

b) Write a correct vector for the component of the acceleration directed west.

c) Write a correct vector for the component of the acceleration directed south.

7.) A force of magnitude $F = 378\ Newtons$ is applied to a massive object in a direction for which

$$\theta_x = 40.00°,$$
$$\theta_y = 112.00°,$$
$$\theta_z = 58.51°.$$

Use this information to do the following:

a) Using a straight edge, draw an appropriate coordinate system and a vector to represent the applied force.
b) Write a correct vector for the x-component of the applied force.
c) Write a correct vector for the y-component of the applied force.
d) Write a correct vector for the z-component of the applied force.
e) Write a correct vector for the applied force.

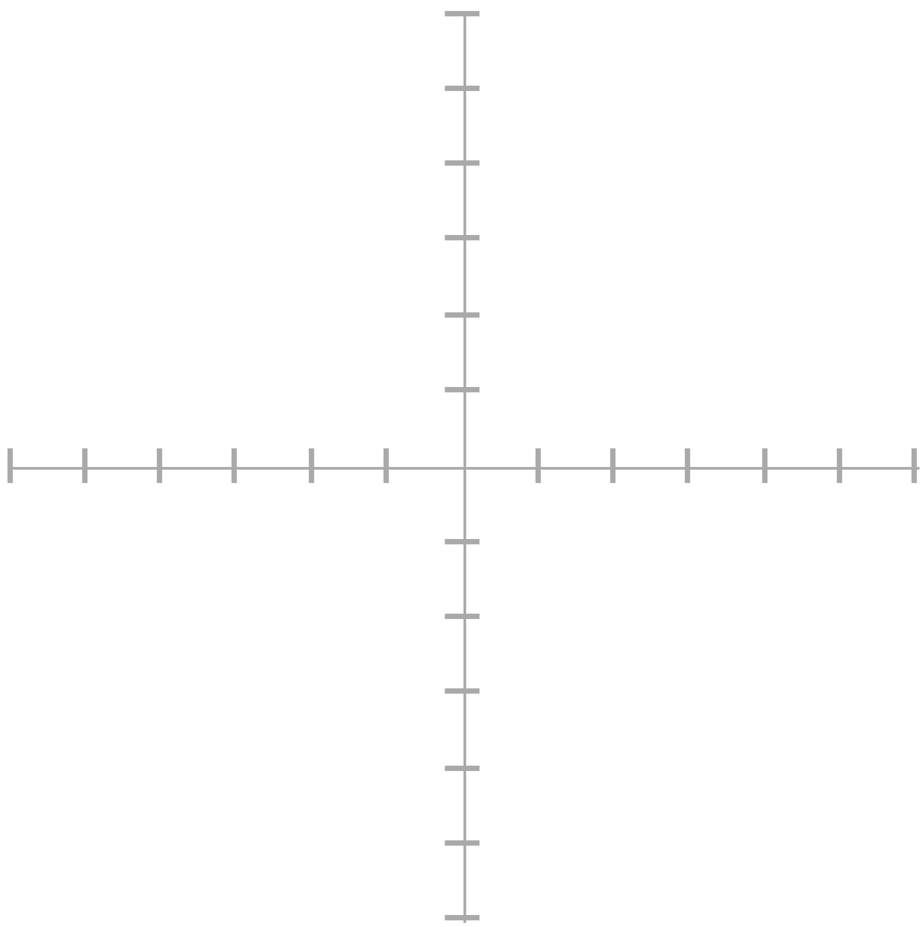
8.) An aircraft of mass $M = 7.0 \times 10^4\ kg$, is on final approach to an airport. The plane is moving from west to east, relative to the ground, with an instantaneous speed of $112\ m/s$. The plane encounters a wind blowing out of the south with a speed of $6.75\ m/s$, relative to the ground. The plane is also descending at a rate of $1.75\ m/s$. Use this information to do the following:

a) Using a straight edge, draw an appropriate coordinate system and a vector to represent the instantaneous velocity.
b) Write a correct vector for the component of the velocity directed east.
c) Write a correct vector for the component of the velocity directed north.
d) Write a correct vector for the component of the velocity directed downward.
e) Write a correct vector for the instantaneous velocity of the plane.

Problems for Chapter 4

1.) At time t_E, a point mass M is located at a point the position of which is given by $\vec{r}_E = 3.000\ m\ \hat{i} + 2.000\ m\ \hat{j}$. At time t_L, the position of the point mass is given by $\vec{r}_L = -\ 5.000\ m\ \hat{i} + 6.000\ m\ \hat{j}$. Use this information to do the following:

a) Using a straight edge, draw a pictorial representation of $\vec{r}_E$, $\vec{r}_L$, and $\Delta\vec{r}$.
b) Determine the magnitude of the change in position vector.
c) Determine the unit vector that represents the direction of the change in position vector.
d) Determine the magnitude of the angles the change in position vector makes to each of the coordinate axes.



2.) At time t_1, a point mass M is observed at a position given by $\vec{r}_1 = 5.00\,m\,\hat{\boldsymbol{i}} - 6.00\,m\,\hat{\boldsymbol{j}}$. At a later time t_2, the point mass is observed at the position $\vec{r}_2 = 2.00\,m\,\hat{\boldsymbol{i}} + 4.00\,m\,\hat{\boldsymbol{j}}$. Use this information to do the following:

a) Using a straight edge, draw a pictorial representation of $\vec{r}_1$, $\vec{r}_2$, and $\Delta\vec{r}$.

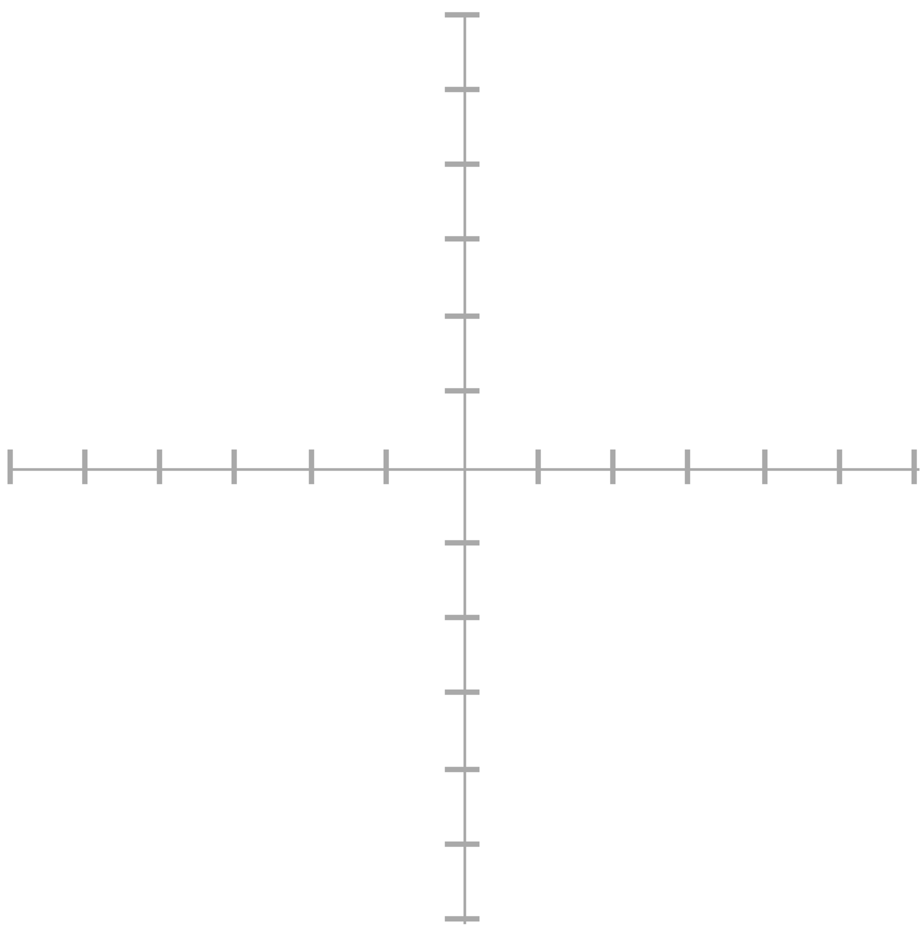
b) Determine the change in position $\Delta\vec{r}$.

c) Determine the magnitude Δr of the change in position.

d) Determine the unit vector $\widehat{\Delta r}$ which represents the direction of the change in position vector.

e) Determine the angle θ_x that the change in position vector makes to the positive branch of the x-axis.

f) Determine the angle θ_y that the change in position vector makes to the positive branch of the y-axis.



3.) At time t_o , a point mass $M = 0.50\ kg$ is observed at a position given by $\vec{r}_o = -5.00\,m\ \hat{i} - 3.00\ m\ \hat{j}$. At a later time t_L , this point mass was observed at a position given by $\vec{r}_L = 4.00\ m\ \hat{i} - 6.00\ m\ \hat{j}$. Use this information to do the following:

a) Using a straight edge, draw a correct graphic representation of vectors $\vec{r}_o$, $\vec{r}_L$, and $\Delta\vec{r}$.

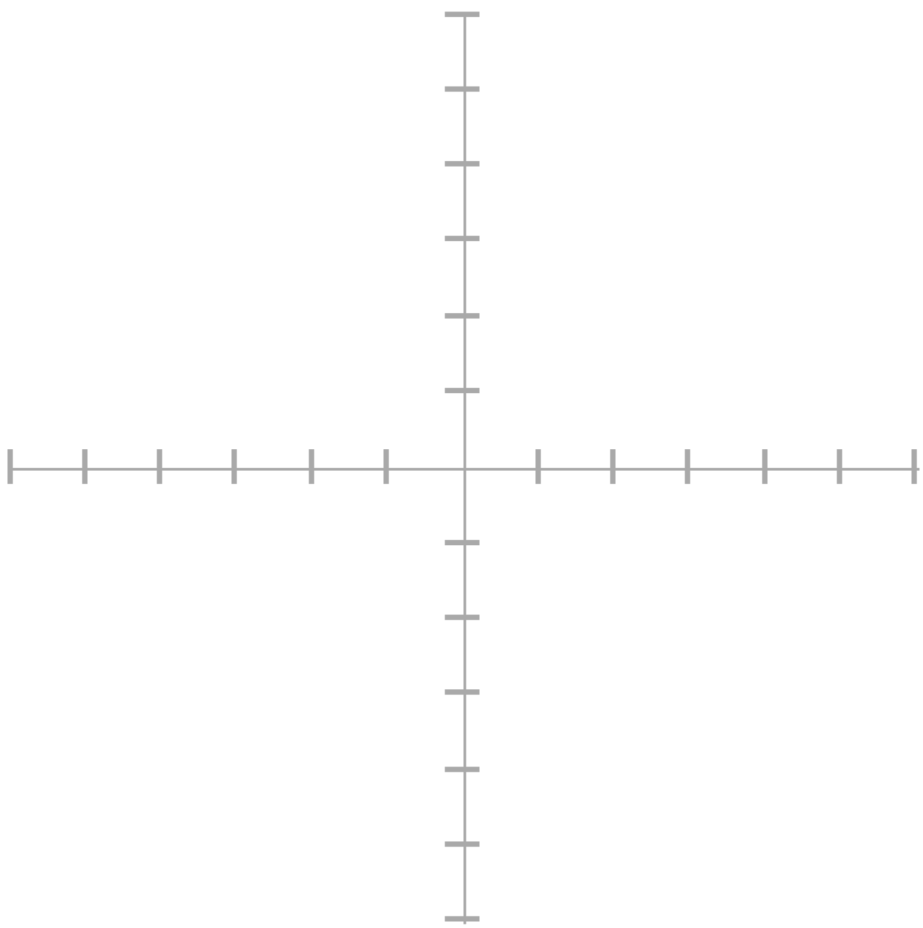
b) Determine the change in position $\Delta\vec{r}$.

c) Determine the magnitude, Δr , of this vector.

d) Determine the unit vector, $\widehat{\Delta r}$, that represents the direction of this vector.

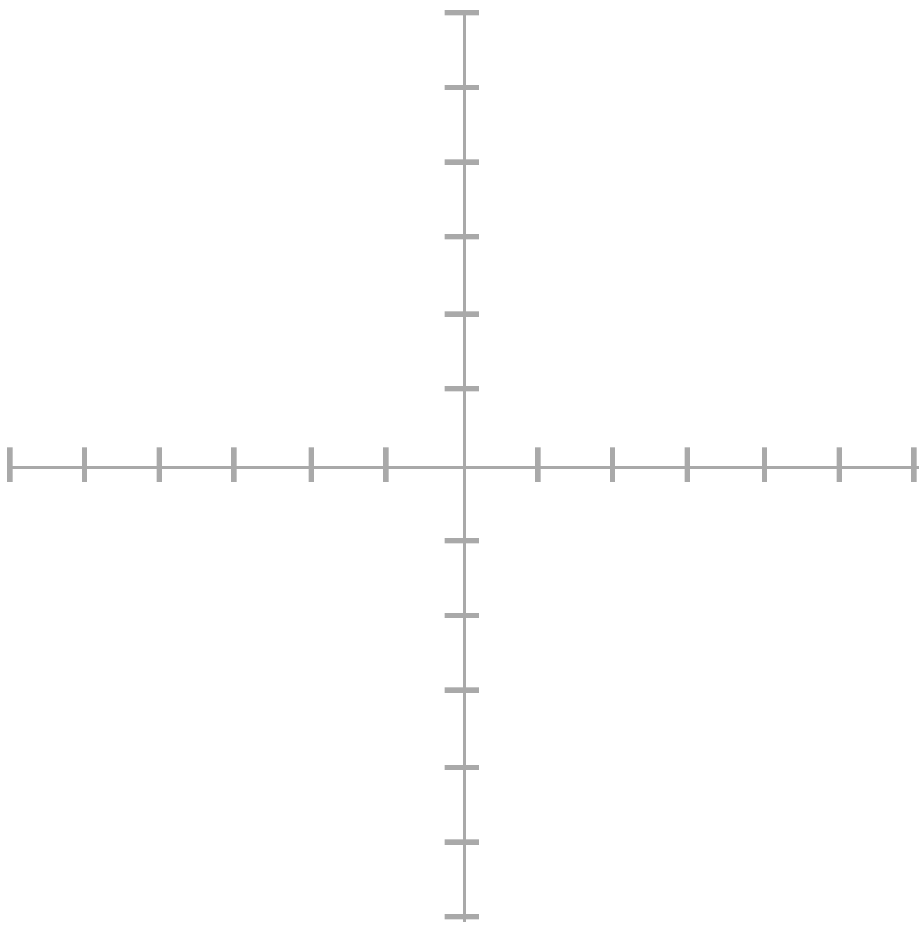
e) Determine the angle, θ_x , this vector makes to the positive branch of the x-axis.

f) Determine the angle, θ_y , this vector makes to the positive branch of the y-axis.



4.) A point-like physical thing of mass $M = 0.775\ kg$ was first observed in a Cartesian coordinate system at the position $\vec{r}_1 = 2\,m\ \hat{\boldsymbol{i}} + 4\,m\,\hat{\boldsymbol{j}}$. Six *seconds* later, a second observation was made and the object was at the position $\vec{r}_2 = -4\,m\ \hat{\boldsymbol{i}} + 3m\ \hat{\boldsymbol{j}}$. Use this information to do the following:

a) Using a straight edge, draw correct representations for position vectors $\vec{r}_1$ and $\vec{r}_2$ and the change in position vector $\Delta\vec{r}$.
b) Find the change in position, $\Delta\vec{r}$, of this object.
c) Calculate the magnitude of the change in position, Δr.
d) Determine the unit vector, $\widehat{\Delta r}$, which represents the direction of the change in position.
e) Calculate the angle, θ_x, between the vector $\Delta\vec{r}$ and the positive branch of the x-axis.
f) Calculate the angle, θ_y, between the vector $\Delta\vec{r}$ and the positive branch of the y-axis.



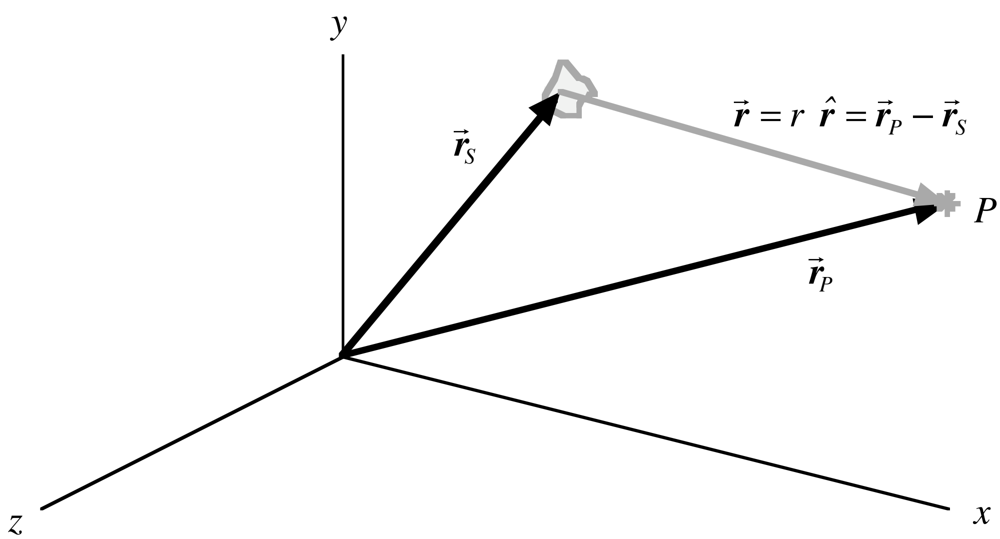
5.) There are numerous instances in physics where a physical thing is the **source** of a physical field. In these instances, we are always interested in the value of that field at some point P in space. The magnitude of a field always depends on the distance between the source and the point of interest. This state of affairs is illustrated in the diagram below. Use this information to find r and $\hat{\boldsymbol{r}}$ for the following pairs of points:

a) $P_S(4,3,0) \quad P_P(-6,2,0)$,

b) $P_S(0,3,5) \quad P_P(0,2,-4)$,

c) $P_S(-3,4,2) \quad P_P(5,5,-4)$.

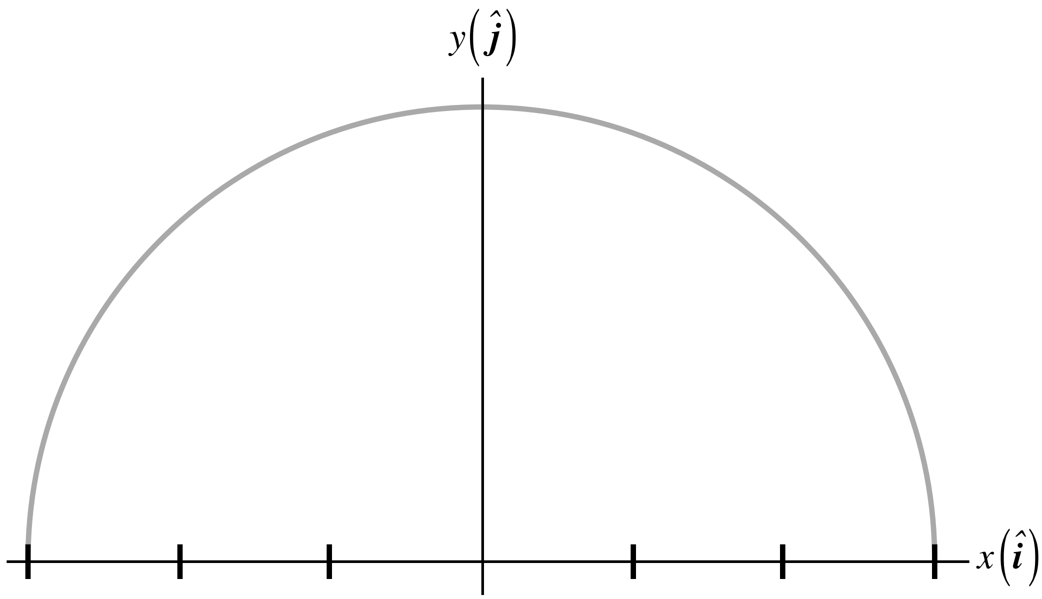
(Note that this representation is like transforming the origin to the location of the source, as $\vec{\boldsymbol{r}}$ is measured from there.)



Problems for Chapter 5

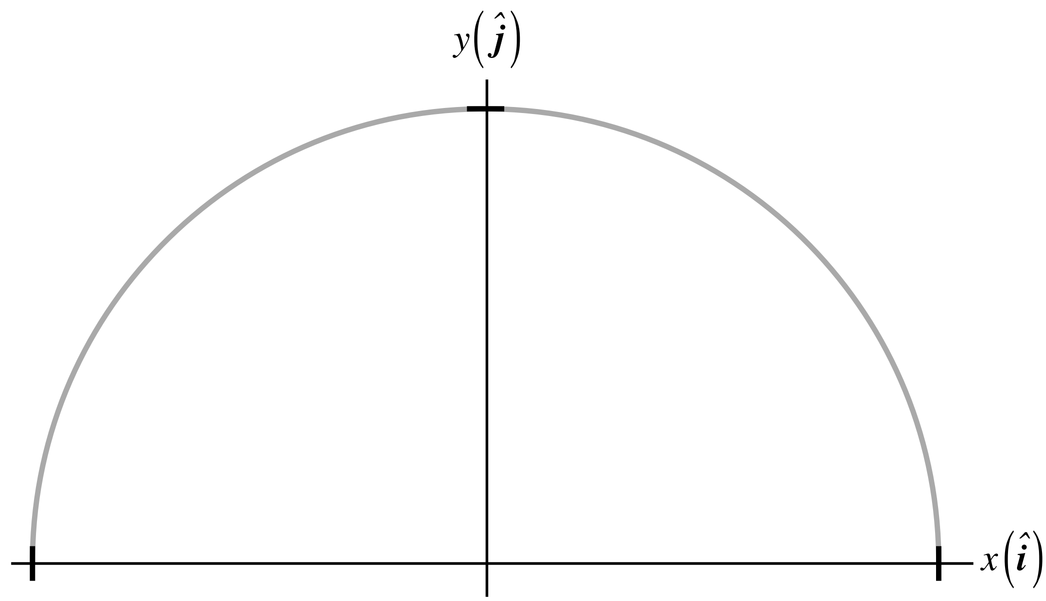
1.) A point mass M is moving with a constant speed $v = 6.2832\ m/s$ in a counterclockwise sense on a circle of radius $R = 3.0000\ m$. Initially, the point mass is at a position given by $\vec{r}_o = R\,\hat{i}$, while one *second* later, the position is given by $\vec{r}_L = -\ 1.5000\ m\ \hat{i} + 2.5981\ m\ \ \hat{j}$. Use this information to do the following:

a) Using a straight edge, draw representations for the vectors $\vec{r}_o$, $\vec{r}_L$ and $\Delta\vec{r}$. Also, clearly indicate the actual path traveled.
b) Determine the change in position vector,
c) Determine the average velocity vector.
d) Determine the **magnitude of the average velocity**.
e) Determine the actual path length $\Delta\ell$ of the point mass in this time interval.
f) Determine the **average speed** of the point mass in this time interval.
g) Are the values found in d) and f) equal? Do you understand why they are or are not?



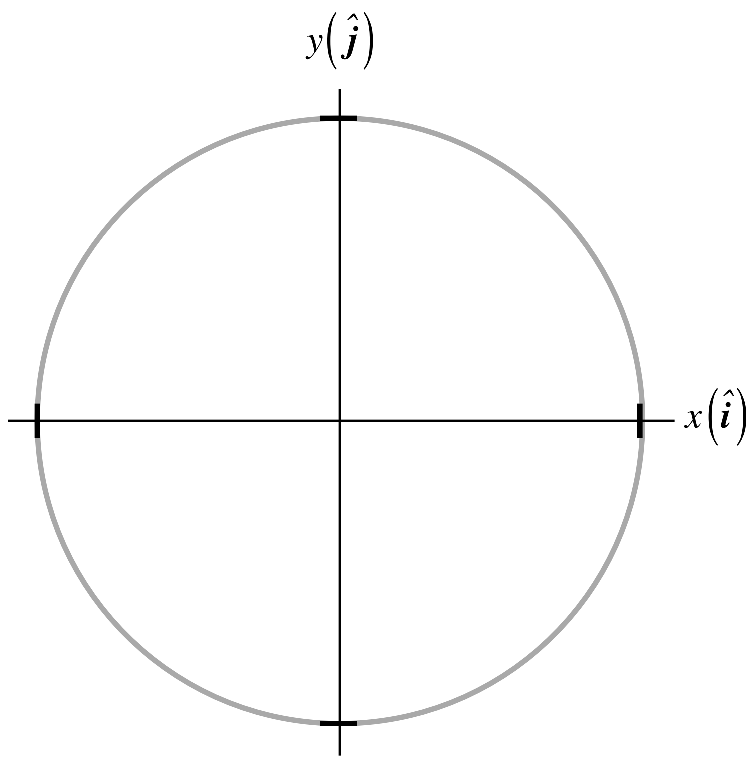
2.) A point mass M is constrained to move with constant speed in a counterclockwise sense about a circle of radius $R = 2.900\,m$. The center of the circle coincides with the origin of a Cartesian coordinate system. At time t_1, the position is given by $\vec{r}_1 = R\,\hat{\boldsymbol{i}}$. At time $t_2 = t_1 + 0.500\,s$, the position vector has rotated through an angle of $\varphi_2 = 135°$ in a counterclockwise sense to the positive branch of the x-axis. Use this information to do the following:

a) Using a straight edge, draw representations for the vectors $\vec{r}_1$, $\vec{r}_2$ and $\Delta\vec{r}$. Also, clearly indicate the actual path traveled.
b) Determine the change in position vector,
c) Determine the average velocity vector.
d) Determine the **magnitude of the average velocity**.
e) Determine the actual path length $\Delta\ell$ of the point mass in this time interval.
f) Determine the **average speed** of the point mass in this time interval.
g) Are the values found in d) and f) equal? Do you understand why they are or are not?



