All answers should be to two significant figures, and include SI units where appropriate.

Problem 1

You throw a ball of mass $m = 0.80$ kg straight downwards with an initial speed of $v_i = 1.5$ m/s from a height of $h_i = 2.2$ m. The ball bounces off the ground straight upwards. You would like to predict how high the ball will bounce.

(a): 5 points

What two major assumptions do you need to make in order to solve this problem?

(b): 8 points

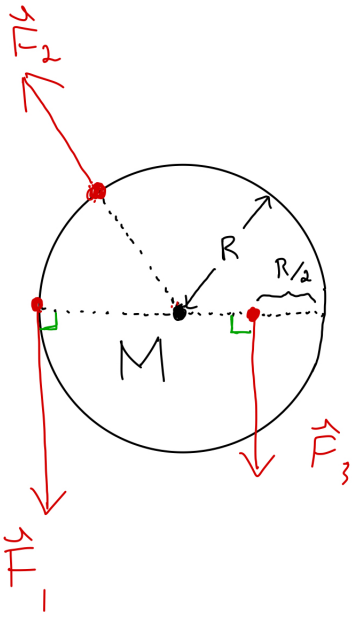
Calculate how high the ball will bounce.

(c): 7 points

What was the impulse delivered to the ball by the ground during its bounce?

Problem 2

Consider a wheel of mass $M = 24$ kg and radius $R = 86$ cm, that is free to rotate around its center. Constant forces $\vec{F}_1, \vec{F}_2, \vec{F}_3$ are applied to the wheel as shown. The black dotted lines are radial lines. $\vec{F}_1$ and $\vec{F}_2$ are applied at points on the outer rim of the wheel; $\vec{F}_3$ is applied a distance $R/2$ away from the axis of rotation. $\vec{F}_1$ and $\vec{F}_3$ are perpendicular to the radial line and $\vec{F}_2$ is parallel to the radial line. The magnitudes of the forces are $|\vec{F}_1| = 4.0$ N, $|\vec{F}_2| = 3.0$ N, $|\vec{F}_3| = 2.0$ N. The vectors are not drawn to scale.



(a): 5 points

Calculate the net torque acting on the pulley.

(b): 5 points

Calculate the angular acceleration of the pulley.

(c): 5 points

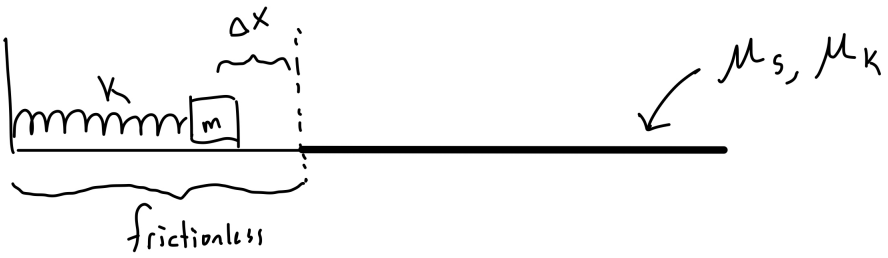
After 2.0 s, through what angular displacement has the pulley been rotated?

(d): 5 points

After 2.0 s, at what speed do the blocks move?

Problem 3

A horizontal spring of spring constant $k = 7.0$ N/m and a block of mass $m = 0.40$ kg sit on a table. Initially, the spring is compressed horizontally by the block to a displacement $\Delta x = 8.0$ cm from equilibrium. The block is released, and it slides across a table until it comes to rest [the block is not attached to the spring]. The portion of the table beneath the spring is frictionless. The coefficients of static and kinetic friction for the block and the rest of the table are $\mu_s = 0.60$ and $\mu_k = 0.50$, respectively.



(a): 6 points

Draw a free-body diagram of the block as it slides across the table (after it has left the spring, before it has come to rest). Be sure to label your force vectors clearly. Include a net force vector off to the side of the diagram.

(b): 7 points

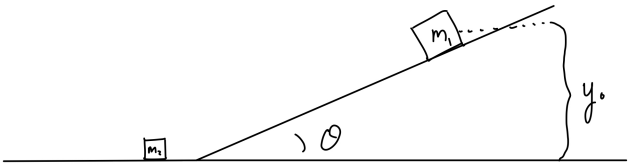
How far does the block slide before coming to rest (measured from the equilibrium point of the spring)?

(c): 7 points

How much thermal energy was produced during this process?

Problem 4

A block of mass $m_1 = 0.30$ kg sits on a frictionless ramp that makes an angle of $\theta = 21°$ with the horizontal. The block is released from rest at a height $y_0 = 9.0$ cm above the ground.



(a): 7 points

How long does it take the block to reach the end of the ramp?

(b): 6 points

What is the speed of the block when it reaches the end of the ramp?

(c): 7 points

If the block then strikes another block of mass $m_2 = 0.20$ kg that sits at rest at the bottom of the ramp, and the blocks stick together and move forwards on a frictionless surface, what is the final speed of the blocks?

Problem 5

For each of the following statements, indicate whether the statement is true or false, and explain your reasoning.

(a): 5 points

If object A has a higher speed than object B, object A's momentum is necessarily higher.

(b): 5 points

If an object at rest explodes into two pieces that fly apart from each other, the two pieces must move in exactly opposite directions.

(c): 5 points

If an object moves in a circular trajectory, its acceleration vector must point directly towards the center of the circle.

(d): 5 points

If you and your friend both throw a ball at the same speed, and you throw the ball straight upwards and your friend throws it horizontally, the two balls will have equal speeds when they hit the ground. [Ignoring air resistance.]