3.) A point mass $M = 0.750\ kg$ is moving with constant speed v in a clockwise sense about a circle of radius $R = 3.50\ m$. At time $t_o = 0$ the object is at a position given by $\vec{r}_o = R\ \hat{j}$. At a later time $t_L = 2.50\ s$, the object is at a position given by $\vec{r}_L$. (You may assume that the period of this motion is $\tau = 3.25\ s$.) Use this information to do the following:

a) Determine the change in position $\Delta\vec{r}$.
b) Determine the average velocity $\vec{v}_{ave}$.
c) Determine the magnitude, v_{ave} , of this vector.
d) Determine the unit vector, $\hat{v}_{ave}$, that represents the direction of this vector.
e) Determine the actual path length, $\Delta\ell$.
f) Determine the average speed, s_{ave} .
g) In this case, how does the average speed compare with v?



4.) The center of mass of a physical thing of mass $M = 2{,}500\ kg$ is constrained to move along a horizontal circular path of radius $R = 2.40 \times 10^{3}\ m$ at a **constant speed** of $v = 90.77\ m/s$. Initially, this object was at the position of $\vec{r}_o = R\,\hat{i}$. A second observation of this object was made at a time $t_L = t_o + 76.139\ s$ at the position $\vec{r}_L = -0.96589\,R\,\hat{i} - 0.25897\,R\,\hat{j}$. Use this information to do the following:

a) Using a straight edge, draw representations for the vectors $\vec{r}_o$, $\vec{r}_L$ and $\Delta\vec{r}$. Also, clearly indicate the actual path traveled.

b) Determine the change in position, $\Delta\vec{r}$. (You should be able to prove that the center of mass has not yet gone completely around the circle once.)

c) Determine the average velocity, $\vec{v}_{ave}$, of this object over the time interval given.

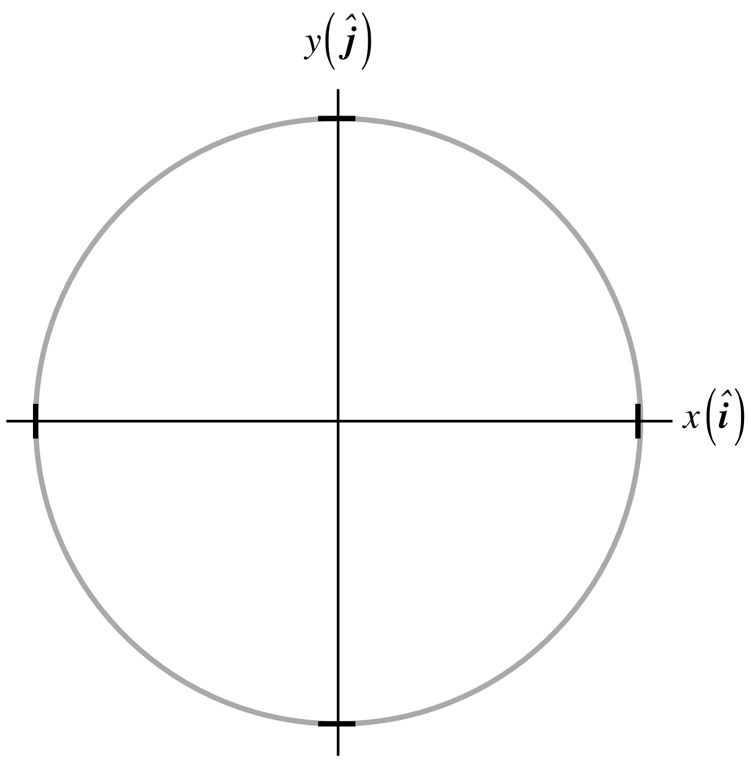
d) Determine the **magnitude of the average velocity**, v_{ave} .

e) Determine the unit vector, $\hat{v}_{ave}$, that represents the direction of the average velocity.

f) Determine the amount of time it would take for this object to go around this circle only once at the speed given--this time is known as the period, and signified by the lower case Greek letter τ (tau).

g) The actual distance, $\Delta\ell$, this object traveled in going from its initial position to its later position.

h) The ratio of the constant speed to the magnitude of the average velocity.



5.) A point-like physical thing of mass $M = 3.75\ kg$ is initially observed at a position given by $\vec{r}_o = 4\ m\ \hat{i} + 2\ m\ \hat{j}$, Four *seconds* later, this same object is observed at the position $\vec{r}_L = -5\ m\ \hat{i} + 4\ m\ \hat{j}$. Use this information to do the following:

a) Using a straight edge, draw an appropriate coordinate system and draw representations for the vectors $\vec{r}_o$, $\vec{r}_L$ and $\Delta\vec{r}$.

b) Determine the change in position vector $\Delta\vec{r}$.

c) Determine the magnitude of the change in position Δr .

d) Determine the average velocity $\vec{v}_{ave}$.

e) Determine the magnitude and the direction of $\vec{v}_{ave}$.

Problems for Chapter 6

1.) A truck of mass $M_T = 10{,}000\ kg$ is moving with a speed of $v = 20\ m/s$. Use this information to do the following:

a) Calculate the magnitude of the linear momentum of the truck.

b) Calculate the kinetic energy of the truck.

c) At what speed must a vehicle of mass $m = M_T / 10$ travel to have:

i) The same magnitude of linear momentum as that of the truck.

ii) The same kinetic energy as that of the truck.

2.) A bullet of mass $M_b = 0.050\ kg$ is moving with a speed of $v = 400\ m/s$.

a) Calculate the magnitude of the linear momentum of the bullet.

b) Calculate the kinetic energy of the bullet.

3.) A tank fires a projectile of mass $M = 4.40\ kg$ at a speed of $v = 1{,}400\ m/s$.

a) Calculate the magnitude of the linear momentum of the projectile.

b) Calculate the kinetic energy of the projectile.

4.) At takeoff, a "wet" Boeing 747-8 has a mass of about $M = 440{,}000\ kg$ and is moving with a speed of about $v = 81.0\ m/s$.

a) Calculate the magnitude of the linear momentum of the aircraft.

b) Calculate the kinetic energy of the aircraft.

5.) The Earth has a mass measured to be $M_{\oplus} = 5.97 \times 10^{24}\, kg$ and moves with a speed measured, with respect to the Sun, to be about $v = 2.98 \times 10^{4}\ m/s$.

a) Calculate the magnitude of the orbital linear momentum of the Earth.

b) Calculate the orbital kinetic energy of the Earth.

Problems for Chapter 7

1.) A ball is initially observed moving upward with a speed of $v_o = 26.5460\ m/s$. At a second observation, $2.500\ s$ later, the ball was still moving upward with a speed $v_L = 2.0335\ m/s$. Set up an appropriate Cartesian coordinate system and, relative to that coordinate system, determine the magnitude and the direction of the average acceleration.

2.) A woman is looking out the window of her apartment when she observes a ball traveling upward with a speed of $v = 19.610\ m/s$. Four *seconds* later, the woman sees the same ball traveling downward with the same speed. Set up an appropriate Cartesian coordinate system and determine the following:

a) The magnitude of the average acceleration, a_{ave}.

b) The direction of the average acceleration, $\hat{\boldsymbol{a}}_{ave}$.

3.) A vehicle of mass $M = 1.10 \times 10^3\ kg$ is initially observed moving due east with an instantaneous speed of $v_o = 24.587\ \ m/s$. Three *seconds* later, the car is moving due east with an instantaneous speed $v_L = 2.526\ \ m/s$. Set up an appropriate Cartesian coordinate system and do the following:

a) Determine the magnitude of the average acceleration over this time interval.

b) Determine the direction of the average acceleration over this time interval.

4.) A car of mass $M = 1000\ kg$ is initially moving due north with a speed of $v_o = 17.882\ m/s$ $(40\,mph)$. Six *seconds* later, the car is moving due west with a speed of $v_L = 33.528\ m/s\ (75\,mph)$. Set up an appropriate Cartesian coordinate system and find the following:

a) The average acceleration vector $\vec{a}_{ave}$ of the car over this time interval.

b) The magnitude and the direction of the average acceleration $\vec{a}_{ave}$.

c) What can you tell me about the actual path the car took?

5.) Challenge Problem: A woman tosses an engagement ring of mass $M = 0.012\,kg$ vertically downward from the edge of a very deep well. The speed of the ring when it left her hand was $v_o = 8.000\ m/s$. Three *seconds* later, the speed of the ring was $v_L = 37.415\ m/s$. Set up an appropriate Cartesian coordinate system and determine the following:

a) The magnitude and direction of the average acceleration of the ring over this time interval.

b) Assume that 3.35 *seconds* after she threw the ring, she heard the splash. If the speed of sound is $v_{sound} = 343\ m/s$, determine the depth d of the well.

6.) A point-like object of mass $M = 0.750\ kg$ is moving with constant speed $v = 6.500\ m/s$ on a circular path of radius $R = 2.250\ m$. If the initial position of this object is given by $\vec{r}_o = R\,\hat{i}$, and if at time $t_L = t_o + 0.5437\ s$ the object is at the position given by $\vec{r}_L = R\,\hat{j}$, as represented in the diagram below, then determine the following:

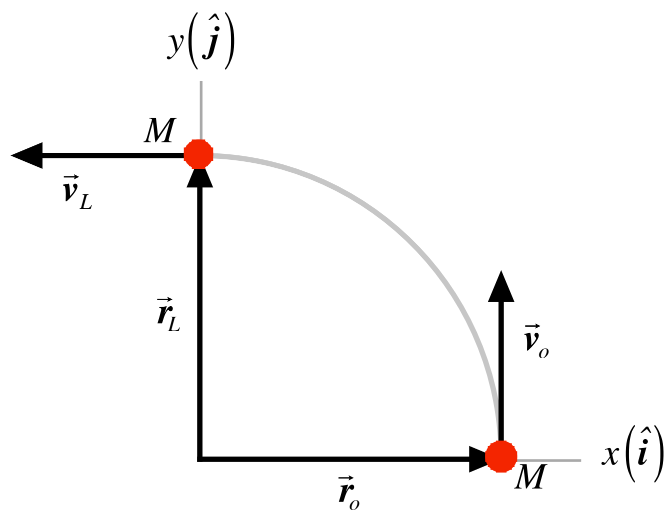
a) The magnitude and direction of the change in position $\Delta\vec{r}$ of this object.

b) The magnitude and direction of the average velocity $\vec{v}_{ave}$ of the object.

c) The magnitude and direction of the average acceleration $\vec{a}_{ave}$ of the object.

d) The period τ of this motion?

e) The actual path length $\Delta\ell$.



7.) The center of mass of a physical thing of mass $M = 6.62\,kg$ is constrained to move with constant speed along a circular path of radius $R = 10.0\ m$ in a counterclockwise sense, as represented in the diagram below. At the initial position, the position vector makes an angle of $\varphi_o = 30.00°$ to the positive branch of the x-axis. Three *seconds* later, the position vector makes an angle of $\varphi_L = 45.00°$ to the negative branch of the x-axis. Use this information to find:

a) The magnitude and direction of the change in position $\Delta\vec{\boldsymbol{r}}$ over this time interval.

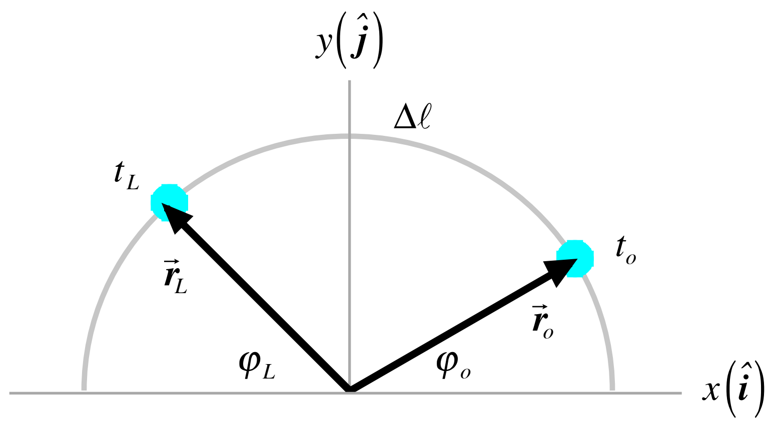
b) The magnitude and direction of the average velocity $\vec{\boldsymbol{v}}_{ave}$ over this time interval.

c) The magnitude and direction of the average acceleration $\vec{\boldsymbol{a}}_{ave}$ over this time interval.

d) The magnitude of the actual path length $\Delta\ell$.

e) The average speed of this object over this time interval, $s_{ave} = \Delta\ell / \Delta t$.

f) The period τ of this motion.



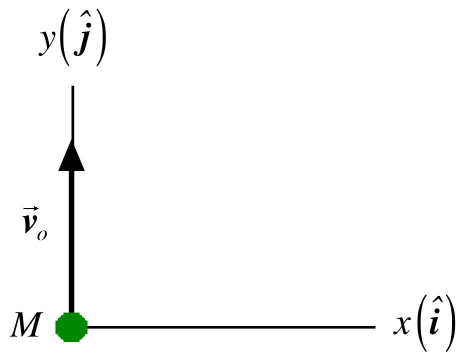
8.) A point mass $M = 0.750\ kg$ is launched with an initial speed of $v_o = 25.00\ m/s$ at an angle of $\theta_o = 35.00°$ above the horizontal from ground level. (You may ignore air resistance.) Use this information to do the following:

a) Calculate the maximum height attained by the point mass.
b) Find the horizontal distance from the starting point at which the point mass strikes the ground.
c) Determine the speed of the point mass as it strikes the ground.
d) Find the angle made to the horizontal by the velocity vector of the point mass an impact.

9.) A point mass $M = 2.50\ kg$ is launched with an initial speed of $v_o = 15.00\ m/s$ vertically upward from ground level. (You may ignore air resistance.) Use this information to do the following:

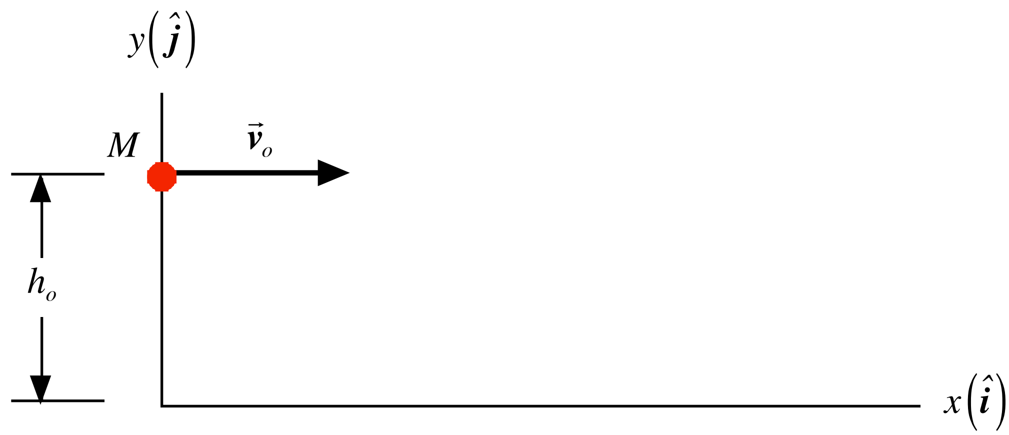
a) Find the maximum height attained by the point mass.

b) Calculate the height above the ground at which the point mass will have a speed of $v = v_o / 2$.



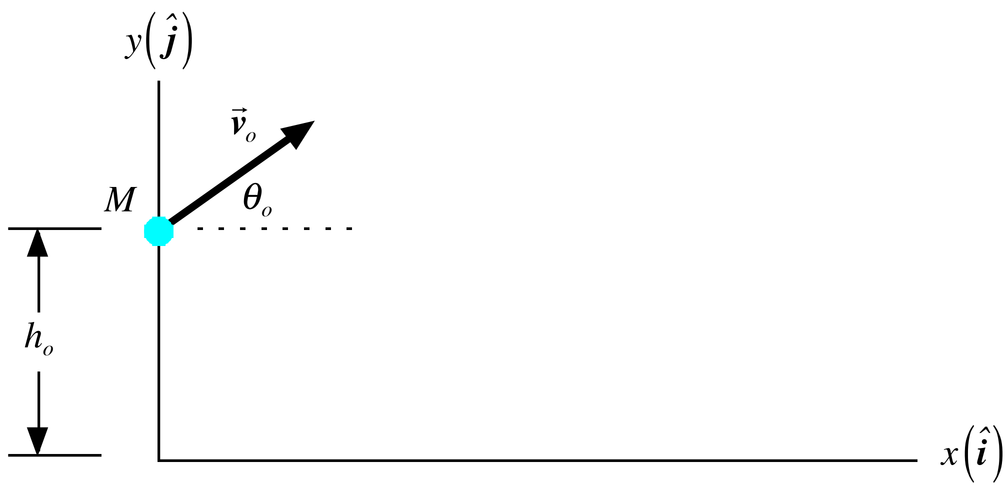
10.) A point mass $M = 5.20\ kg$ is launched horizontally with a speed $v_o = 45.75\ m/s$ from a point that is a distance $h_o = 22.50\ m$ above level ground. (You may ignore air resistance.) Use this information to do the following:

a) Find the horizontal distance from the starting point at which the point mass strikes the ground.
b) Determine the speed of the point mass as it strikes the ground.
c) Find the angle, relative to the horizontal, of the velocity vector at impact.



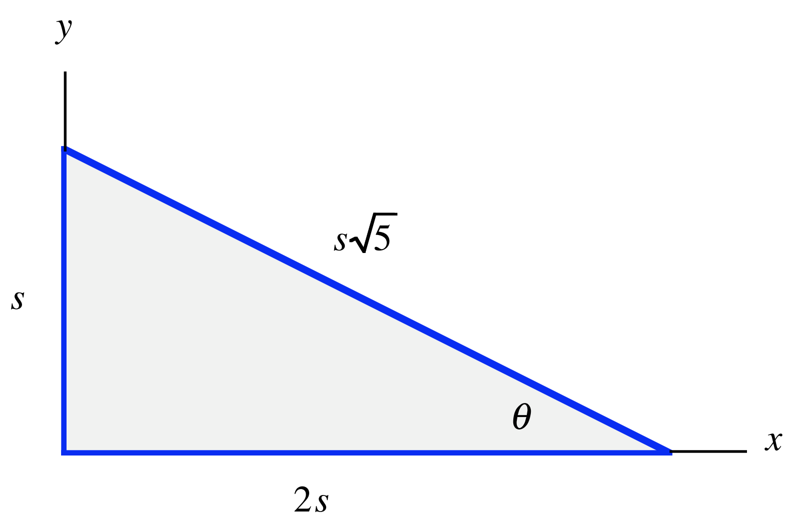
11.) A point mass $M = 0.750\ kg$ is launched with an initial speed of $v_o = 25.00\ m/s$ at an angle of $\theta_o = 35.00°$ above the horizontal from a point ten *meters* above level ground. (You may ignore air resistance.) Use this information to do the following:

a) Calculate the maximum height attained by the point mass.
b) Find the horizontal distance from the starting point to the point at which the projectile strikes the ground.
c) Determine the speed of the point mass as it strikes the ground.
d) Find the angle, relative to the horizontal, of the velocity vector at impact.

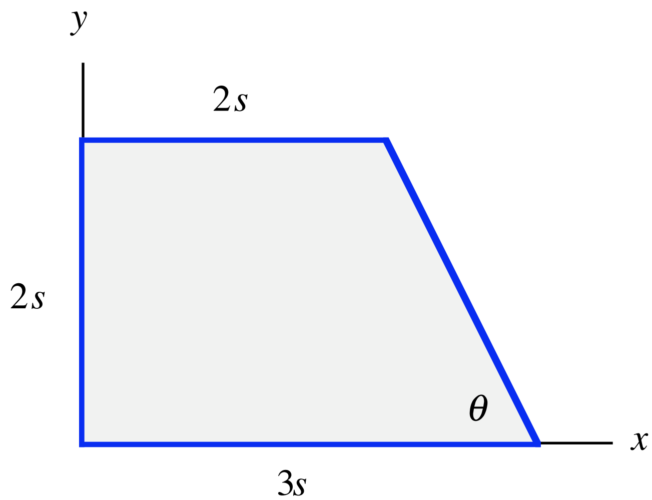


Problems for Chapter 8

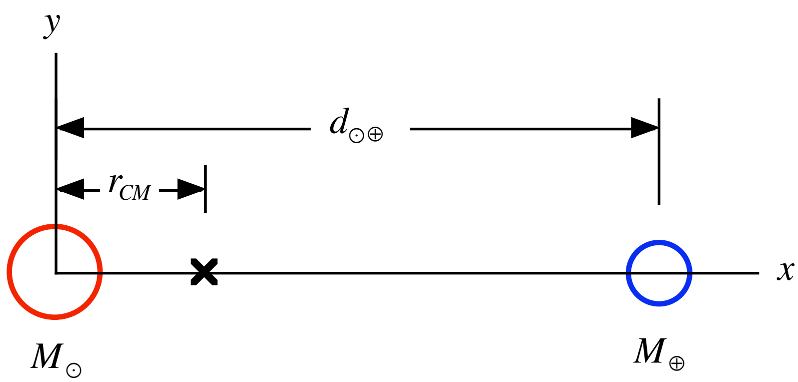
1.) Find the center of mass of the triangle show below. The triangle is made up of a homogeneous material. (Hint: As the material is homogeneous, the center of mass coincides with the centroid. So, from each vertex, run a line segment to the midpoint of the side opposite the angle. The point at which these lines intersects, will be the center of mass.)



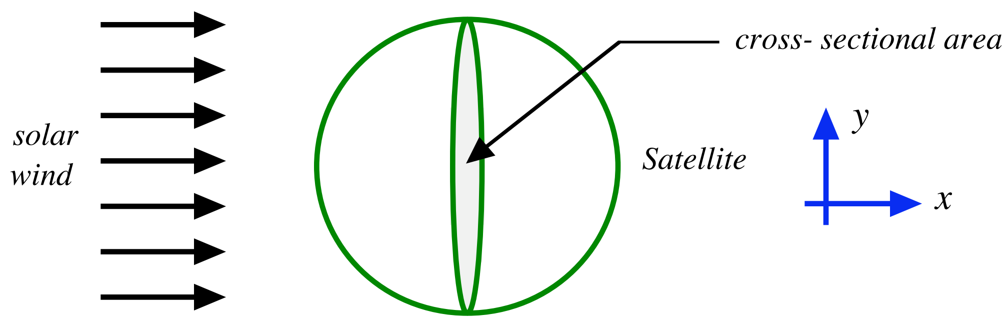
2.) Find the center of mass of the homogeneous planar figure shown below. (Hint: divide the figure into two separate figures for which you can determine the center of mass of each.)



3.) On average, the center the Sun is at a distance $d_{\odot\oplus} = 1.496 \times 10^{11}\ m$ from the center of the Earth. The mass of the Earth is $M_{\oplus} = 5.98 \times 10^{24}\ kg$ while the mass of the Sun is $M_{\odot} = 1.99 \times 10^{30}\ kg$. The radius of the Earth is measured to be $R_{\oplus} = 6.378 \times 10^{6}\ m$ and the radius of the Sun is measured to be $R_{\odot} = 6.955 \times 10^{8}\ m$. Find the center of mass of these two bodies, r_{CM} ; this point is called the **barycenter**.



4.) **Challenge Problem:** The solar wind sweeping by the Earth consists of a stream of particles, primarily protons of mass $M_p = 1.673 \times 10^{-27}\ kg$. There are, on average, 10^7 protons per cubic meter moving with a speed of about $v_p = 4.0 \times 10^5\ m/s$. If the magnitude of the average force exerted on an object is defined by $F_{ave} = \Delta p / \Delta t$, where p is the magnitude of the linear momentum, find the force exerted on a spherical satellite showing a cross-sectional area of one *square meter* to the stream.



ASSIGNMENT TWO

PROBLEMS FOR CHAPTERS NINE AND TEN

Problems for Chapters Nine and Ten

Gravitational Problems

1.) The mass of the Sun is measured to be $M_\odot = 1.99 \times 10^{30}\,kg$ and its radius is measured to be $R_\odot = 6.955 \times 10^{8}\,m$. The Earth has a mass measured to be $M_\oplus = 5.97 \times 10^{24}\,kg$ and a radius measured to be $R_\odot = 6.378 \times 10^{6}\,m$. The average distance between the Sun and the Earth is called an astronomical unit, AU, and measured as $1\ AU \equiv 1.496 \times 10^{11}\,m$. Use this information, and Newton's law of universal gravitation, to calculate the following:

a) The average magnitude of the gravitational force exerted on the Sun by the Earth.
b) The magnitude of the acceleration due to the Sun's gravitational force on an object released from rest close to the surface of the Sun.

2.) The mass of the Earth is measured to be $M_{\oplus} = 5.97 \times 10^{24}\ kg$. The mass of Jupiter is measured to be $M_J = 1.90 \times 10^{27}\ kg$. The equatorial radius of Jupiter is measured to be $R_J = 7.14 \times 10^{7}\ m$ while that of the Earth is $R_{\oplus} = 6.378 \times 10^{6}\ m$. At its closest approach to the Earth, Jupiter is at a distance from the Earth of approximately $d_{J\oplus} = 6.29 \times 10^{11}\ m$. Use this information and Newton's universal law of gravity, to determine the following:

a) The magnitude of the gravitational force exerted on the Earth by Jupiter.

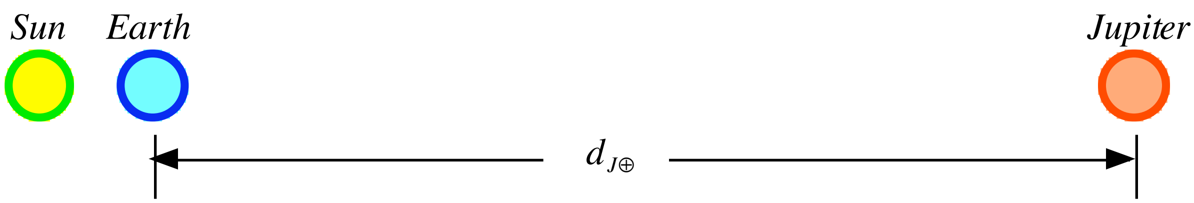
b) The magnitude of the gravitational acceleration of an object near the surface of Jupiter.

Recall Newton's universal law of gravity is given by:

$$F_{12}^{G} = \frac{GM_1 M_2}{r_{12}^{2}} = F_{21}^{G},$$

where

$$G = 6.67 \times 10^{-11} Nm^2 / kg^2 .$$



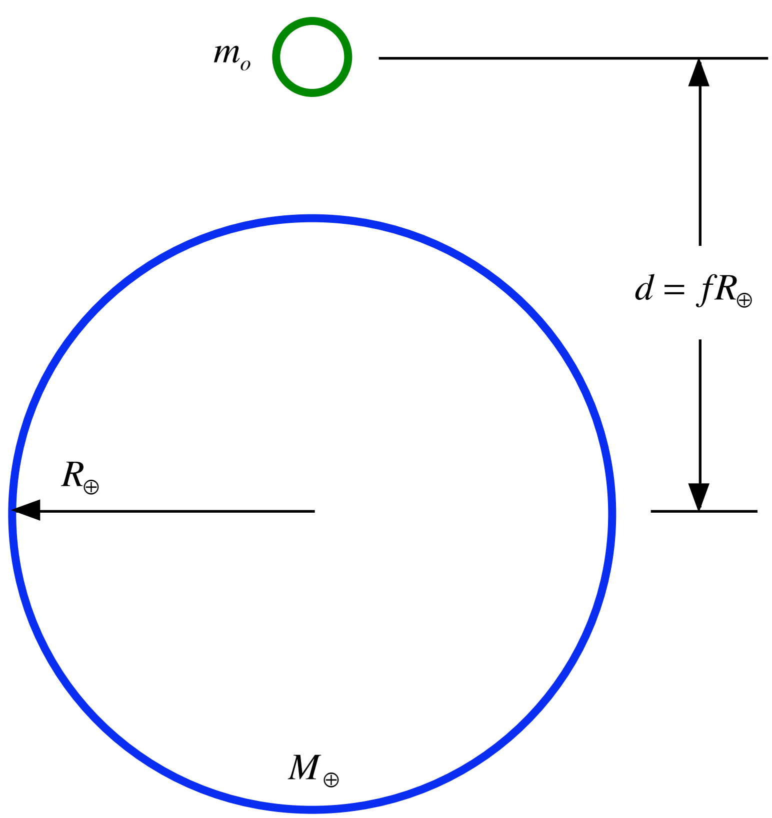
3.) We can model the Earth as a sphere of $M_\oplus = 5.97 \times 10^{24}\,kg$ and radius $R_\oplus = 6.378 \times 10^{6}\,m$. (See the diagram below.) Assume that an object of mass m_o is a distance $d = fR_\oplus$ from the center of the Earth, where $f \geq 1$. Use Newton's universal law of gravitation to do the following:

a) Derive an equation for the magnitude of the gravitational force that would be exerted on the object of mass m_o at a distance d from the center of the Earth.

b) Graph the values for the equation derived in part a) for f values of $1, 2, 3, 4,$ and 5. Express the weight in terms of multiples of $m_o g$.

c) Derive an equation for the magnitude of the acceleration of the object mass m_o.

d) Calculate the magnitude of the acceleration on the object mass m_o when $f = 3$.



4.) Johannes Kepler, using data from observations of the planet Mars made by Tycho Brahe, was able to establish that planets orbit the Sun on elliptical paths. The Sun is located at one of the foci of the ellipse. The average distance of the planet from the Sun is called the semi-major axis and is signified by a. The non-circularity of the ellipse is called the eccentricity and is signified by ε. When the planet is closest to the Sun, it is said to be at perihelion, and, there it has its greatest speed. The planet moves most slowly at its furthest point from the Sun, a point called aphelion. At perihelion and at aphelion the planet is moving instantaneously of a circular path. Use this information to do the following:

a) Derive an equation for the gravitational force exerted on the planet by the Sun at:
   (i) some arbitrary point a distance r away
   (ii) perihelion.
   (iii) aphelion.

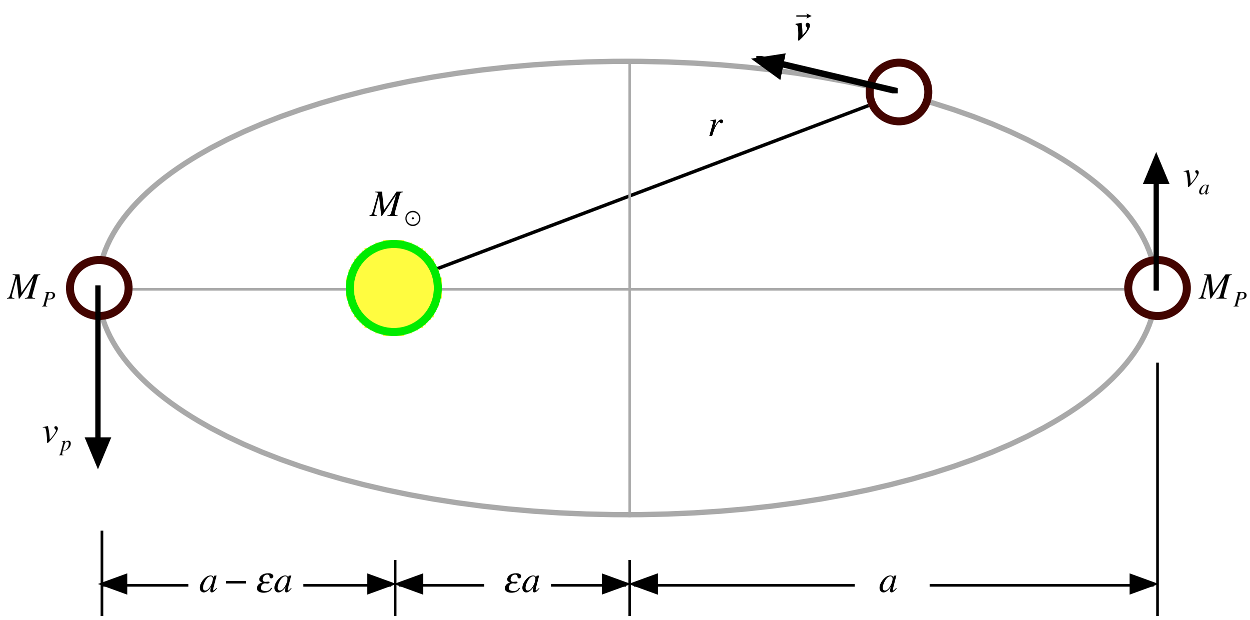
b) Derive an equation for the speed of the planet at:
   (i) perihelion.
   (ii) aphelion.

c) Calculate the speed of the Earth at:
   (i) perihelion.
   (ii) aphelion.

Recall:

$$M_{\oplus} = 5.97 \times 10^{24}\,kg \;;\; \varepsilon_{\oplus} = 0.0167 \;;\; R_{\oplus} = 6.378 \times 10^{6}\,m \;;$$

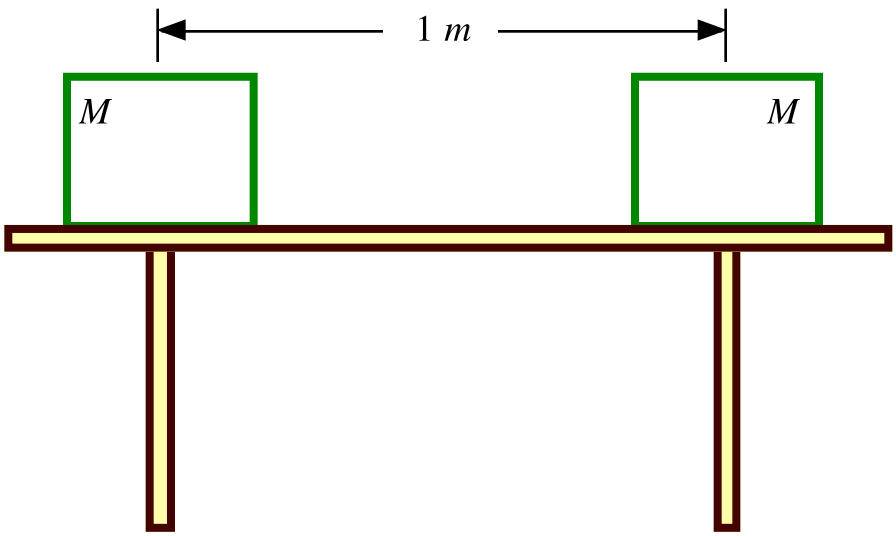
$$a_{\oplus} = 1.496 \times 10^{11}\,m \;;\; M_{\odot} = 1.99 \times 10^{30}\,kg \;;\; G = 6.67 \times 10^{-11}\,Nm^2 / kg^2 \,.$$



5.) Two blocks of identical mass $M = 100\ kg$ are initially separated by a distance of *one meter*. The blocks are on an absolutely level surface. Do the following:

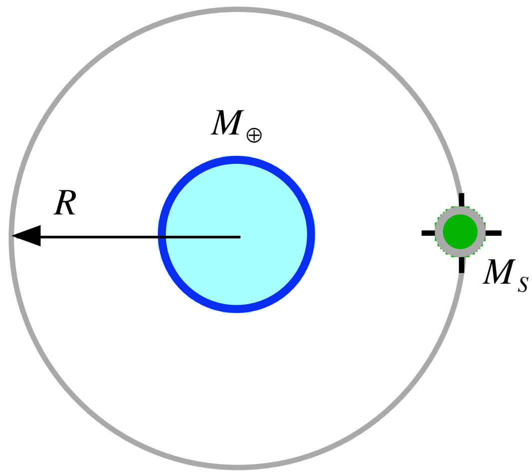
a) If the surface is completely frictionless, calculate the magnitude of the horizontal acceleration of each block due to their mutual gravitational interaction.

b) If the surface is rough and the coefficient of static friction between the blocks and the surface is $\mu_S = 0.600$, calculate the magnitude of the frictional force exerted on each block.



6.) A satellite of mass $M_S = 2.50 \times 10^5\ kg$ orbits the Earth on a circular orbit of radius $R = 3R_{\oplus}$. Do the following:

a) Calculate the magnitude of the gravitational force exerted on the satellite by the Earth.
b) The magnitude of the acceleration of the satellite.
c) The orbital speed of the satellite.
d) The amount of time it takes the satellite to make one complete orbit of the Earth; this is called the orbital period and signified by τ_{orb}.



Blocks on Inclined Planes

7.) A block of mass M is released from rest at the top of a frictionless inclined plane, as represented in the diagram below. The plane is inclined an angle θ with respect to the horizontal. Do the following:

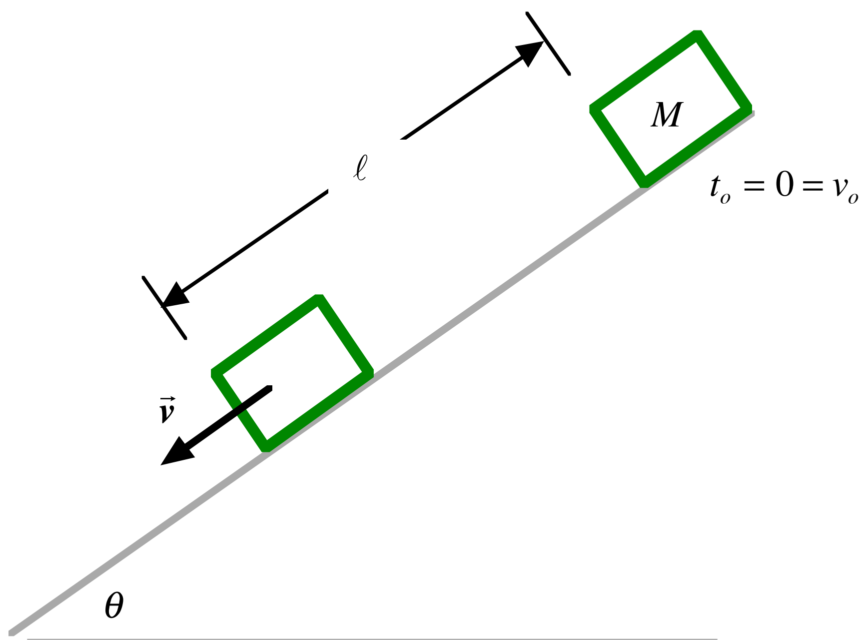
a) Using a straight edge, draw a clear and correct free body diagram of all of the relevant forces acting on the block. Indicate an appropriate coordinate system.

b) Derive an equation for the magnitude of the normal force exerted on the block by the incline.

c) Derive an equation for the magnitude of the acceleration of the block relative to the incline.

d) Derive an equation for the magnitude of the instantaneous speed of the block at the instant it has moved a distance ℓ.

e) If $M = 2.50\ kg$, $g = 9.80\ m/s^2$, $\theta = 35.00°$, and $\ell = 1.250\ m$, find the correct values for the quantities described in parts b), c), and d).



8.) A block of mass M is released from rest at the top of a rough inclined plane, as represented in the diagram below. The plane is inclined an angle θ with respect to the horizontal and the coefficients of friction are related by $\mu_s = (3/2)\mu_k$. Do the following:

a) Using a straight edge, draw a clear and correct free body diagram of all of the relevant forces acting on the block. Indicate an appropriate coordinate system.

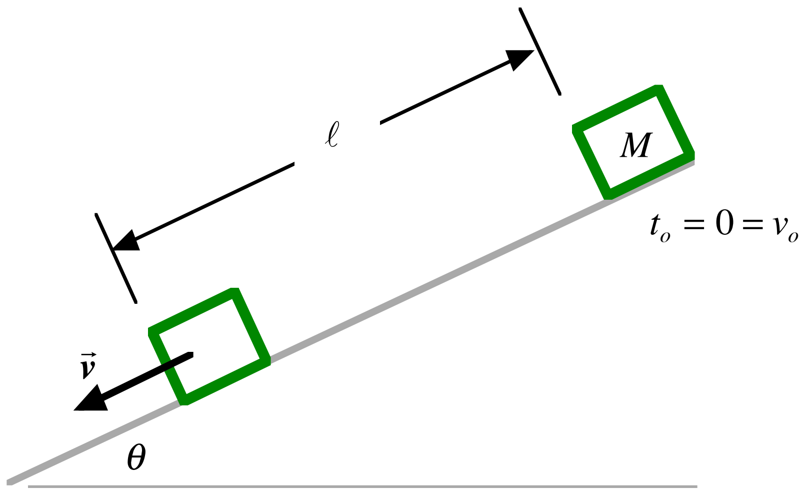
b) Derive an equation for the magnitude of the normal force exerted on the block by the incline.

c) Derive an equation for the magnitude of the kinetic frictional force exerted on the block by the incline.

d) Derive an equation for the magnitude of the acceleration of the block.

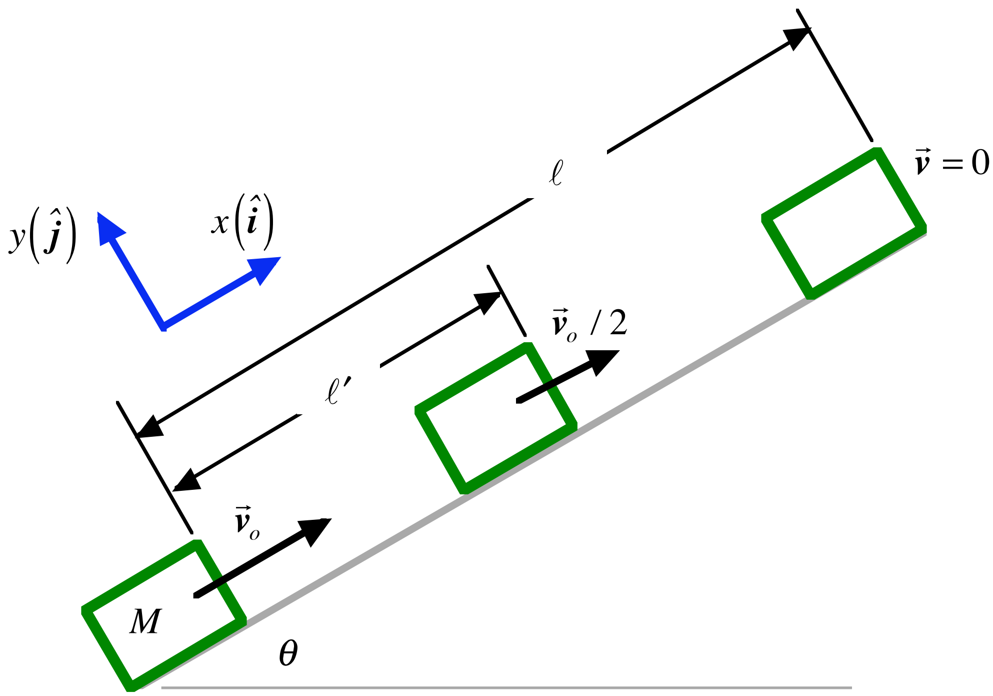
e) Derive an equation for the magnitude of the instantaneous speed of the block at the instant it has moved a distance ℓ.

f) If $M = 2.50\ kg$, $g = 9.80\ m/s^2$, $\mu_s = 0.450$, $\theta = 25.00°$, and $\ell = 1.250\ m$, find the correct values for the quantities described in parts b), c), d), and e).



9.) A block of mass $M = 5.00\ kg$ is moving with a speed of $v = 12.75\ m/s$ as it begins to move up a rough inclined plane, as represented in the diagram below. The plane is inclined an angle of $\theta = 30°$ with respect to the horizontal. The coefficient of kinetic friction between the block and the incline is $\mu_k = 0.350$. Do the following:

a) Calculate the magnitude of the acceleration of the block relative to the incline.
b) Calculate the distance the block will move parallel to the incline before coming to instantaneous rest.
c) Calculate the distance the block will have moved at the instant its speed is one half of its initial speed.

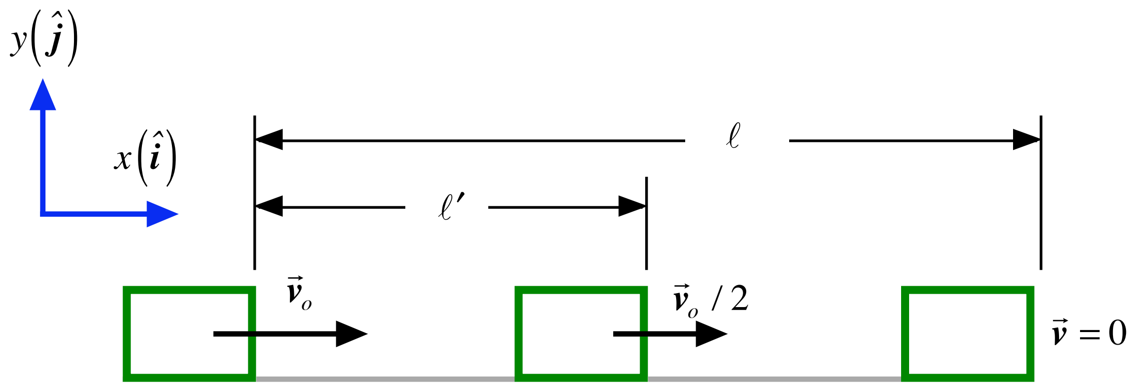


10.) A block of mass $M = 3.50\ kg$ is moving with an instantaneous speed $v = 15.50\ m/s$ when it begins to move over a rough, level surface, as represented in the diagram below. The coefficient of kinetic friction between the block and the incline is $\mu_k = 0.420$. Use this information, and Newton's second law of motion, to determine:

a) The magnitude of the acceleration of the block.

b) The distance ℓ the block will move before coming to rest.

c) The distance ℓ' the block will have moved at the instant its speed is one-half of its initial speed.



Blocks and Pulleys

11.) A block of mass M_1 is attached to one end of a light string. A second block of mass M_2 is attached to the other end of the string. The masses are such that $M_1 > M_2$. The string is draped over a massless, frictionless pulley as represented in the diagram below. This system of blocks is released from rest and each block accelerates through a distance ℓ. Do the following:

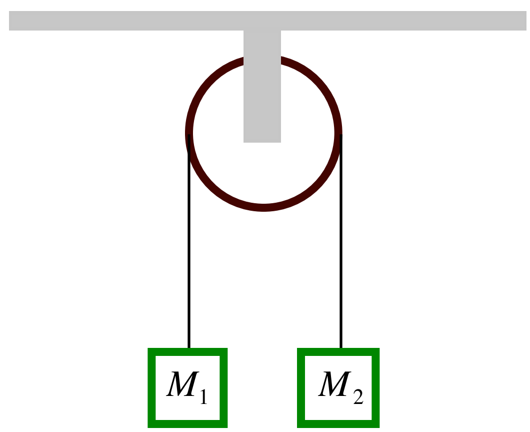
a) Draw a free body diagram of the forces acting on each block at an arbitrary point on each block's path.

b) Derive an equation for the magnitude of the acceleration of each block.

c) Derive an equation for the magnitude of the tension in the string.

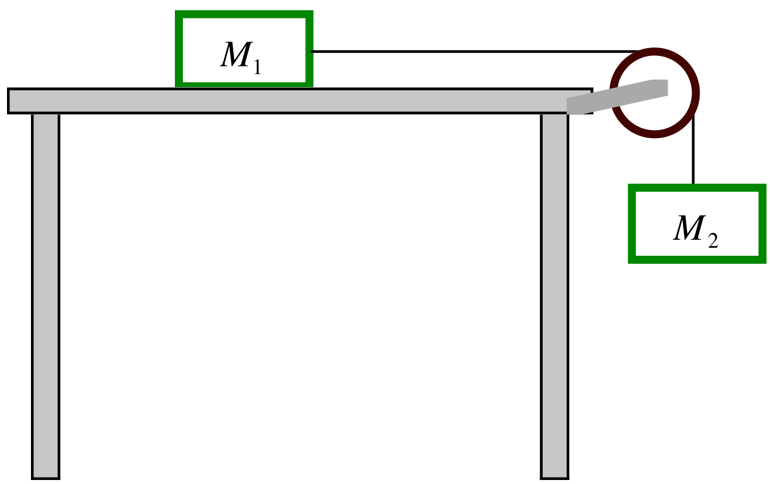
d) Derive an equation for the speed of each block at the instant each has moved a distance ℓ.

e) If $M_1 = (3/2)M_2 = 3.00\,kg$, $g = 9.80\,m/s^2$, and $\ell = 0.750\ m$, calculate the magnitude of the acceleration of each block, the magnitude of the tension in the string, and the speed of each block at the instant they have moved a distance ℓ.



12.) One end of a light string is attached to a block of mass $M_1 = 8.50\ kg$. The other end of the string is attached to a block of mass $M_2 = 10.50\ kg$. The string is draped over a massless, frictionless pulley, as represented in the diagram below. Block one is constrained to move over a level, rough surface for which the coefficient of kinetic friction is $\mu_k = 0.675$. This system is released from rest. Use this information and Newton's second law of motion to do the following:

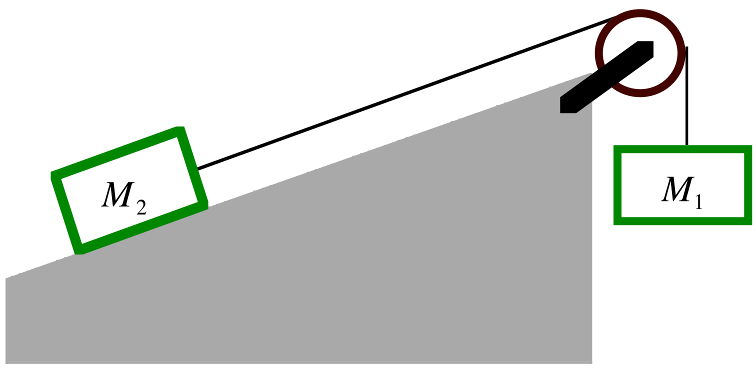
a) Using a straight edge, draw accurate free body diagrams of all of the relevant forces acting on each block and the pulley. Be sure to include an appropriate coordinate system for each block.
b) Determine the magnitude of the normal force exerted on block one.
c) Determine the magnitude of the kinetic friction exerted on block one.
d) Determine the magnitude of the acceleration of each block.
e) Determine the magnitude of the tension in the string.



13.) A block of mass $M_1 = 5.500\ kg$ is attached to one end of a light string. A block of mass $M_2 = 4.500\ kg$ is attached to the other end of the string. In turn, the string is draped over a massless, frictionless pulley as represented in the diagram below. The inclined plane is inclined an angle of $\theta = 20.00°$ and the coefficient of kinetic friction between the block and the incline is $\mu_k = 0.300$. This system is released from rest. Use this information, and Newton's second law of motion, to determine:

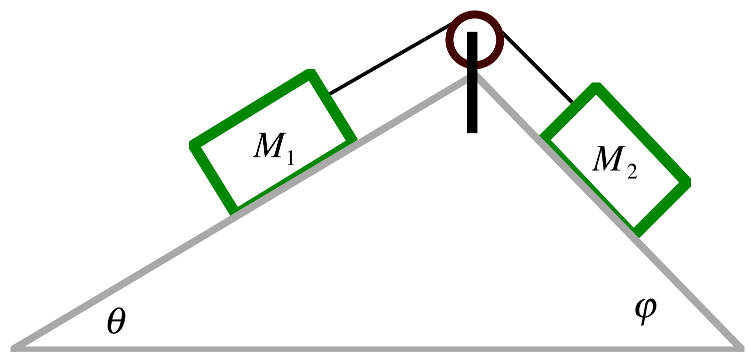
a) The magnitude of the acceleration of each block.
b) The magnitude of the tension in the string.
c) The speed of each block at the instant each block has moved a distance $\ell = 0.500\ m$.

(Be sure to draw an accurate free body diagram of the relevant forces exerted on each block at an arbitrary point on its path.)



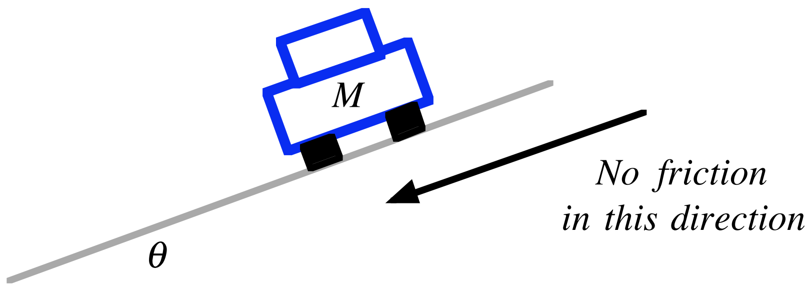
14.) Two blocks of mass $M_2 = 2M_1 = 8.00\ kg$ are attached to opposite ends of a light string. The light string is draped over a massless, frictionless pulley. The blocks are constrained to move over rough inclined planes, as represented in the diagram below. The planes are inclined, with respect to the horizontal, at angles given by $\varphi = 45° = (1.50)\theta$. The coefficients of kinetic friction between the inclines and the blocks are given by $\mu_1 = (3/2)\mu_2 = 0.450$. Do the following:

a) Calculate the magnitude of the acceleration of each block.
b) Calculate the magnitude of the tension in the string.
c) Calculate the magnitude of the velocity of each block at the instant they have moved a distance $\ell = 0.500\ m$.

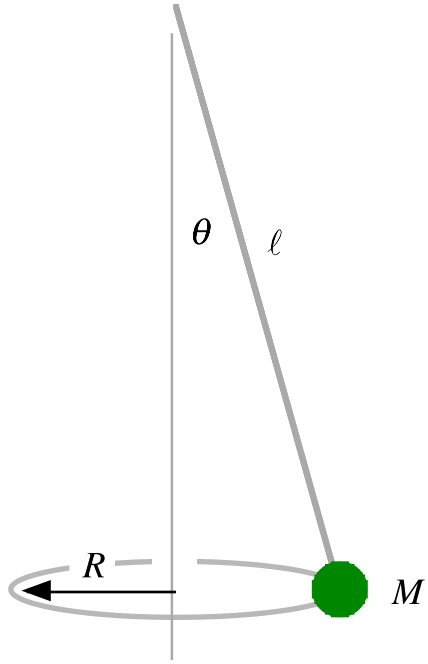


Circular Motion

15.) A vehicle of mass M is moving with instantaneous speed v on a circular path of radius R. The road surface on which the vehicle moves is inclined to the horizontal at an angle θ. There is an optimal speed v_{opt} at which the vehicle can safely negotiate the turn even if there is **no friction** directed parallel to the road surface and perpendicular to the direction of motion. Derive an equation for the optimal speed.



16.)



One end of a light sting of length $\ell = 1.50\ m$ is attached to a frictionless pivot. The other end of the string is attached to a point-like mass $M = 2.75\ kg$. The mass moves on a horizontal circular path of radius R at a constant speed v. The string maintains an angle--with respect to the vertical--of $\theta = 15°$, as represented in the diagram above. Use this information and Newton's second law of motion to do the following:

a) Determine the tension in the string.
b) Determine the speed with which the mass will move around the circle.

17.) A vehicle of mass M is moving with speed v as it moves along a rough, horizontal road while turning on a curve of radius R. During the entire turn, the vehicle does not skid and, therefore, static friction is maintained on the tires in a radial direction. (You may assume that the static friction is at its maximum sustainable value throughout the turn--i.e. radial motion is impending.) The coefficient of static friction is μ_s.

a) Using a straight edge and compass, or circle template, draw two free body diagrams:
   (1) from a perspective above the road and
   (2) from a perspective parallel to the road looking in the direction of the instantaneous motion. In each drawing, be sure to include an appropriate coordinate system.

b) Derive an equation for the magnitude of the normal force exerted on the car by the road.

c) Derive an equation for the magnitude of the radial (centripetal) force exerted on the car by the road.

d) Derive an equation for the magnitude of the radial (centripetal) acceleration of the car.

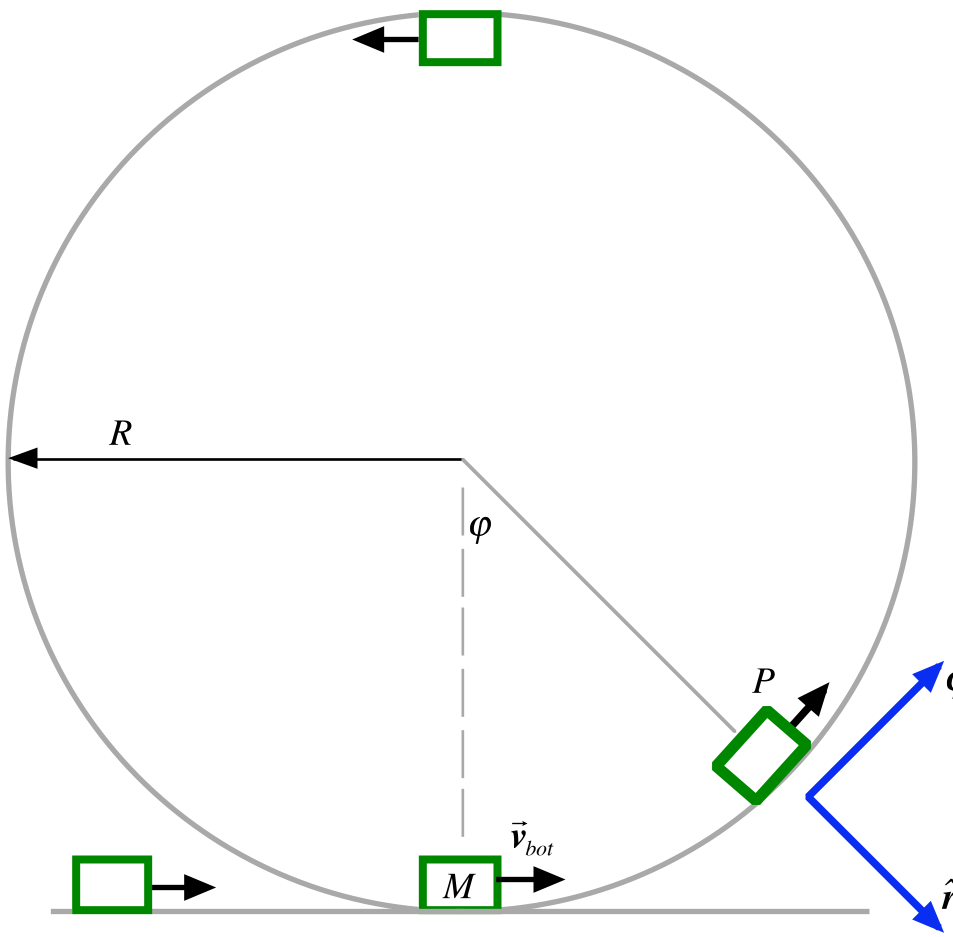
e) If $M = 1.025 \times 10^3\ kg$, $\mu_s = 0.900$, and $g = 9.80\ m/s^2$, find the values for the quantities described in parts b), c) and d).

f) If $v = 20.117\ m/s$, determine the turn radius of the road.

18.) A car of mass M moves on a roller coaster. At the bottom of a loop-the-loop of radius R, the car has an instantaneous speed v_{bot}, as represented in the diagram below. Do the following:

a) Assuming negligible friction, derive an equation for the speed of the carrier at an arbitrary point P. This will, in fact, be a general expression for the speed at any point on the loop.

b) Use the equation found in part a) to find the **minimum speed** the carrier can have at the top of the loop and still be able to go safely all the way around the loop.

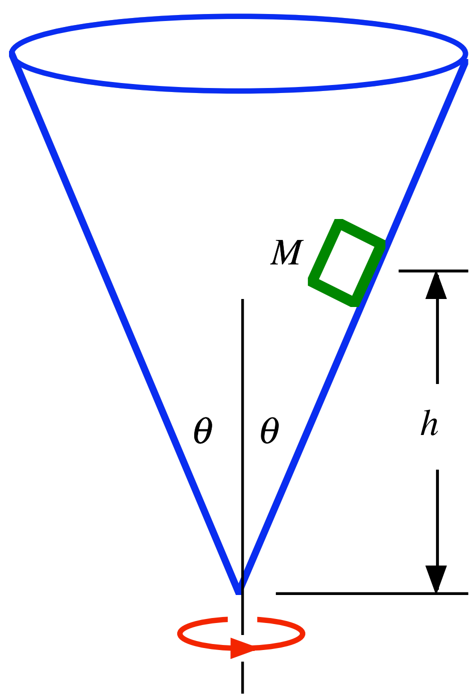


19.) A small block of mass M is placed inside an inverted cone that is rotating about a vertical axis at a constant rate such that the time for one revolution of the cone is its period τ. The walls of the cone make an angle θ with the vertical, as represented in the diagram below. The coefficient of static friction between the block and the cone is μ_s. Do the following:

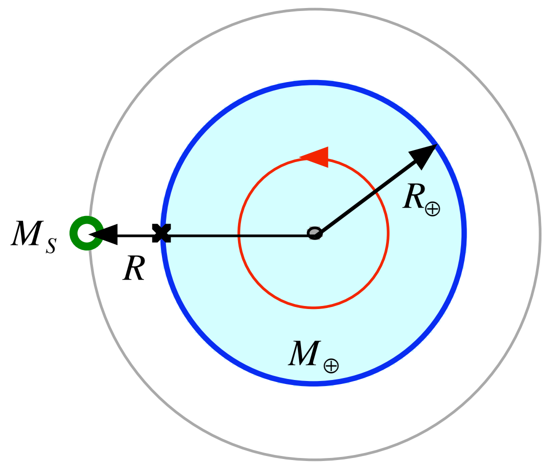
a) Derive an equation for the **minimum period** of the cone for which the block will remain at a constant height h above the apex of the cone.

b) Derive an equation for the **maximum period** of the cone for which the block will remain at a constant height h above the apex of the cone.

(Hint: be sure to draw a careful diagram of the forces acting on the block paying close attention to the static frictional force.)



20.) A satellite of mass M_S orbits the Earth on a circular path of radius R. Determine how far above the surface of the Earth this satellite will be if it remains directly above the same point on the surface of the Earth. Such an orbit is said to be a **geostationary** orbit. (You may approximate the period of the Earth's rotation as twenty-four hours.)



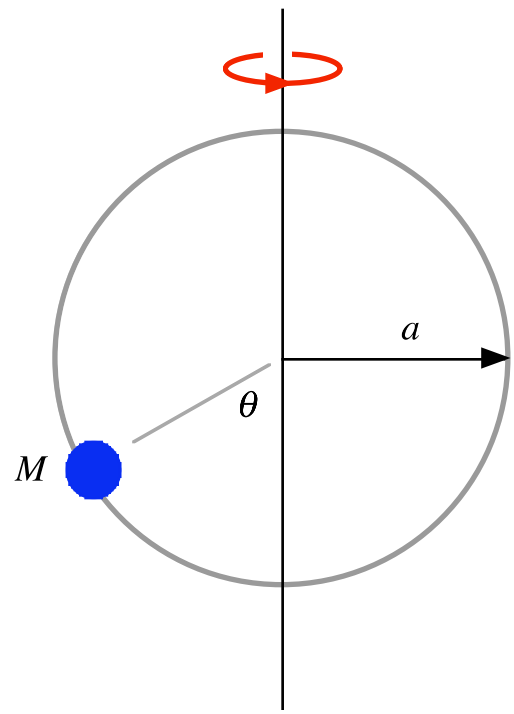
21.) A small bead of mass $M = 0.010\ kg$ is free to slide without friction on a thin, circular hoop of wire. The radius of the hoop is given by $a = 0.100\ m$. The hoop rotates at a constant rate of $3.00\ rev/s$ about a vertical diameter, as represented in the diagram below. Do the following:

a) Draw a clear picture of the relevant forces acting on the bead. Include an appropriate coordinate system.

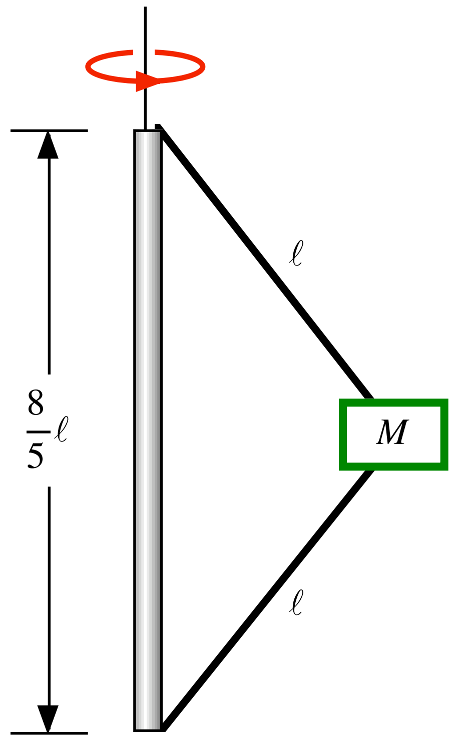
b) Find the angle θ at which the bead is in vertical equilibrium. (There is, of course, a radial acceleration.)

c) At what rate must the hoop rotate if the bead is to "ride" at the same vertical height as the center of the circle?

d) What is the minimum rate at which the hoop must rotate if the angle θ is to be greater than zero?



22.)



A block of mass $M = 4.00\ kg$ is attached to a vertical rod by means of two light strings, as represented in the diagram above. When the rod rotates, the mass extends the strings into the configuration indicated, where $\ell = 1.250\ m$. Do the following:

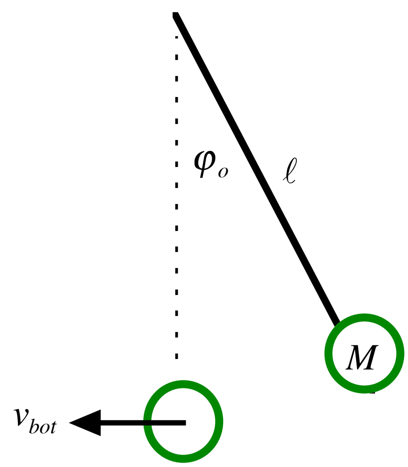
a) Draw an accurate free body diagram of all of the relevant forces acting on the block and set up an appropriate coordinate system.

b) Calculate the angular frequency at which the system must rotate if the tension in the upper string is to be $T_U = 90.00\ N$. Express your answer in *rpm--revolutions per minute*.

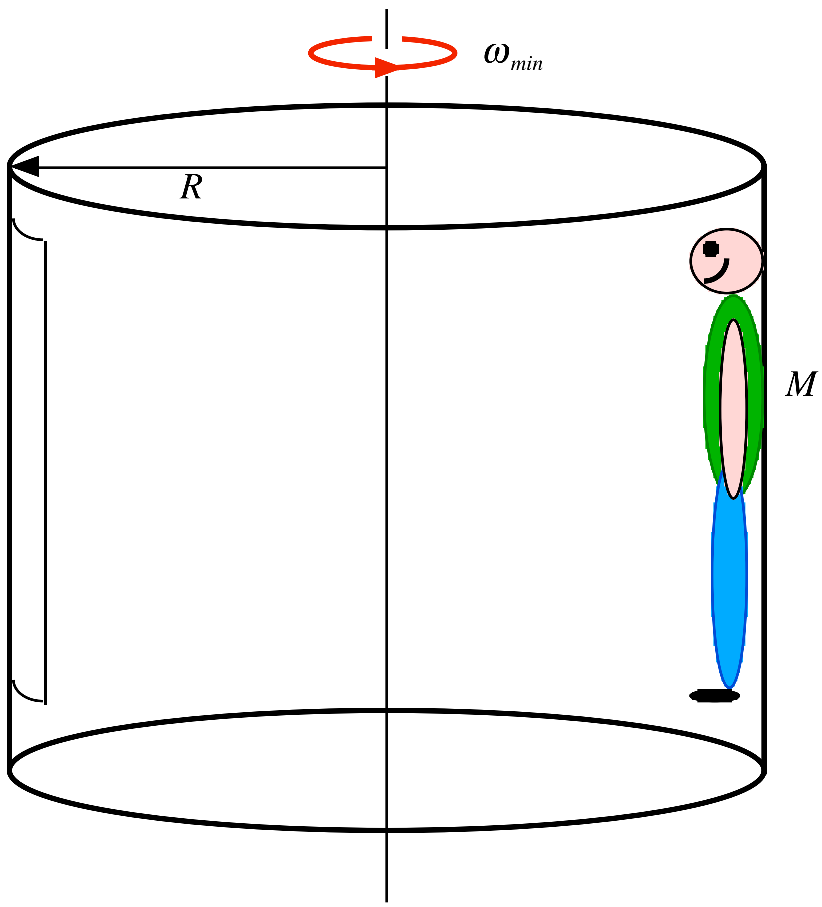
c) Calculate the tension in the lower string, T_L at this same angular frequency.

23.) A small sphere of mass $M = 7.256\ kg$ is attached to one end of a light string of length $\ell = 4.572\ m$. The other end of the string is attached to a frictionless pivot in the ceiling. The sphere is pulled to the side and released from rest. The sphere swings back and forth as a pendulum. When the string passes through the vertical, the sphere is moving with a speed of $v_{bot} = 5.486\ m/s$. Do the following:

a) Draw an accurate representation of the physical states of affairs, including a free body diagram of the relevant forces acting on the sphere, and set up an appropriate coordinate system.
b) Derive a general equation for the magnitude and direction of the tension in the string.
c) Derive a general equation for the magnitude and direction of the acceleration of the sphere.
d) Calculate the acceleration, magnitude and direction, of the sphere at the instant the string passes the vertical.
e) Calculate the magnitude of the tension in the string at this instant it passes the vertical.



24.) A person of mass M walks through a door into a cylinder of radius R that is open at the top. He stands on the floor with his back pressed up against the wall. The cylinder begins to spin about a vertical axis. After the cylinder has reached a certain angular speed, the floor is lowered and the person remains spinning and no longer in contact with the floor. If the coefficient of static friction between his clothes and the wall is μ_s, calculate the minimum angular speed at which the cylinder must be rotate so that it is safe to lower the floor.

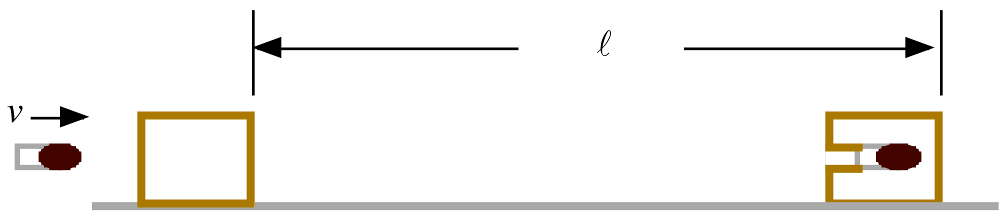


ASSIGNMENT THREE

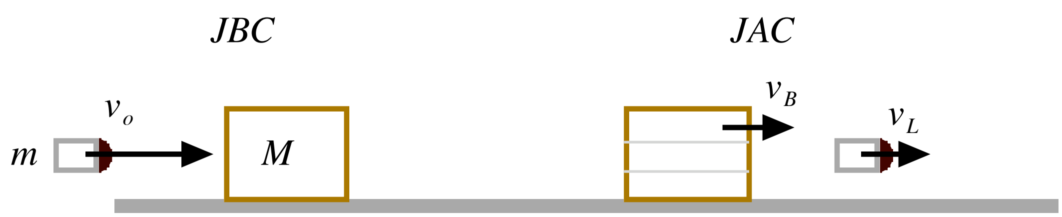
PROBLEMS FOR CHAPTERS ELEVEN THROUGH FIFTEEN

Problems for Chapter 11

1.) A block of mass $M = 5.830\ kg$ is initially at rest on a rough, horizontal surface. A bullet of mass $m = 0.055\ kg$ is moving horizontally with a speed of $v = 380.000\ m/s$ when it collides and embeds in the block. If the coefficient of kinetic friction between the block and the horizontal surface is $\mu_k = 0.820$, determine how far along the surface the block will slide before coming to rest. (Hint, divide the problem into two phases. Phase one: the collision phase in which the linear momentum is conserved. Phase two: the sliding phase in which the system undergoes a constant frictional force.)



2.) A bullet of mass $m = 0.0150\ kg$ is moving horizontally with a speed $v_o = 400.00\ m/s$ when it collides with a stationary, wooden block of mass $M = 2.0000\ kg$ initially at rest on a level, frictionless surface, as represented in the diagram below. After passing through the wooden block, the bullet has a speed of $v_L = (1/4)v_o$. Use this information to determine the speed, v_B, of the wooden block just after the collision. (You may assume that there is no mass loss in the collision.)



3.) A bullet of mass m emerges from the muzzle of a gun with a speed of $v = 300.00 \ m/s$. The net force on the bullet, while it is in the barrel of the gun, is given by

$$F = (400 \ N) - (1.333 \times 10^5 N/s)t,$$

where t is the time in the barrel in *seconds*.

a) If the force on the bullet is zero at the end of the barrel, compute the time the bullet is in the barrel.
b) Calculate the magnitude of the average force.
c) Calculate the magnitude of the average impulse.
d) Calculate the mass of the bullet.

Problems for Chapter 12

1.) Do the following:

a) What angle, measured in *radians*, is subtended by an arc of length $\Delta\ell = 5.000\ m$ on the circumference of a circle the radius of which is $R = 2.000\ m$. What is the measure of this angle in *degrees*?

b) The angle between two radii of a circle with radius $R = 1.500\ m$ is $0.600\ rad$. What length of arc is intercepted on the circumference of the circle by the two radii?

c) An arc of length $\Delta\ell = 0.450\ m$ on the circumference of a circle subtends a central angle of $42.00°$. Calculate the radius of the circle.

2.) A circular flywheel of radius $R = 0.125\ m$ rotates with a constant angular frequency of $3800\ rpm$ (*revolutions per minute*). Calculate the following:

a) The angular speed of the flywheel.
b) The radial acceleration (centripetal) of a point on the rim of the flywheel.
c) The angle through which a point on the rim of the flywheel would pass in a time interval of two *seconds*.
d) The magnitude of the tangental speed of a point on the rim of the flywheel.

3.) A bicycle wheel of radius $R = 0.3302\ m$ has an initial angular speed of $2.200\ rad/s$. The wheel is subjected to a **constant angular acceleration** of magnitude $0.200\ rad/s^2$. What is the angular speed of the wheel at the instant it has turned through 3.500 *revolutions*? What is the magnitude of the radial acceleration at a point on the rim of the wheel at this instant?

4.) A right circular cylinder of radius $R = 0.125\ m$ requires three *seconds* to rotate through $186.00\ rad$. At the end of this time, the cylinder has an angular speed of $108.00\ rad / s$. Assuming a **constant angular acceleration**, find

a) the angular speed at the beginning of the three *second* interval;
b) the magnitude of the angular acceleration.

5.) A circular disk of radius $R = 1.500\ m$ rotates with a constant angular speed of $16.00\ rad / s$ in a clockwise sense about a horizontal axle that passes through the center of the disk and is perpendicular to the circular plane of the disk.

a) Calculate the magnitude of the radial (centripetal) acceleration of a point P_1 a distance $r_{\perp P_1} = 0.500\ m$ from the center of the disk.

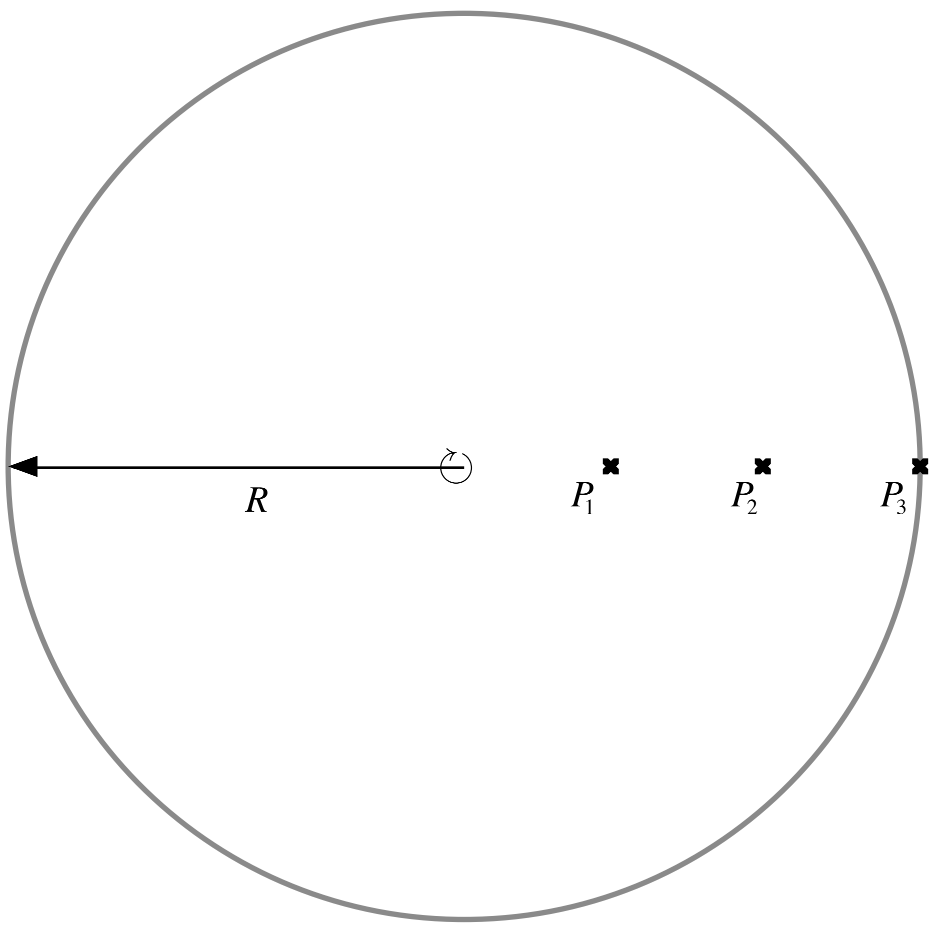
b) Calculate the tangential speed of point P_1.

c) Calculate the magnitude of the radial (centripetal) acceleration of a point P_2 a distance $r_{\perp P_2} = 1.000\ m$ from the center of the disk.

d) Calculate the tangential speed of point P_2.

e) Calculate the magnitude of the radial (centripetal) acceleration of a point P_3 a distance $r_{\perp P3} = 1.500\ m$ from the center of the disk.

f) Calculate the tangential speed of point P_3.



6.) A wheel of radius $R = 0.350\ m$, having started from rest, acquires an angular speed $125\ rad/s$ in a time interval of $15.25\ s$. Assuming a constant angular acceleration, do the following:

a) Calculate the angular acceleration of the wheel over this time interval.

b) Calculate the magnitude of the radial (centripetal) acceleration of a point on the rim of the wheel at the instant the wheel is rotating at $125\ rad/s$.

c) Calculate the tangential speed of point on the rim of the wheel at this same instant.

7.) An automobile engine is idling at $500\ rpm$. Five *seconds* after the accelerator is engaged, the engine tachometer indicates $3000\ rpm$. Assuming a constant angular acceleration, calculate:

a) The initial and final angular speeds in *radians per second*.
b) The angular acceleration in *radians per second squared*.
c) How many revolutions the engine's crankshaft made in this time interval.
d) The tangential speed of a point on the rim of the flywheel, if the flywheel of the engine has a a diameter of $0.295\ m$ and the tachometer reads $3000\ rpm$.
e) The radial acceleration of a point on the rim of the flywheel, if the tachometer reads $3000\ rpm$.
f) The tangential acceleration of a point on the rim of the flywheel during the constant angular acceleration.

Problems for Chapter 13

1.) A point mass $M = 1.250\ kg$ is moving in a Cartesian coordinate system with an instantaneous velocity given by $\vec{v} = 35.75\ m/s\ \hat{i} - 27.43\ m/s\ \hat{j} - 41.17\ m/s\ \hat{k}$. At the instant the point mass has this velocity, it is located at a position given by $\vec{r} = 4.00\ m\ \hat{i} + 7.00\ m\ \hat{j} - 12.00\ m\ \hat{k}$. Calculate the instantaneous angular momentum of this point mass with respect to the origin of the Cartesian coordinate system with respect to which we have given its velocity and position.

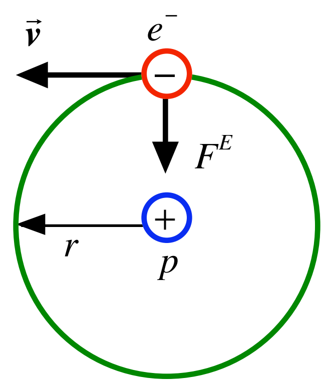
2.) The Sun has a mass of $M_{\odot} = 1.99 \times 10^{30}\, kg$ and rotates on it own axis. The rotational period for a point at the equator of the Sun is $25.05\ days$. If we model the Sun as a rigid body, calculate the spin angular momentum of the Sun about its own axis. (The Sun is by no means a rigid body. Points closer to the "poles" take closer to thirty-four days to rotate once. This differential rotation rate gives rise to many interesting solar phenomena, including Sun spots.)

3.) In monatomic hydrogen, a single electron "orbits" a solitary proton. If we model this orbit as circular, then the force that holds the electron on its orbit is called the electrical force and its magnitude is given by

$$F^E = \frac{ke^2}{r^2}\ , \qquad (1)$$

where k is the electrical constant, e is the magnitude of electric charge on both the electron and the proton, and r is the distance between the electron and the proton. Use this force and the equations for circular motion to derive an equation for the orbital angular momentum of the electron. Using the following accepted values, calculate a number for the orbital angular momentum of the electron.

$k = 8.99\times10^9\,Nm^2/C^2$, $e = 1.602\times10^{-19}\,C$, $r = 5.3\times10^{-11}\,m$, $M_{e^-} = 9.11\times10^{-31}\,kg$.



Problems for Chapter 14

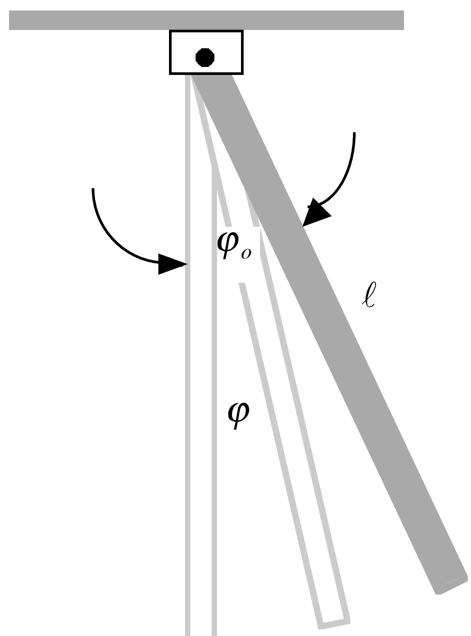
1.) A uniformly thin vertical rod of mass $M = 12.50\ kg$ and length $\ell = 2.250\ m$ is attached to a horizontal ceiling by a frictionless pivot at one end of the rod, as represented in the diagram below. The rod is initially displaced through an angle, with respect to the vertical, of $\varphi_o = 25.00°$. Do the following:

a) Draw an accurate free-body diagram of all of the relevant forces acting on the rod at an arbitrary angle φ.

b) Derive an equation for the angular acceleration of the rod at an arbitrary angle φ. It should have the functional form $\alpha = \alpha(g, \varphi, \ell, M)$.

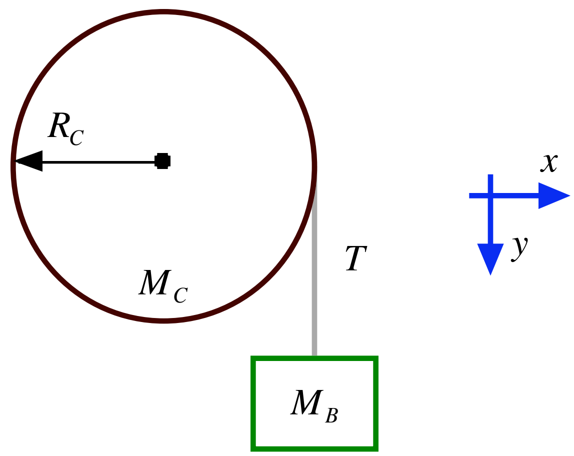
c) Using the equation found in part b), calculate the magnitude of the angular acceleration at the instant the rod is released from rest.

d) Using the equation found in part b), calculate the magnitude of the angular acceleration at the instant the rod passes through the vertical.



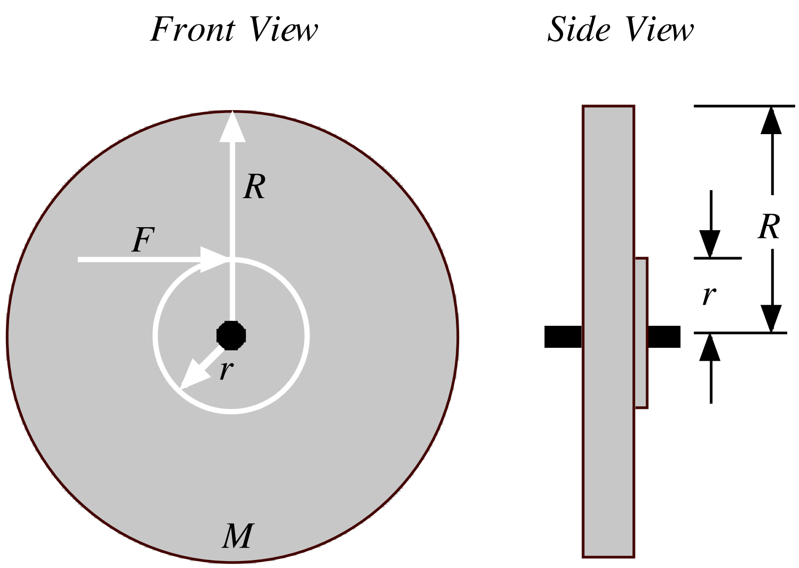
2.) One end of a light string is attached to a cylinder of mass $M_C = 9.500\ kg$ and radius $R_C = 0.150\ m$, as represented in the diagram below. In turn, the string is wrapped around the cylinder, and a block of mass $M_B = 5.000\ kg$ is attached to the free end of the string. Recall that the moment of inertia of a cylinder about its symmetry axis is given by $I_C = (1/2) M_C R_C^2$. The system is released from rest. Do the following:

a) Draw a correct free-body diagram of all of the relevant forces acting on the cylinder and the block.
b) Determine the magnitude of the linear acceleration of the block.
c) Determine the magnitude of the angular acceleration of the cylinder.
d) Determine the speed of the block at the instant it has moved a distance of $\ell = 3.000\ m$.



3.) A uniform circular disk of mass $M = 4.000\ kg$ and radius $R = 0.180\ m$ is free to rotate about a fixed, frictionless, horizontal axle. The moment of inertia of the disk can be approximated by $I = (1/2)MR^2$. The disk is initially at rest. A **constant force** $F = 76.08\ N$ is applied to the hub of the disk for which the radius is $r = 0.060\ m$, as represented in the diagram below. Do the following:

a) Determine the magnitude of the net torque exerted on the disk.
b) Determine the magnitude of the angular acceleration of the disk.
c) Determine the angular speed of the disk at the instant it has turned through a total angle $\Delta\varphi = 147\ radians$.

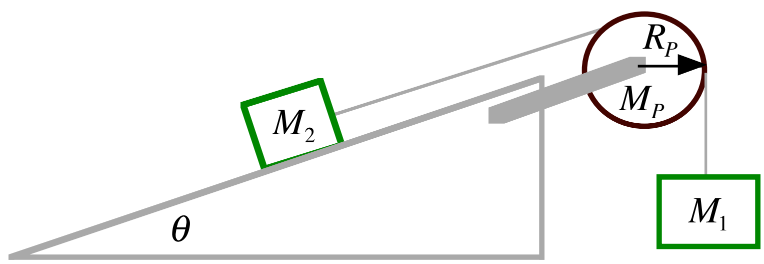


4.) A block of mass $M_1 = 8.000\ kg$ is attached to one end of a light string. Attached to the other end of the string is a second mass $M_2 = 4.000\ kg$. Also, the string is draped over a pulley of mass $M_P = 2.000\ kg$ and radius $R_P = 0.140\ m$, as represented in the diagram below. Initially, the first block is hanging vertically while the second block sits on a rough inclined plane. The plane is inclined an angle of $\theta = 25.00°$ to the horizontal and the coefficient of kinetic friction is $\mu_k = 0.250$. The system is released from rest. Do the following:

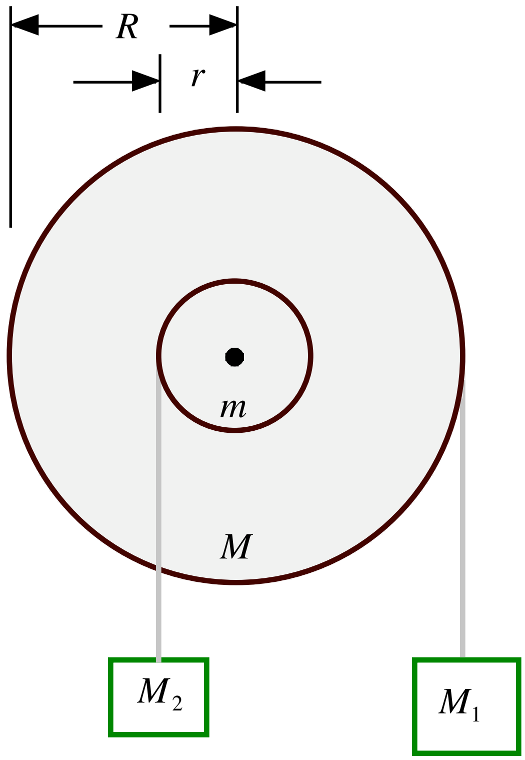
a) Draw a correct free-body diagram of the relevant forces acting on each block and on the pulley

b) Determine the magnitude of the linear acceleration of each block.

c) Determine the speed of each block at the instant they have moved a distance $\ell = 5.750\ m$. (You may assume that there is friction between the rope and the pulley, and assume that there is no friction on the axle of the pulley. Recall that for a cylindrical object with respect to its major axis of symmetry, $I = (1/2)MR^2$.)



5.) Challenge Problem:



A circular cylinder of mass M and radius R has a light string wrapped around its rim. Attached to one end of the string is a block of mass M_1. This cylinder is free to rotate about a horizontal axle passing through the center of the cylinder and perpendicular to the plane of the cylinder. A second, coaxial cylinder of mass m and radius r is welded onto the first cylinder. A second string is wound around the second cylinder and a second mass M_2 is attached to one end of the second string, as represented in the diagram above. The system is released from rest. Do the following:

a) Draw a correct free-body diagram of all of the relevant forces acting on the system: block one, block two and the cylinders that are welded together.

b) Determine the magnitude of the linear acceleration of each block. (Hint, the magnitudes of the linear accelerations of the two blocks are not equal!)

c) Determine the magnitude of the speed of each block at the instant block M_1 has moved a vertical distance $\ell = 0.750 \ m$.

(Assume the masses are related by $M = 9m = M_1 = 3M_2 = 18.00 \ kg$ and the radii are related by $R = 3r = 0.120 \ m$.)

6.) A block of mass M_1 is connected to one end of a massless, inextensible string, as represented in the diagram below. Block one is constrained to move over a level, rough surface for which the coefficient of kinetic friction is $\mu_k = 0.352$. Another block of mass M_2 is attached to the other end of the string. Also, the string is draped over a pulley of mass M_p and radius $R = .100\ m$. The masses are related by $M_1 = (2/3)M_2 = 3M_P = 6.000\ kg$. There is friction between the string and the pulley, but the pulley is free to rotate about a frictionless axle. The system is released from rest. Do the following:

a) Draw a free-body diagram of the relevant forces acting on each block and on the pulley.
b) Determine the magnitude of the linear acceleration of each block.
c) Determine the speed of each block at the instant each block has moved a distance $\ell = 0.750\ m$
d) Redo this problem assuming that block one moves on a **frictionless** surface

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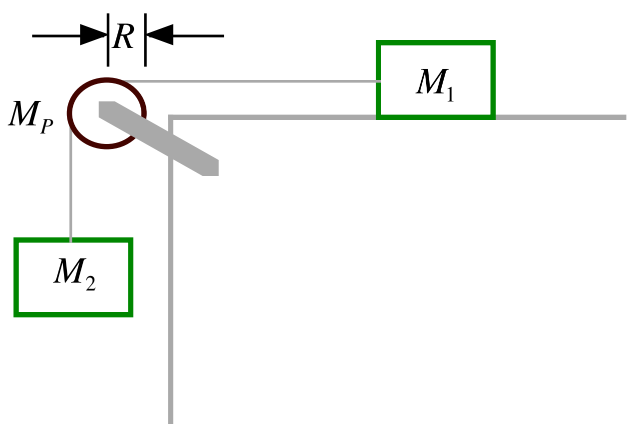
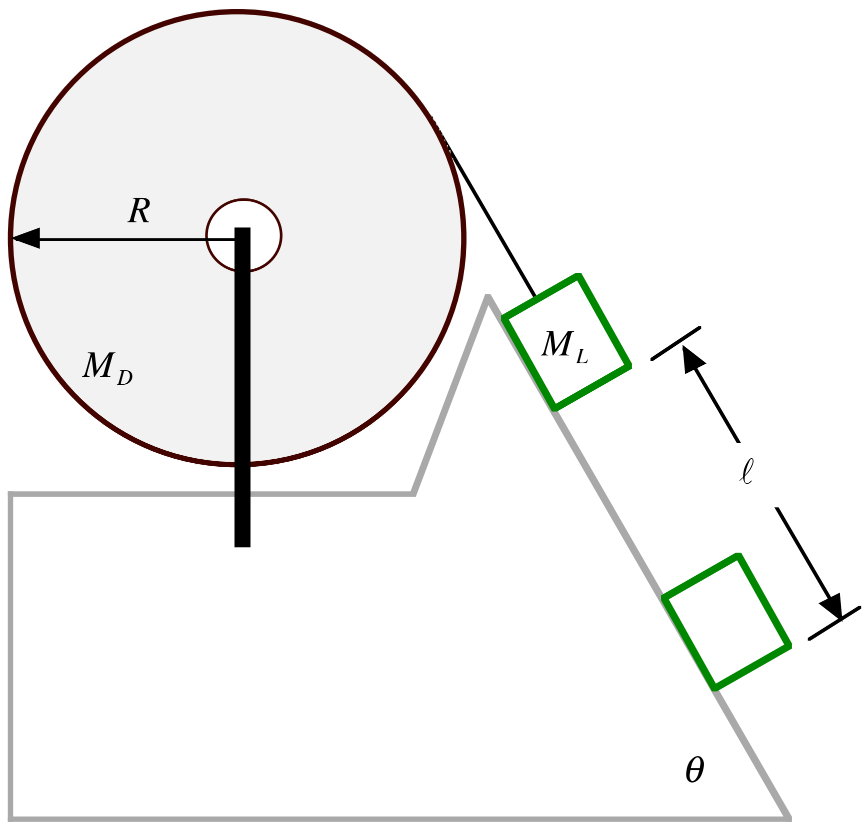


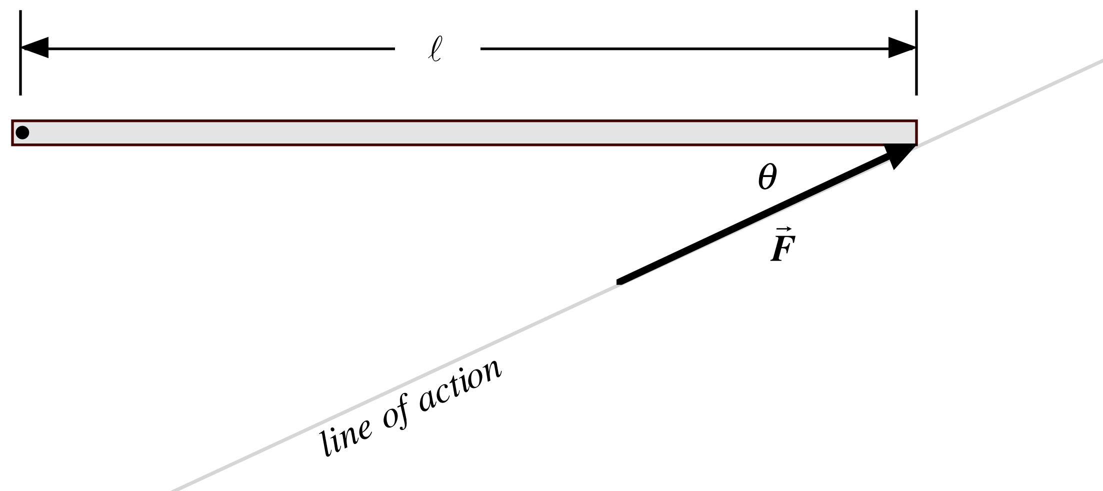
7.) A cylindrical disk of mass $M_D = 75.000\ kg$ and radius $R = 0.450\ m$ is free to rotate about a horizontal axle through the center of the disk perpendicular to the plane of the disk, as represented in the diagram below. One end of a light, flexible cable is attached to the disk and wrapped around the disk. A block of mass $M_L = 125.00\ kg$ is attached to the other end of the cable. (There is friction between the disk and the cable.) Recall that the moment of inertia of a disk about its major axis of symmetry is given by $I_{disk} = (1/2) M_{disk} R_{disk}^2$. The block is released from rest and constrained to move on a **frictionless incline**. The incline makes an angle $\theta = 60°$ to horizontal. Determine the following:

a) The magnitude of the acceleration of the block along the incline.
b) The magnitude of the angular acceleration of the disk.
c) The speed of the block at the instant it has moved a distance $\ell = 1.250\ m$.

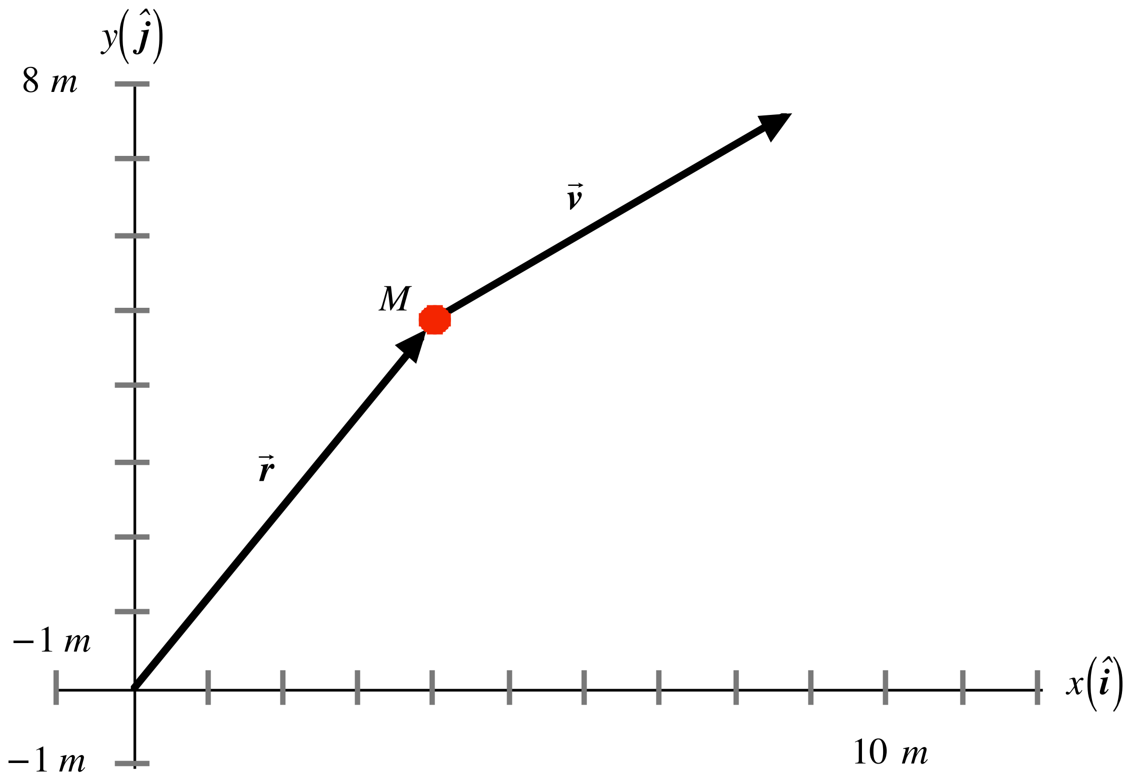


8.) A thin rod of mass $M = 12.000\ kg$ and length $\ell = 2.000\ m$ is free to rotate on top of a horizontal, **frictionless plane** about a vertical axis at one end of the rod, as represented in the diagram below. (Seen from a position above the rod.) A force of constant magnitude $F = 21.500\ N$ is applied at the free end of the rod. The force is applied at a constant angle of $\theta = 25.00°$ with respect to the rod. The moment of inertia of a thin rod with respect to an end point is given by $I_R = (1/3) M_R \ell_R^2$. Determine the following:

a) The magnitude of the net torque exerted on the rod.
b) The magnitude of the angular acceleration that would result from the net torque.



9.)

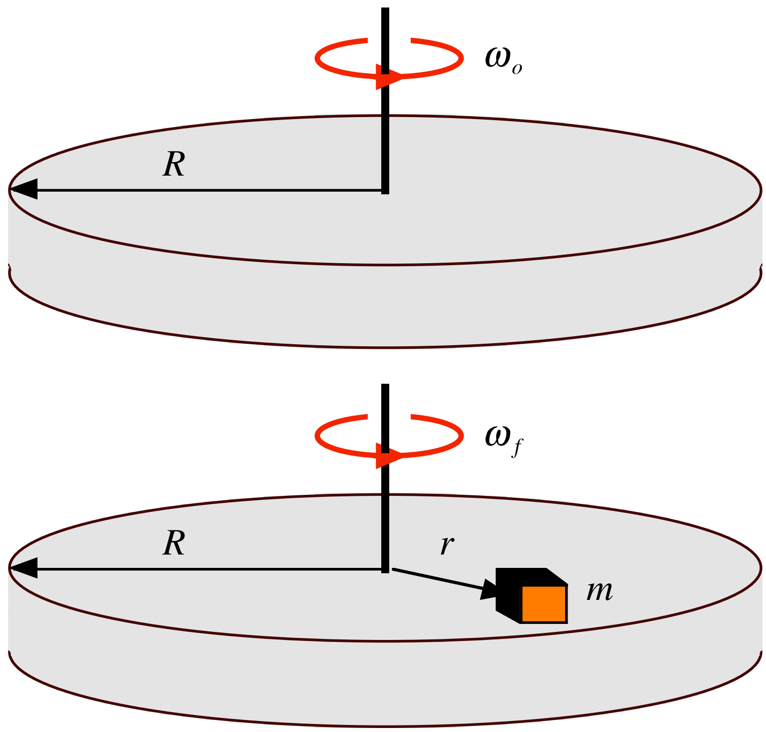


A point mass $M = 3.234\ kg$ is moving with an instantaneous velocity given by $\vec{v} = v\,\hat{v} = (26.500\ m/s)\left[\cos 30^\circ\ \hat{i} + \cos 60^\circ\ \hat{j}\right]$, as represented in the diagram above. The instantaneous position of this point mass at this time is given by $\vec{r} = 4.000\ m\ \hat{i} + 5.000\ m\ \hat{j}$. Use this information to determine the following:

a) The instantaneous linear momentum of the point mass.

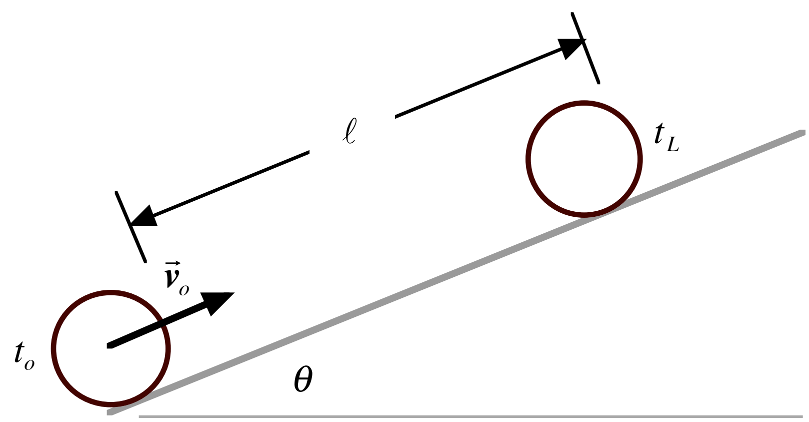
b) The instantaneous angular momentum of the point mass relative to the origin.

10.) A turntable of mass $M = 148\ kg$ and radius $R = 10\ m$ is initially rotating with an angular speed of $\omega_o = 12\ rad/s$. Calculate the final angular speed of the turntable after a sandbag has been dropped onto the disk from a short distance above the disk. You may assume that during the brief collision, the angular momentum is conserved. Note that $m = 25\ kg$ and $r = (2/3)R$.



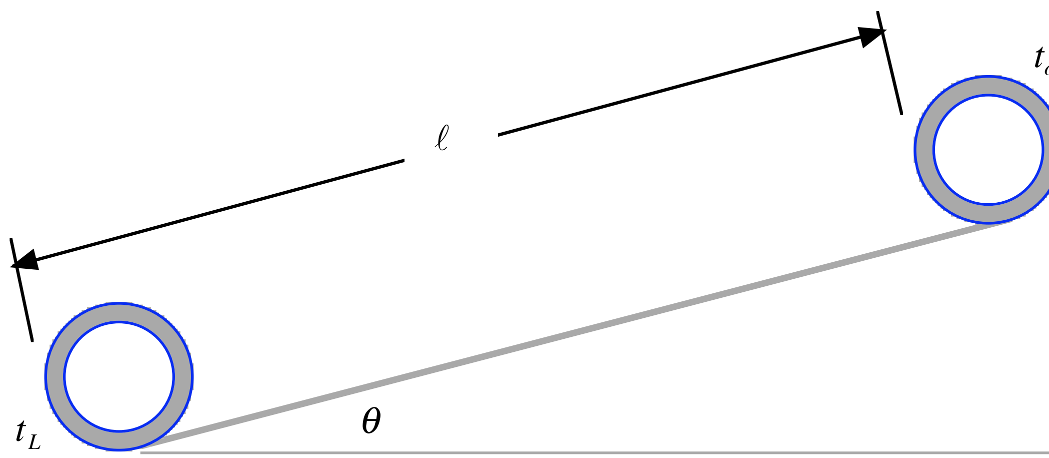
11.) The center of a **hollow sphere** of mass $M = 0.642\ kg$ and radius $R = 0.120\ m$ has a translational speed of $v_o = 13.68\ m/s$ when it begins to roll without slipping **up** an inclined plane. The plane is inclined an angle $\theta = 22°$, with respect to the horizontal, as represented in the diagram below. Recall that the moment of inertia of a hollow sphere about any diameter is given by $I_{hs} = (2/3) M_{hs} R_{hs}^2$. Use this information to do the following:

a) Draw an accurate free-body diagram of the relevant forces acting on the hollow sphere.
b) Calculate the magnitude of the translational acceleration of the center of the hollow sphere with respect to the incline.
c) Calculate the magnitude of the angular acceleration of the hollow sphere with respect to its center.
d) Calculate the distance ℓ along the incline the center of the hollow sphere will move before coming to instantaneous rest.
e) Determine the value of the coefficient of friction, μ. (You may assume that $f = \mu \mathcal{N}$).



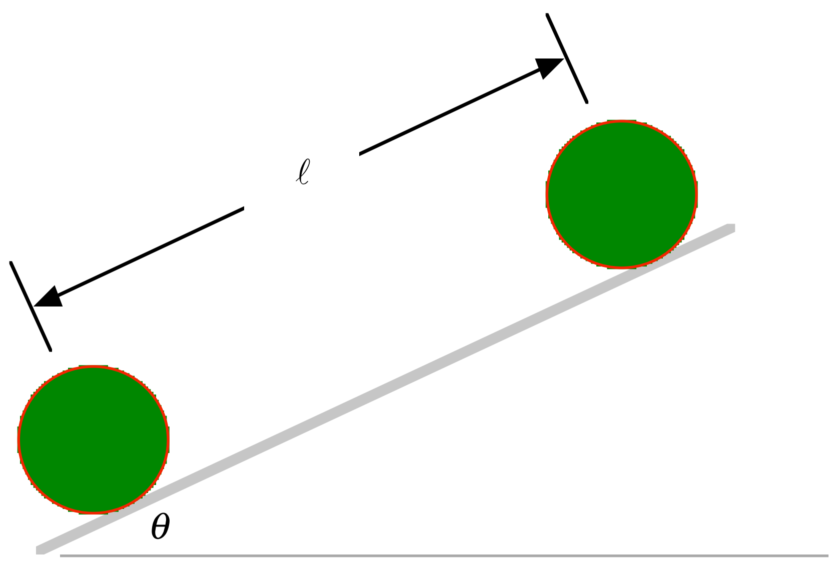
12.) A thin hoop of radius $R = 0.160\ m$ and mass $M = 0.875\ kg$ is released from rest at the top of an inclined plane, as represented in the diagram above. The hoop rolls without slipping along the incline that is inclined an angle of $\theta = 15°$, with respect to the horizontal. Recall that the moment of inertia of a thin hoop about its major axis of symmetry is given by $I_{hoop} = M_{hoop} R^2_{hoop}$. Do the following:

a) Draw an accurate free-body diagram of the relevant forces acting on the hoop.
b) Calculate the translational acceleration of the center of the hoop relative to the incline.
c) Determine the magnitude of the angular acceleration of the hoop.
d) Calculate the instantaneous speed of the center of the hoop at the instant it has moved a distance $\ell = 1.500\ m$ along the incline.
e) Determine the value of the coefficient of friction, μ. (You may assume that $f = \mu \mathcal{N}$).

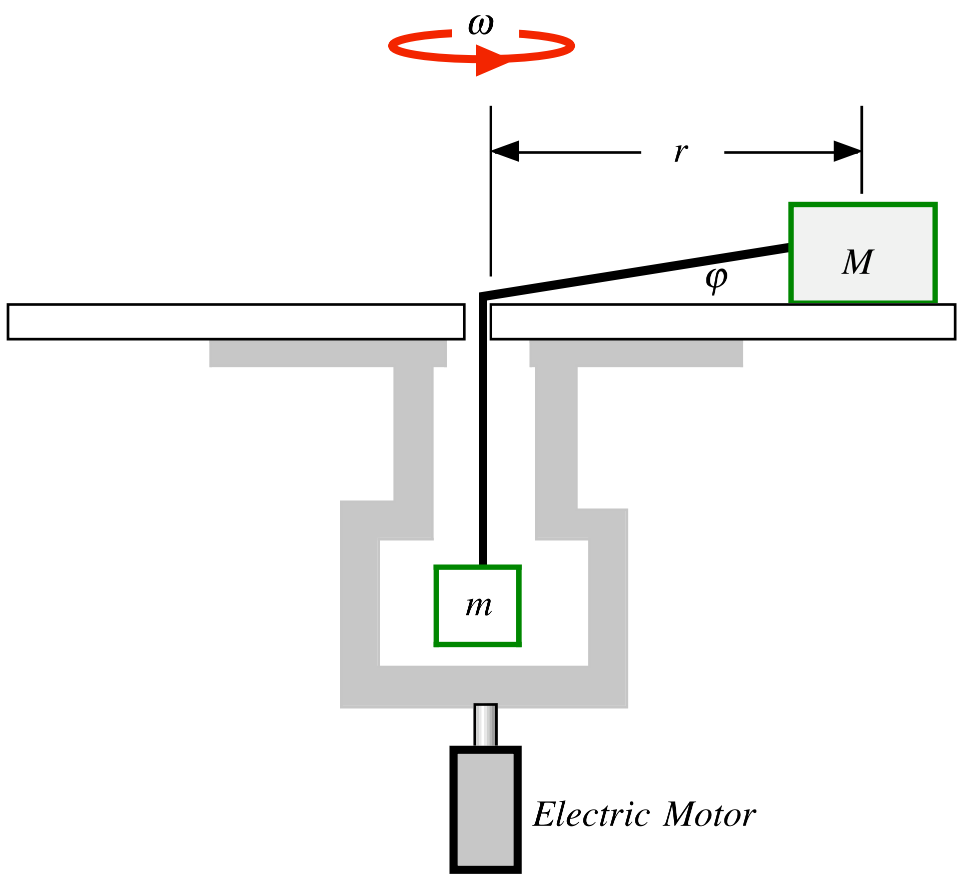


13.) A uniform cylinder of mass $M = 0.736\ kg$ and radius $R = 0.558\ m$ is released from rest at the top of an inclined plane, as represented in the diagram below. The cylinder rolls without slipping along the incline. The incline makes an angle of $\theta = 25°$ to the horizontal. The moment of inertia of the cylinder is, with respect to its axis of rotation, $I = 0.1146\ kg\,m^2$. Use this information to do the following:

a) Draw an accurate free-body diagram of the relevant forces acting on the cylinder.
b) Calculate the translational acceleration of the center of the cylinder relative to the incline.
c) Determine the magnitude of the angular acceleration of the cylinder with respect to its center.
d) Calculate the instantaneous speed of the cylinder at the instant it has moved a distance $\ell = 1.500\ m$.
e) Determine the value of the coefficient of friction, μ. (You may assume that $f = \mu\mathcal{N}$).



14.) Challenge Problem: A block of mass M sits on a horizontal turntable that rotates at a constant angular speed ω, as represented in cross-section in the diagram below. A smooth string of negligible mass runs from the block through a hole in the center of the turntable and is attached to a hanging mass m. The coefficient of static friction between mass M and the surface of the turntable is μ. Find the largest and smallest values of r for which mass M will not slip as it rotates. (Smooth string means there is no friction where the string makes contact with the turntable.)



Problems for Chapter 15

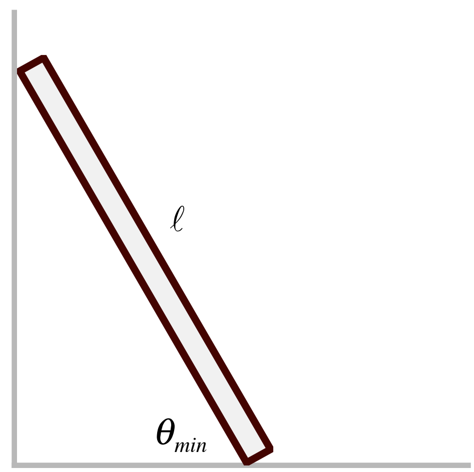
1.) A uniform ladder of mass $M = 46.00\ kg$ and length $\ell = 1.750\ m$ leans against a smooth vertical wall while sitting on a level rough floor. The coefficients of friction are related by $\mu_s = 2\mu_k = 0.426$. Do the following:

a) Draw a correct free-body diagram of all of the relevant forces acting on the ladder.

b) Determine the minimum angle θ_{min}, measured with respect to the floor, at which the ladder will begin to slip on the floor.

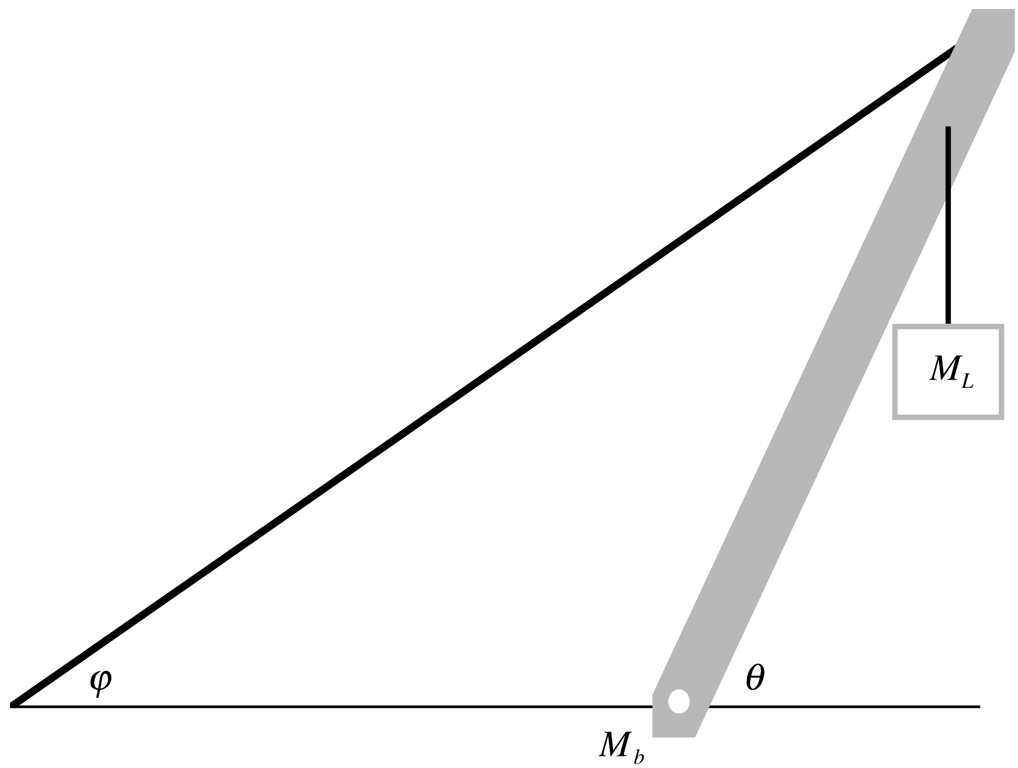
c) If a person of mass $M_p = C_1 M$, where $C_1 > 0$, is standing on the ladder, a distance $\ell' = C_2 \ell$ from the base of the ladder, where $0 < C_2 \leq 1$, derive an equation for the θ_{min}.

d) Using the equation you found in part c), calculate θ_{min} if $C_1 = 6C_2 = 2$.



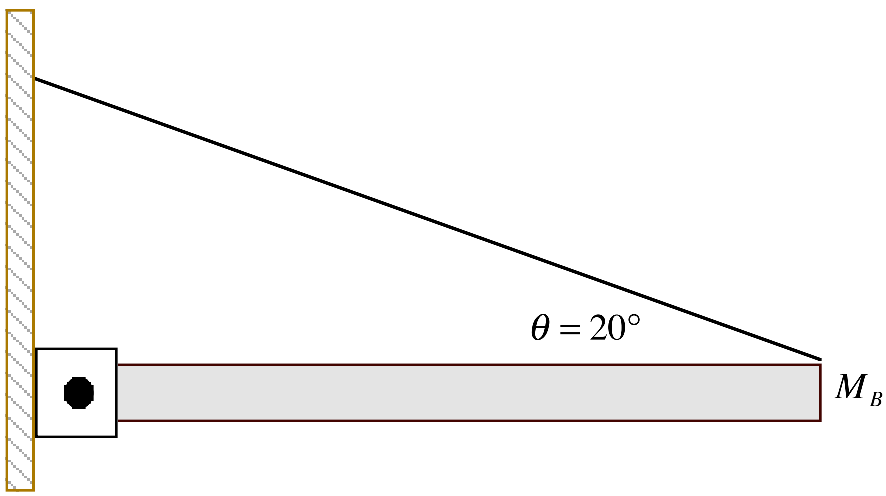
2.) A uniform beam of mass $M_b = 80.00\ kg$ and length $\ell = 10.00\ m$ is free to pivot about a frictionless pin at its base. A load of mass $M_L = 360.00\ kg$ is attached to the beam at a distance of four-fifths of the length of the beam from its base. The beam is inclined an angle $\theta = 65.00°$ to the horizontal. One end of a cable is attached to the end of the beam while the other end is attached to the ground. The cable makes an angle $\varphi = 35.00°$ to the horizontal, as represented in the diagram below. The system is in static equilibrium. Do the following:

a) Draw a correct free-body diagram of the relevant forces acting on the beam and the load mass.
b) Determine the magnitude of the tension in the cable that is attached to the load mass.
c) Determine the magnitude of the tension in the cable that is attached to the ground.
d) Determine the magnitude of the horizontal and vertical components of force exerted on the beam by the pin.



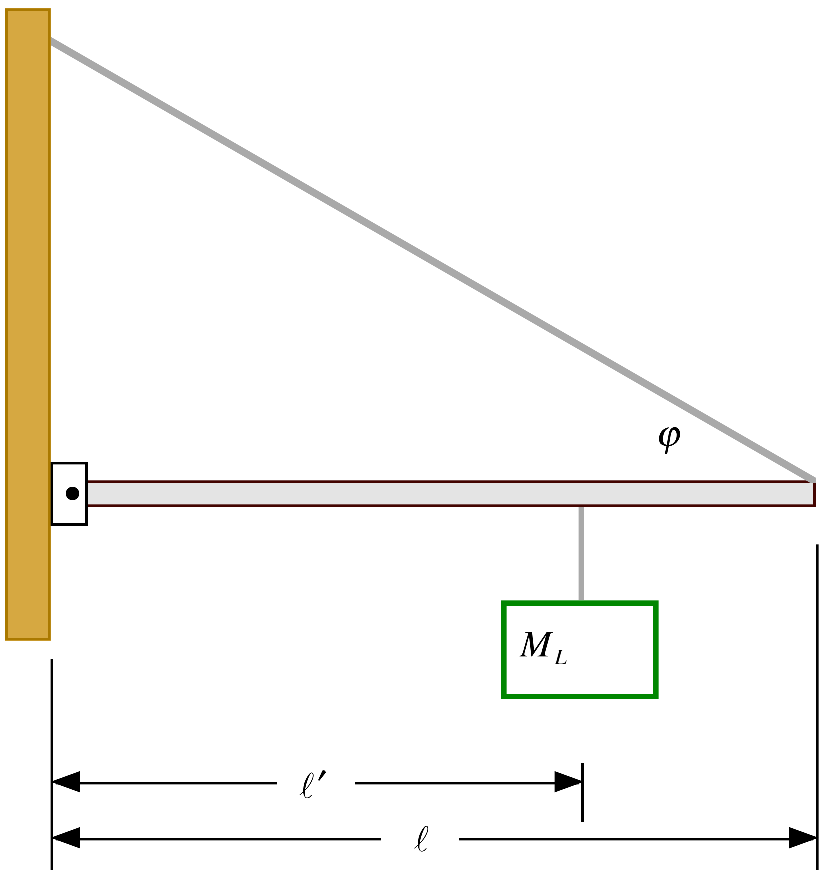
3.) A uniform steel beam of mass $M_B = 80.00\ kg$ and length $\ell = 4.00\ m$ is attached to a vertical wall by means of a frictionless, horizontal pin in a hinge assembly. The other end of the beam is held up by means of a massless, flexible, inextensible cable that is also attached to the wall, as represented in the diagram below. The beam is in static equilibrium. Do the following:

a) Draw a correct free-body diagram of the relevant forces acting on the beam.
b) Determine the magnitude of the tension in the cable that is attached to the wall.
c) Determine the magnitude of the horizontal and vertical components of force exerted on the beam by the pin.



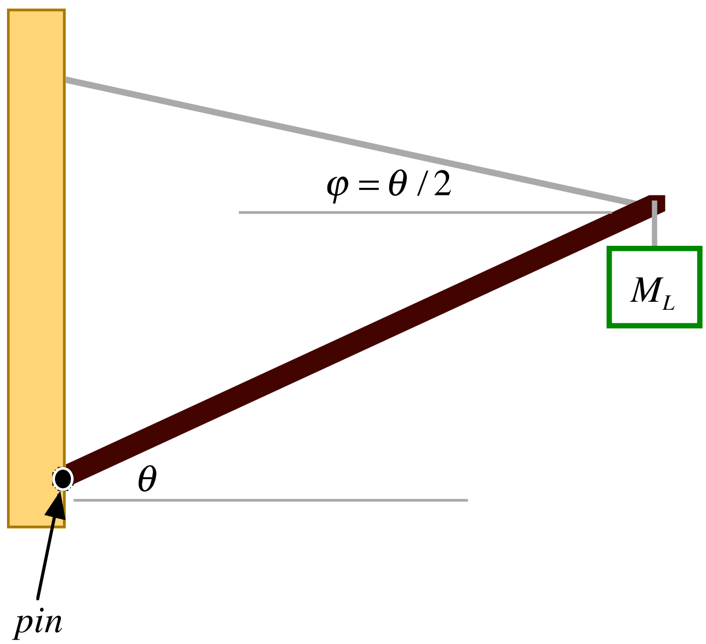
4.) A thin beam of length $\ell = 4.50\ m$ and mass $M_B = 55.0\ kg$ is in static equilibrium, as represented in the diagram below. The beam supports a load of mass $M_L = 500.0\ kg$ that is suspended at a point a distance $\ell' = (3/4)\ell$ from the end of the beam where there is a pin about which the beam is free to rotate. There is a light cable on the end of the beam opposite the pin that makes an angle of $\varphi = 30°$ with respect to the beam. Do the following:

a) Draw a correct free-body diagram of the relevant forces acting on the beam and the load mass.
b) Determine the magnitude of the tension in the cable that is attached to the load mass.
c) Determine the magnitude of the tension in the cable that is attached to the wall.
d) Determine the magnitude of the horizontal and vertical components of force exerted on the beam by the pin.



5.) A uniform beam of mass $M_B = 25.0\ kg$ and length $\ell = 8.00\ m$ is pivoted at one end about a pin. The other end of the beam is attached to a cable. In turn, the cable is attached to a vertical wall. The beam makes an angle of $\theta = 25°$ to the horizontal. A load of mass $M_L = 6M_B$ is suspended from one end of the beam, as represented in the diagram below. If the system is in static equilibrium, do the following:

a) Draw a correct free-body diagram of the relevant forces acting on the beam and the load mass.
b) Determine the magnitude of the tension in the cable that is attached to the load mass.
c) Determine the magnitude of the tension in the cable that is attached to the wall.
d) Determine the magnitude of the horizontal and vertical components of force exerted on the beam by the pin.



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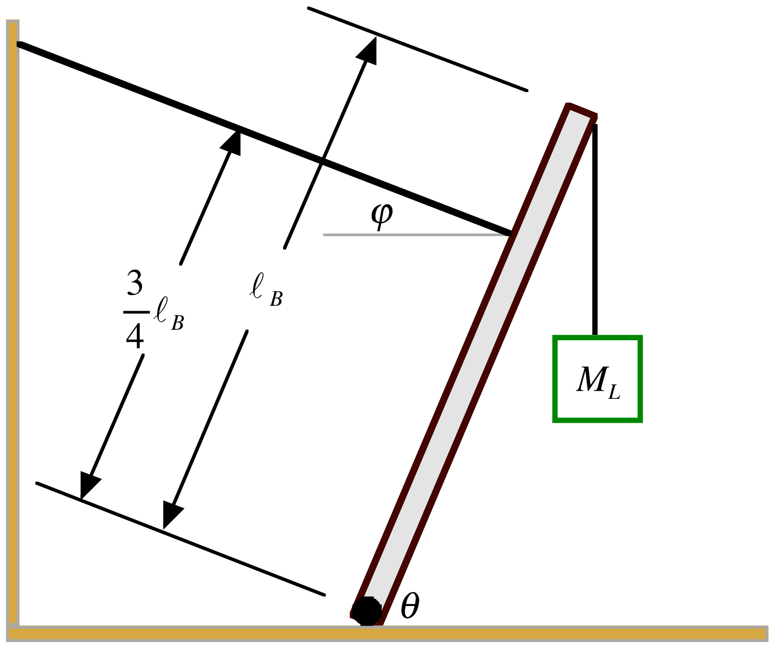
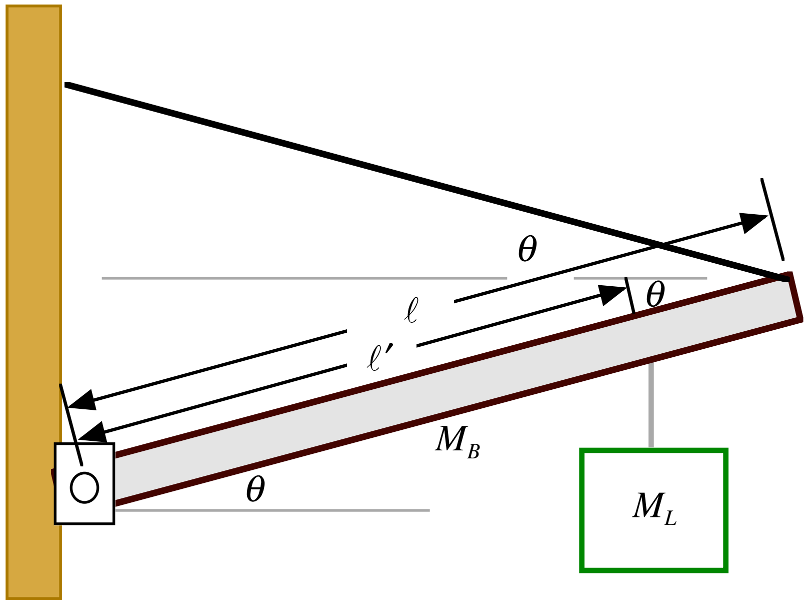


A uniform boom of mass $M_B = 20.0\ kg$ and length $\ell_B = 8.00\ m$ is free to pivot about a hinge assembly at its base. At the end of the boom is suspended a load of mass $M_L = 40.0\ kg$, as represented in the diagram above. To keep the boom from tipping over, one end of a massless, flexible, inextensible cable is attached to the boom at a point a distance of three-fourths of the length of the boom from the pivot. The other end of this cable is fixed to a vertical wall. If the boom is in static equilibrium, and $\theta = 2\varphi = 60°$, do the following:

a) Draw a correct free-body diagram of the relevant forces acting on the beam and the load mass.
b) Determine the magnitude of the tension in the cable that is attached to the load mass.
c) Determine the magnitude of the tension in the cable that is attached to the wall.
d) Determine the magnitude of the horizontal and vertical components of force exerted on the beam by the pin.

7.)



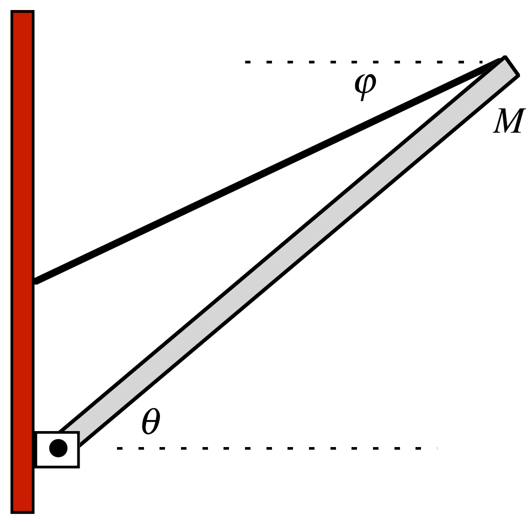
A uniform beam of length $\ell = 10.00\,m$ and mass $M_B = 255\,kg$ is in static equilibrium oriented at an angle of $\theta = 15.00°$ to the horizontal, as represented in the diagram above. One end of the beam is attached to a massless, flexible, inextensible cable. The cable is attached to a vertical wall. The other end of the beam is attached to a hinge by means of a frictionless pin. A mass of $M_L = 544\,kg$ hangs from the beam at a point that is a distance $\ell' = (4/5)\ell$ along the beam with respect to the pin. Do the following:

a) Draw a correct free-body diagram of the relevant forces acting on the beam and the load mass.
b) Determine the magnitude of the tension in the cable that is attached to the load mass.
c) Determine the magnitude of the tension in the cable that is attached to the wall.
d) Determine the magnitude of the horizontal and vertical components of force exerted on the beam by the pin.

8.) A beam of mass M and length ℓ is free to rotate about a horizontal pin that passes through one end of the beam, as represented in the diagram below. The beam makes an angle θ to the horizontal. A cable is attached to the beam and a vertical wall making an angle φ with respect to the horizontal. Assuming static equilibrium, derive equations for the following:

a) The tension in the cable.
b) The horizontal force exerted on the beam by the pin.
c) The vertical force exerted on the beam by the pin.
d) Calculate actual values if:

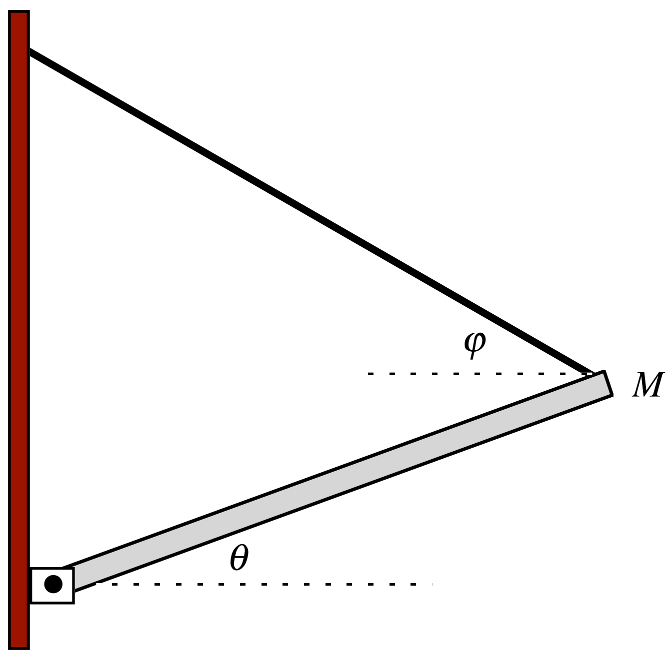
$$M = 125\ kg,$$
$$\ell = 12\ m,$$
$$\theta = 40°,$$
$$\varphi = 30°.$$



9.) A beam of mass M and length ℓ is free to rotate about a horizontal pin that passes through one end of the beam, as represented in the diagram below. The beam makes an angle θ to the horizontal. A cable is attached to the beam and a vertical wall making an angle φ with respect to the horizontal. Assuming static equilibrium, derive equations for the following:

a) The tension in the cable.
b) The horizontal force exerted on the beam by the pin.
c) The vertical force exerted on the beam by the pin.
d) Calculate actual values if:

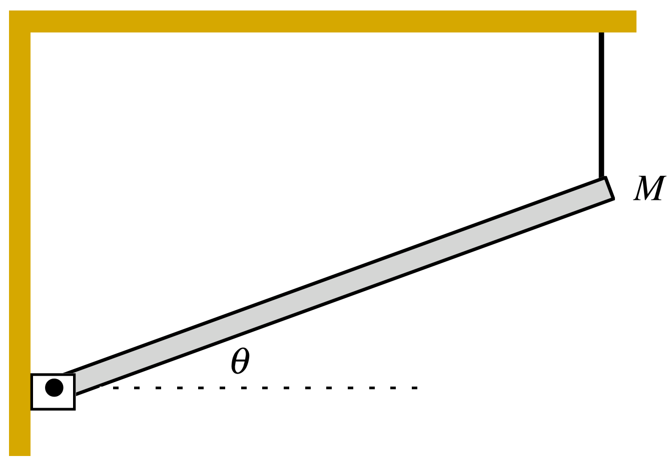
$$M = 125\ kg,$$
$$\ell = 12\ m,$$
$$\theta = 20°,$$
$$\varphi = 30°.$$



10.) A beam of mass M and length ℓ is free to rotate about a horizontal pin that passes through one end of the beam, as represented in the diagram below. The beam makes an angle θ to the horizontal. A vertical cable is attached to the beam and the ceiling. Assuming static equilibrium, derive equations for the following:

a) The tension in the cable.
b) The horizontal force exerted on the beam by the pin.
c) The vertical force exerted on the beam by the pin.
d) Calculate actual values if:

$$M = 125\ kg\ ,$$
$$\ell = 12\ m\ ,$$
$$\theta = 20^\circ\ .$$

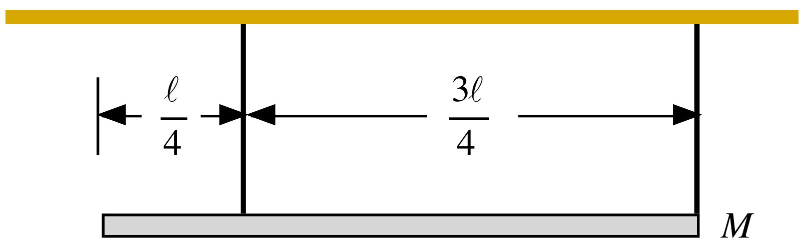


11.) A horizontal beam of mass M and length ℓ is attached to the ceiling by means of two vertical cables, as represented in the diagram below. Assuming static equilibrium, derive equations for the following:

a) The tension in each cable.

b) Calculate actual values if:

$$M = 125\ kg\ ,$$
$$\ell = 12\ m\ .$$

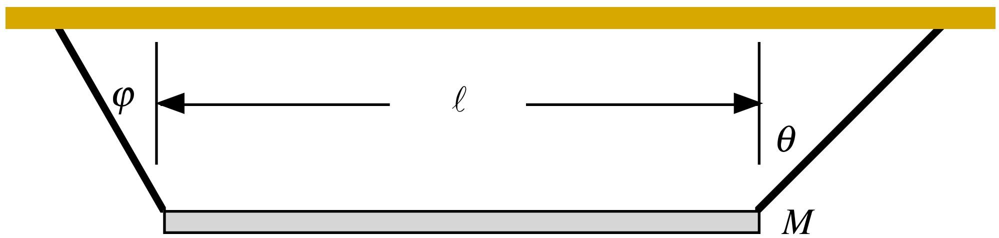


12.) A horizontal beam of mass M and length ℓ is attached to the ceiling by means of two cables, as represented in the diagram below. Assuming static equilibrium, derive equations for the following:

a) The tension in each cable.

b) Calculate actual values if:

$$M = 125\ kg\ ,$$
$$\ell = 12\ m\ ,$$
$$\theta = 45° = (1.5)\varphi\ .$$



ASSIGNMENT FOUR

PROBLEMS FOR CHAPTER SIXTEEN

Problems for Chapter 16

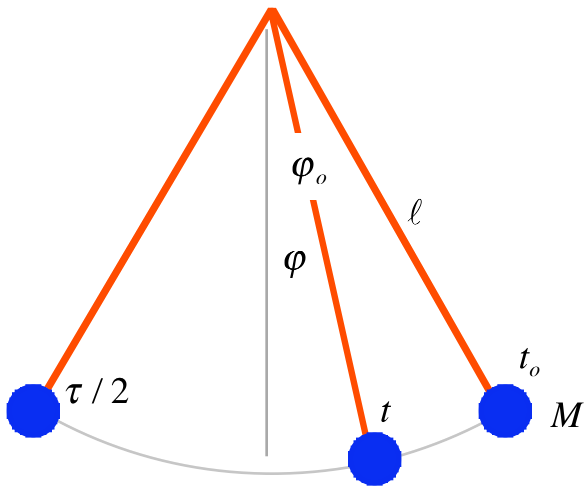
1.) A small spherical bob of mass $M = 0.750\ kg$ is suspended from one end of a light string of length $\ell = 1.250\ m$. The other end of the string is attached to a frictionless pivot, as represented in the diagram below. The bob is released from rest at an angle, measured from the vertical, of $\varphi_o = 30°$. Use work-energy considerations to do the following:

a) Draw a correct free-body diagram of the forces acting on the bob at an arbitrary angle φ.

b) Determine the instantaneous speed of the bob when it is at an angle of $\varphi = 15°$.

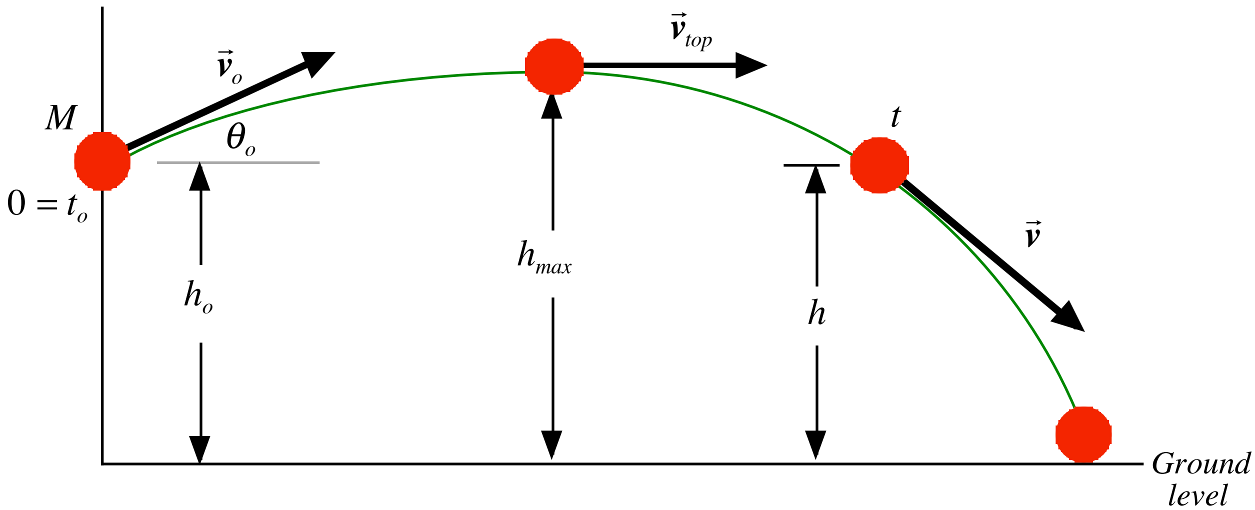
c) Determine the maximum instantaneous speed the bob will attain.

d) Determine that angle at which the bob will have one third of its maximum speed.



2.) A small sphere of mass $M = 0.875\ kg$ is launched with an initial speed of $v_o = 15.00\ m/s$ at an angle, with respect to the horizontal, of $\theta_o = 25°$, as represented in the diagram below. The sphere is launched off of a cliff a distance $h_o = 30.00\ m$ above level ground. The air resistance is negligible Use work-energy considerations to determine the following:

a) The maximum height above the ground attained by the sphere.
b) The speed of the sphere as it strikes the ground.
c) The speed of the sphere the "top" of its path.

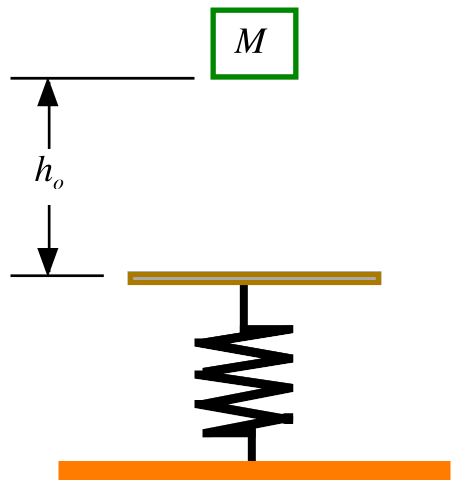


3.) A block of mass $M = 2.50\ kg$ is released from rest a distance $h_o = 2.25\ m$ above an elastic spring with spring constant $k_{sp} = 5.000 \times 10^3\ N/m$. The spring is initially in an equilibrium state. Use work-energy considerations to do the following:

a) Determine the speed of the block at the instant it strikes the spring.

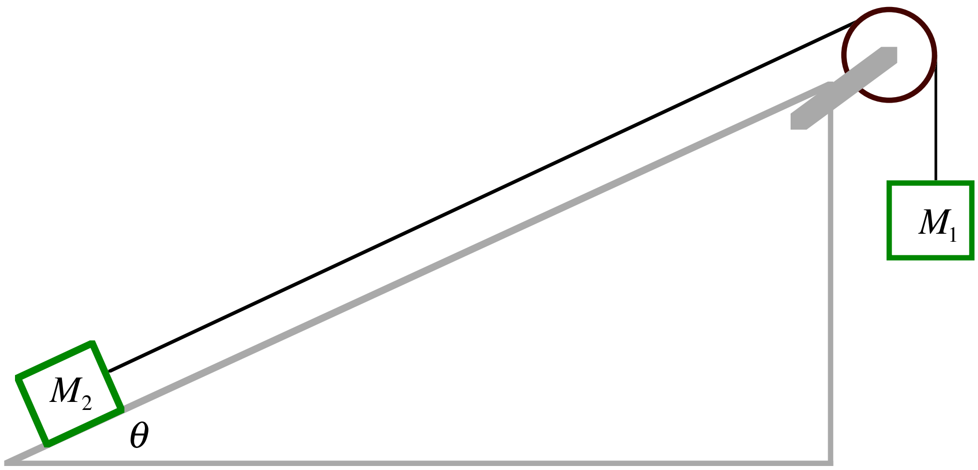
b) Determine the distance the spring will be compressed at the instant the block is moving at half of the speed it had when it struck the spring.

c) Determine the maximum distance the spring will be compressed.

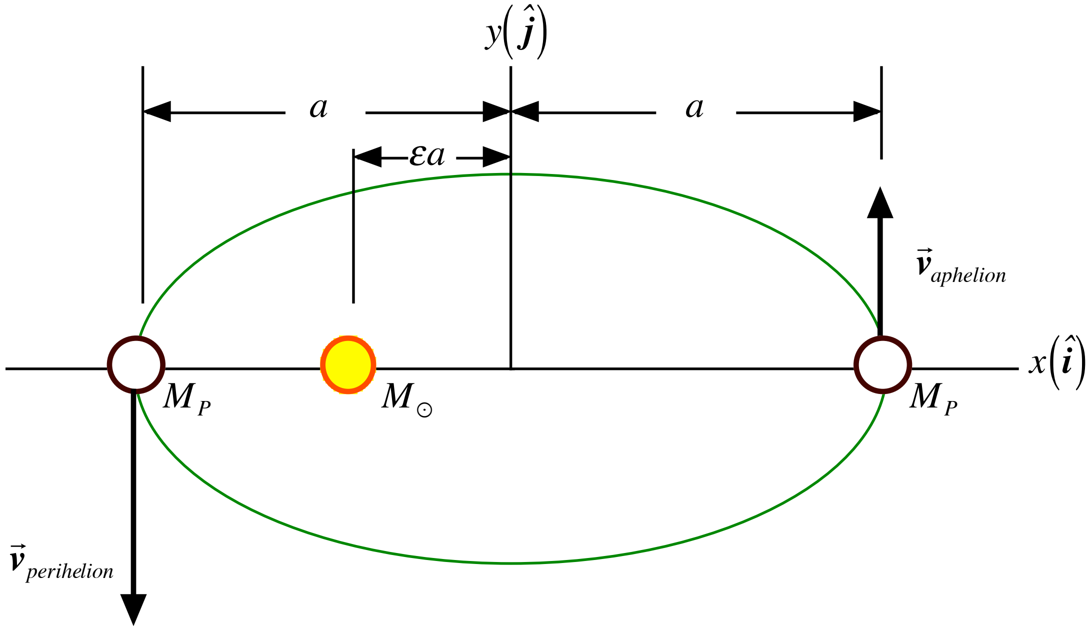


4.) A block of mass $M_1 = 12.00\ kg$ is attached to one end of a light string. The other end of the string is attached to a mass $M_2 = 6.00\ kg$. In turn, the string is draped over a pulley of mass $M_P = 2.00\ kg$ and radius $R = 0.085\ m$. There is friction between the string and the pulley but the axle is free to rotate without friction. The second block sits on a rough inclined plane that is inclined an angle of $\theta = 25°$ to the horizontal. The coefficients of friction are related by $\mu_s = 2\mu_k = 0.400$. The system is released from rest. Use work-energy considerations to find the following:

a) The work done by the normal force.
b) The work done by gravity.
c) The work done by the kinetic friction.
d) The speed of each block at the instant each block has moved a distance $\ell = 1.25\,m$.



5.)



Planets orbit the Sun on elliptical paths. As a consequence of this, they do not remain at a fixed distance from the Sun. When the planet is closest to the Sun it is said to be at perihelion. The planet is at aphelion when it is furthest from the Sun. The speed of the planet relative to the Sun also varies. The planet moves most rapidly at perihelion and most slowly at aphelion. Pictured above is a representation--not drawn to scale--of a planet's orbit of the Sun. The distance marked a is called the semi-major axis, and represents the average distance of the planet from the Sun. The letter ε represents the eccentricity--non-circularity--of the orbit.

The average distance of the Earth from the Sun is called an *Astronomical Unit*, and is given by

$$a_\oplus = 1.496 \times 10^{11}\, m \equiv 1 \;\; Astronomical\ Unit \text{ (AU)} .$$

The eccentricity of the Earth's orbit is

$$\varepsilon_\oplus = 0.0167$$

Use this information, and work-energy considerations, to do the following:

a) Determine the amount of work done by the gravitational force as the Earth **moves from aphelion to perihelion**. Recall that

$$M_\odot = 1.99 \times 10^{30}\ kg ,$$

$$M_\oplus = 5.98 \times 10^{24}\ kg ,$$

and

$$G = 6.67 \times 10^{-11}\, N\, m^2 \,/\, kg^2 .$$

b) Assuming that at perihelion and aphelion the Earth is moving instantaneously on a circular path, determine the speed of the Earth at perihelion and at aphelion.

6.) A small stone of mass $M = 0.500\ kg$ is thrown vertically upward with an initial speed of $v_o = 17.882\ m/s$ from ground level. Ignoring air resistance, use work-energy considerations to do the following:

a) Find the distance above the ground at which the stone will have a speed given by $v_L = (1/2)v_o$.

b) Find the distance above the ground at which the stone is instantaneously at rest.

c) Redo parts a) and b) assuming that there is a constant air resistance force the magnitude of which is given by

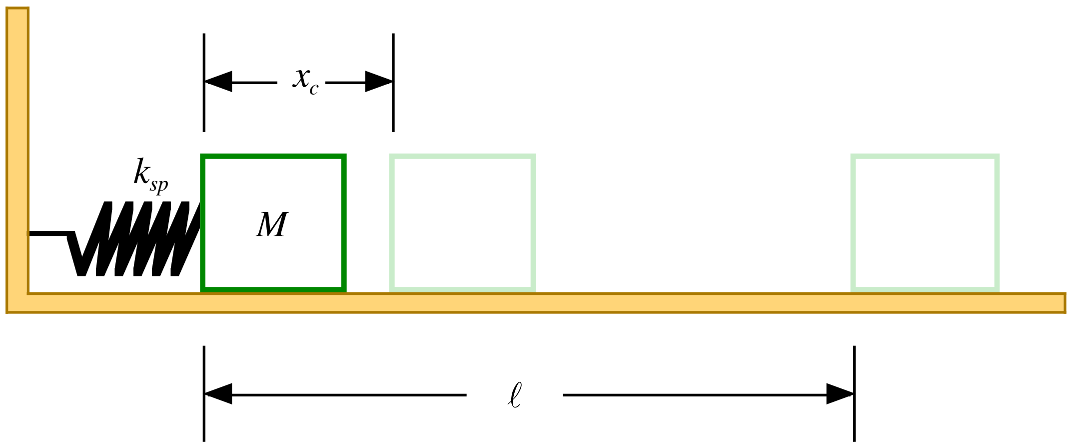
$$F = \mu g ,$$

where

$$\mu = 0.0125\ kg .$$

d) Using the values given in part c), determine the speed of the stone when it strikes the ground.

7.)



A block of mass $M = 1.250\ kg$ is pushed against a spring of spring constant $k_{sp} = 5.125 \times 10^3\ N/m$ compressing the spring a distance of $x_c = 0.120\ m$. The block is released from rest and slides over a rough, level surface for which the coefficient of kinetic friction is given by $\mu_k = 0.680$. Use work-energy considerations to do the following:

a) Calculate the speed of the block at the instant the spring is compressed a distance of only $x = 0.060\ m$; half of the initial compression.

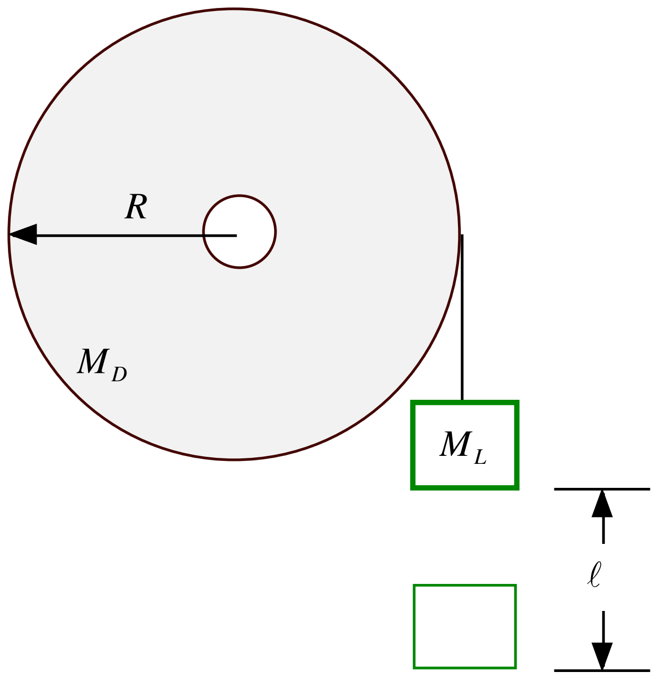
b) The speed of the block at the instant it loses contact with the spring.

c) The total distance ℓ the block will slide before coming to rest.

8.) A right circular disk of mass $M_D = 75.0\ kg$ and radius $R = 0.450\ m$ is free to rotate about a horizontal axle through the center of the disk perpendicular to the plane of the disk, as represented in the diagram below. One end of a light, flexible cable is attached to the disk and wrapped around the disk. A block of mass $M_L = 125.0\ kg$ is attached to the other end of the cable. (There is friction between the disk and the cable, **the pulley will rotate**.) Recall that the moment of inertia of a disk about its major axis of symmetry is given by $I_{disk} = (1/2) M_{disk} R_{disk}^2$. The block is released from rest. Do the following:

a) Using work-energy considerations, determine the speed of the block at the instant is has moved a distance $\ell = 1.250\ m$.

b) Use the equations of motion for constant acceleration to determine the magnitude of the translational acceleration of the block.

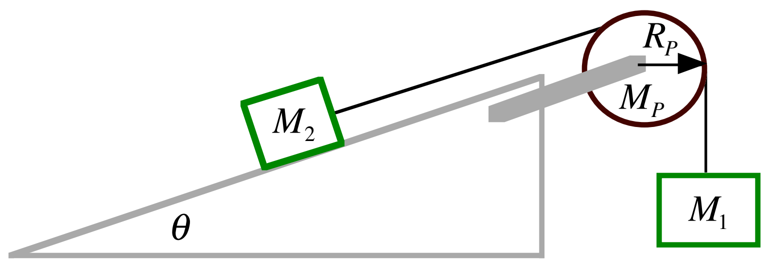


9.) A block of mass $M_1 = 8.0\ kg$ is attached to one end of a light string. Attached to the other end of the string is another mass $M_2 = 4.0\ kg$. The string, in turn, is draped over a pulley of mass $M_P = 2.0\ kg$ and radius $R_P = 0.140\ m$, as represented in the diagram below. Initially, the first block hangs vertically while the second block sits on a rough inclined plane. The plane is inclined an angle of $\theta = 25°$ to the horizontal. The system is released from rest, and the coefficient of kinetic friction between the second block and the inclined plane is $\mu_k = 0.250$. Do the following:

a) Use work-energy considerations to determine the speed of each block at the instant each has moved a distance $\ell = 5.75\ m$.

b) Use the equations of motion for constant acceleration to determine the magnitude of the translational acceleration of each block.

(You may assume that there is friction between the rope and the pulley, and assume that there is no friction on the axle of the pulley. Recall that for a cylindrical object with respect to its major axis of symmetry, $I = (1/2)MR^2$.

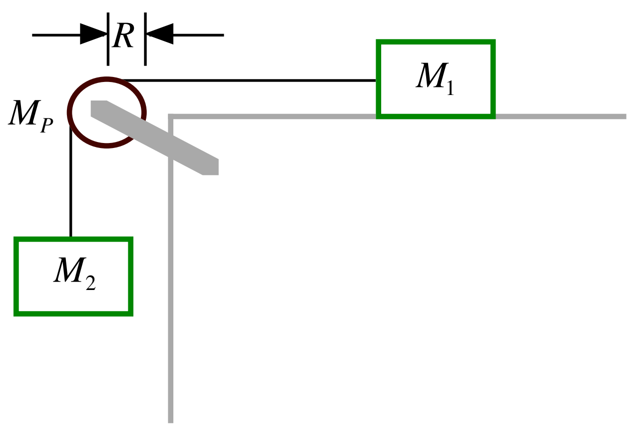


10.) A block of mass M_1 is connected to one end of a light string, as represented in the diagram below. Another block of mass M_2 is attached to the other end of the string. In turn, the string is draped over a pulley of mass M_p and radius $R = .086\,m$. The masses are related by $M_1 = (1/4)M_2 = 4M_P = 2.0\,kg$. There is friction between the string and the pulley, but the pulley is free to rotate about a frictionless axle. Block one is constrained to move along a level, **frictionless surface**. Do the following:

a) Using work-energy considerations, determine the speed of each block at the instant each block has moved a distance $\ell = 0.750\ m$.

b) Use the equations of motion for constant acceleration to determine the magnitude of the translational acceleration of each block.

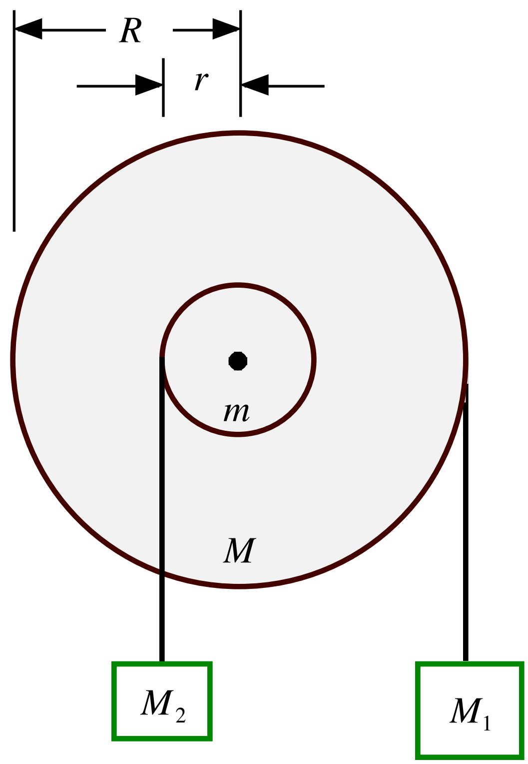
(You may assume the system is released from rest.)



11.) Challenge Problem: A circular cylinder of mass M and radius R has a light string wrapped around its rim. Attached to one end of the string is a block of mass M_1. This cylinder is free to rotate about a horizontal axis passing through the center of the cylinder and perpendicular to the plane of the cylinder. A second, coaxial cylinder of mass m and radius r is welded onto the first cylinder. A second string is wound around the second cylinder and a second mass M_2 is attached to one end of the second string, as represented in the diagram below. This system is released from rest. Do the following:

a) Using work-energy considerations, determine the magnitude of the speed of each block at the instant block M_1 has moved a vertical distance $\ell = 0.750\ m$. (Assume the masses are related by $M = 9m = M_1 = 3M_2 = 18.00\ kg$ and the radii by $R = 3r = 0.120\ m$.)

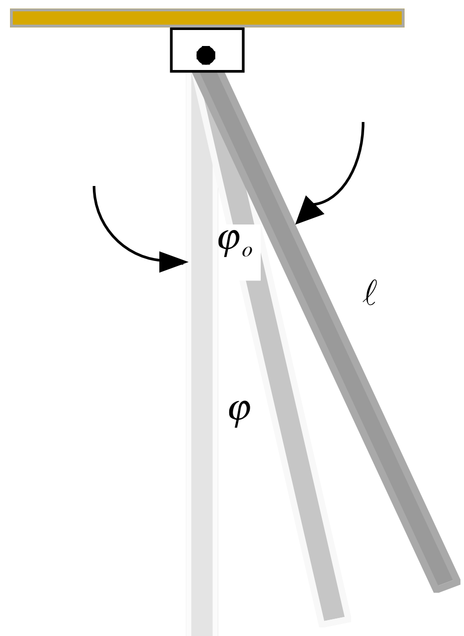
b) Use the equations of motion for constant acceleration to determine the magnitude of the linear acceleration of each block. (These accelerations are not equal.)



12.) A uniformly thin rod of mass $M = 12.50\ kg$ and length $\ell = 2.250\ m$ is attached to a horizontal ceiling by a frictionless pivot at one end of the rod, as represented in the diagram below. The rod is initially displaced through an angle, measured with respect to the vertical, of $\varphi_o = 25°$. Use work-energy considerations to do the following:

a) Determine the angular speed of the rod at the instant it passes through the vertical. (This is its maximum speed.)

b) Determine the angle, with respect to the vertical, at which the rod will have half of its maximum angular speed.

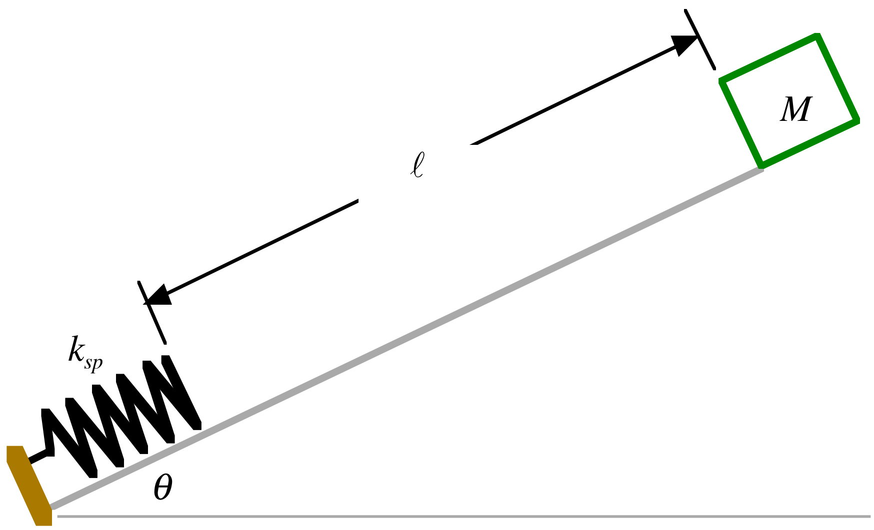


13.) An elastic spring with spring constant $k_{sp} = 4.750 \times 10^{3}\ N/m$ sits in equilibrium at the bottom of a frictionless inclined plane, as represented in the diagram below. The plane is inclined an angle of $\theta = 25°$ to the horizontal. A block of mass $M = 6.75\ kg$ is released from rest a distance of $\ell = 2.25\ m$ from the spring. Using work-energy considerations, do the following:

a) Determine the speed with which the block will strike the spring. (This will be the maximum speed of the block.)

b) Determine the distance the spring will be compressed at the instant the block is moving at half of its maximum speed.

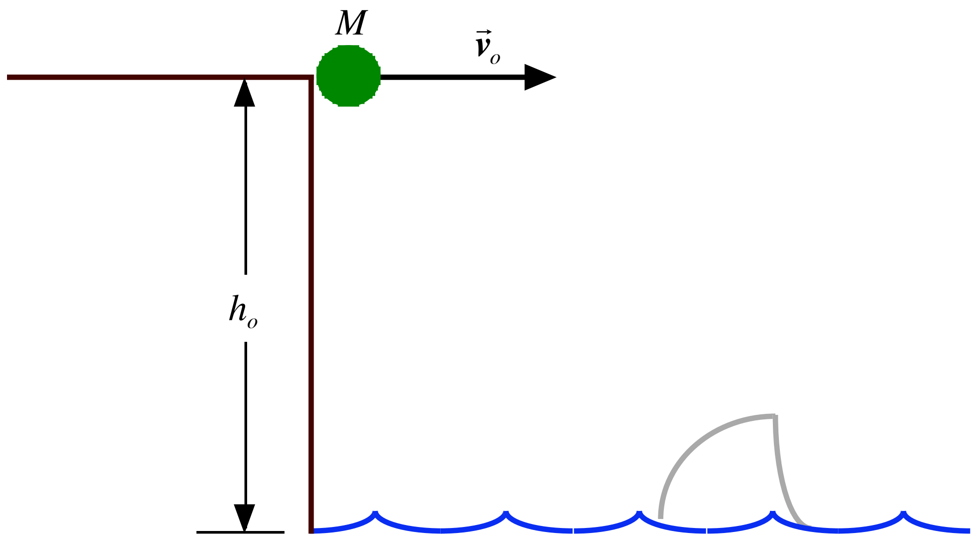
c) Determine the maximum compression distance of the spring.



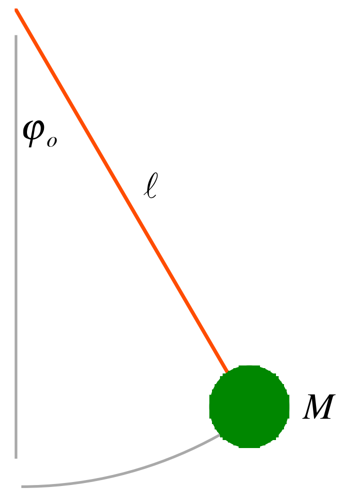
14.) A ball of mass $M = 0.454\ kg$ is thrown horizontally off of a cliff that is a vertical distance $h = 20.0\ m$ above the ocean with an initial speed of $v_o = 18.0\ m/s$, as represented in the diagram below. Using work-energy considerations, do the following:

a) Determine the speed with which the ball will strike the ocean. (This will be its maximum speed.)

b) Determine the vertical distance above the water at which the ball will have a speed of $v = (3/4)v_{max}$.



15.)



A bob of mass $M = 0.025\ kg$ is attached to one end of a light string of length $\ell = 1.675\ m$. The other end of the string is attached to a frictionless ceiling pivot. The bob is released from rest at an initial angle, relative to the vertical, of $\varphi_o = 30°$, as represented in the diagram above. Use work-energy considerations to do the following:

a) Determine the speed of the bob at the instant it passes through the vertical. (This is its maximum speed.)

b) Determine the angle, measured with respect to the vertical, at which the bob is moving with:

i) A speed of $v = (1/4)v_{max}$.

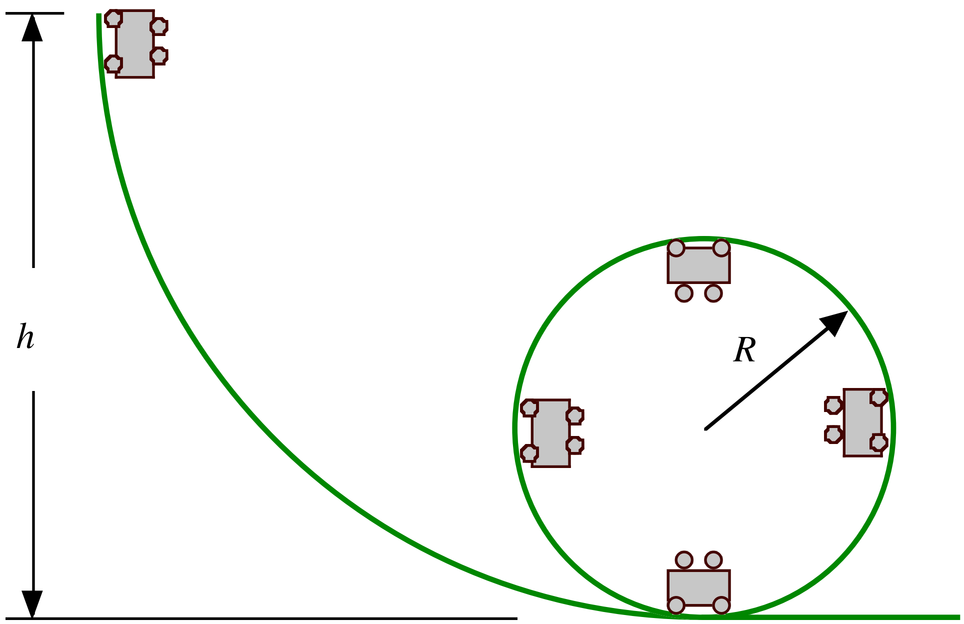
ii) A speed of $v = (1/2)v_{max}$.

iii) A speed of $v = (3/4)v_{max}$.

16.) Challenge Problem: At an amusement park ride, a car of mass M moves without friction around a loop-the-loop track, as represented in the diagram below. The car is pulled up to the top of a hill that is a vertical distance h above the bottom of the loop. Do the following:

a) Using work-energy considerations, determine the **minimum** value of h, in terms of R, such that the car moves around the loop without falling off of the loop at the very top of the loop.

b) Using the equation found in a), calculate the value of h for a radius of $R = 20\ m$.



17.) A uniformly solid sphere of mass $M = 0.85\ kg$ and radius $R = 0.095\ m$ is released from rest at the top of an inclined plane. The plane is inclined at an angle of $\theta = 36.87°$ with respect to the horizontal, as represented in the diagram below. The sphere rolls without slipping. Using work-energy considerations, do the following:

a) Determine the translational speed v of the center of the sphere at the instant it has moved a distance $\ell = 1.360\ m$.

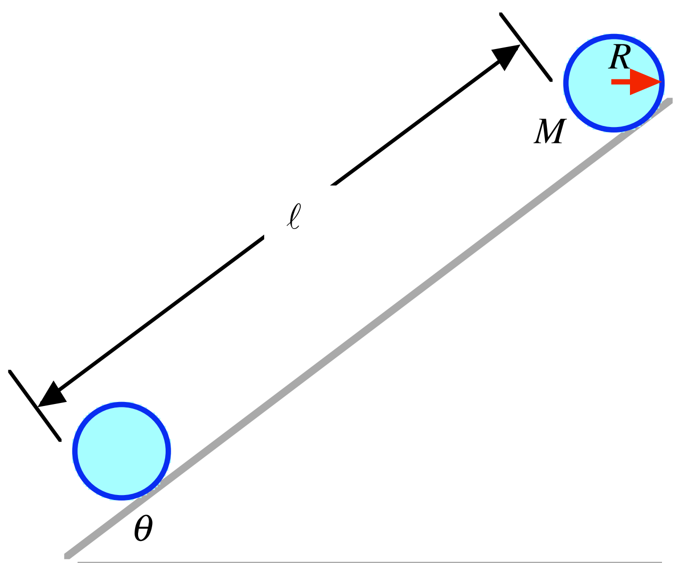
b) Determine the distance the sphere will have moved at the instant its speed is:

i) A speed of $v_1 = (1/4)v$.

ii) A speed of $v_2 = (1/2)v$.

iii) A speed of $v_3 = (3/4)v$.

(The speed v in part b) is the speed found in part a). The moment of inertia of a solid sphere is $I = (2/5)MR^2$)



18.) Challenge Problem: Two steal balls of mass $M_1 = M_2 = 0.500\ kg$ are represented in the diagram below. Initially, the spheres are rotating about a vertical axis with an angular speed $\omega_o = 4.00\ rad/s$ at a distance $r_o = 0.150\ m$. We now force collar C down a distance h until the spheres are at a distance of $r_f = 0.050\ m$ from the vertical axis of rotation. How much work must be done to move the collar down to this position? Note: all of the strings have a length $\ell = 0.1523\ m$.