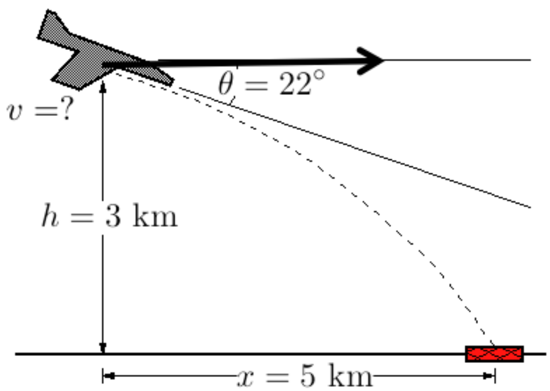
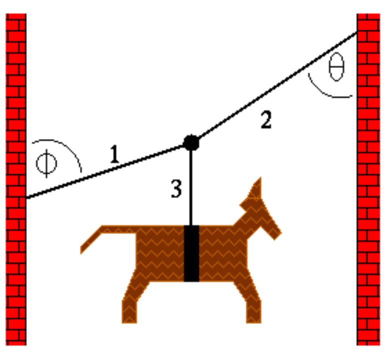
1. **One Dimensional Motion**
A ball is thrown up in the air from a height $y = 0$ m at time $t = 0$ s. It passes by a certain vertical location at time $t = 0.30$ s when going up, then passes by that location again at time $t = 1.80$ s when it's coming down.
   (a) What is the initial velocity of the ball? (10.29 m/s)
   (b) What is the maximum height that the ball reaches? (5.40 m)
   (c) What is the height of the "certain vertical location" that the ball passes at those times? (2.65 m)

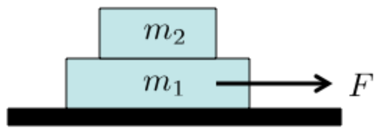
2. **Two Dimensional Motion: Plane Drop**
A plane is diving towards the ground at an angle of $\theta = 22°$ below horizontal, at an altitude of $h = 3$ km. It wants to drop a freely-falling package so it lands on the ground $x = 5$ km ahead. Neglecting air resistance and forces other than gravity, how fast must the plane be going when it drops the package for the package to land in the right place? (381 m/s)



3. **Tensions in Wires: Dingo**
An Australian Dingo, mass 30 kg, is supported by 3 massless cables as shown in the following diagram. What are the tensions of each cable if the angles are $\theta = 50°$ and $\phi = 70°$? ($T_1 = 658.5$ N, $T_2 = 808$ N, $T_3 = 294$ begin)



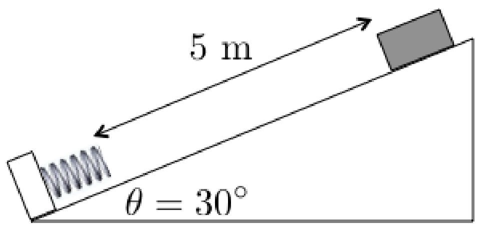
4. **Friction: Slipping while Pulling**
Consider two blocks being accelerated across the floor by a constant force F pulling on the bottom, larger block. The larger block has mass $m_1 = 10$ kg, while the smaller block has mass $m_2 = 3$ kg. The coefficient of kinetic friction between the larger block and the floor is $\mu_k = 0.5$, while the coefficient of static friction between the two blocks is $\mu_s = 0.75$. What is the maximum acceleration of the blocks just before the top one slips? (7.35 m/s^2) What is the maximum force F that can be exerted before the top block slips? (F=159 N)



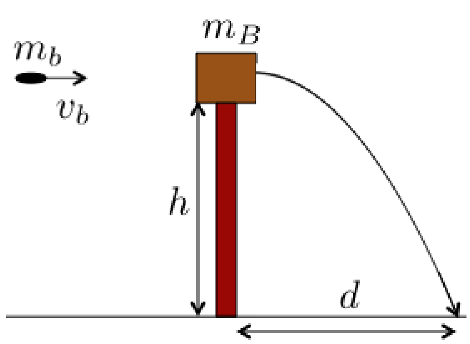
5. **Frictional Inclined Plane**
A block of mass $m = 5.0$ kg is released and slides down an incline ($\theta = 30°$) where the coefficient of kinetic friction is $\mu_k = 0.3$. The block goes 5.0 m and hits an ideal spring with $k = 500$ N/m. Assume that friction is negligible while the block is being acted upon by the spring.

   (a) How far does the block compress the spring? (0.485 m)

   (b) How far does the block go back up the plane on the first rebound? (1.58 m)



6. **Bullet Speed from Collision**
To measure the speed of a bullet, the following situation is set up. A wooden block with mass $m_B = 0.50$ kg is put on top of a fencepost with a height of $h = 1.5$ m. The bullet (mass $m_b = .010$ kg) strikes the block from a perfectly horizontal direction and remains embedded in it. The block is measured to fall $d = 1.6$ m from the base of the post. How fast was the bullet going? (148 m/s)



7. **One-Dimensional Rocket Kinematics** A model rocket of mass $m = 10$ kg launches vertically from a launch pad at height $y = 0$ m and time $t = 0$ s, with initial vertical velocity $v_{y0} = 0$ m/s. For the remainder of this problem, assume that the rocket's mass is constant and that the rocket is on Earth.

   (a) The rocket engines exert a thrust (force) of $F = 300$ N downwards at the start of the flight. What is the net vertical acceleration a_y of the rocket upward in m/s^2? (20.2 m/s^2)

   (b) The rocket engines exert that thrust for $t_1 = 5$ seconds. What is the rocket's height h_1 at the end of that five seconds, in meters? (252.5 m)

(c) After the thrust in part (b), the rocket engines shut off and the rocket continues upward subject to only the vertical acceleration of gravity. Find the maximum height of the rocket above the ground, h_{max}, in meters. (773 m)

(d) Find the final velocity of the rocket when it hits the ground in m/s, and the time that it hits the ground in seconds. (123 m/s; 27.9 s)

8. **Fluid and Oscillator Concepts and Short Answers**

(a) You are holding a glass of water with an ice cube floating in it, and get on an elevator. As the elevator accelerates upward, does the ice cube...

i. Sink deeper into the water?
ii. Stay at the same level in the water?
iii. Rise up out of the water?

Why?

(b) A mass attached to a spring oscillates with a frequency of 10 Hz. What frequency does it oscillate with if the mass is doubled?

i. 7.1 Hz (this one)
ii. 14.1 Hz
iii. 5 Hz
iv. 20 Hz
v. 10 Hz

Why?

(c) You are in a car moving at constant velocity, holding a helium balloon that “hangs” straight up. As the car accelerates forward, does the balloon...

i. Move towards the front of the car?
ii. Move towards the back of the car?
iii. Stay stationary?

Why?

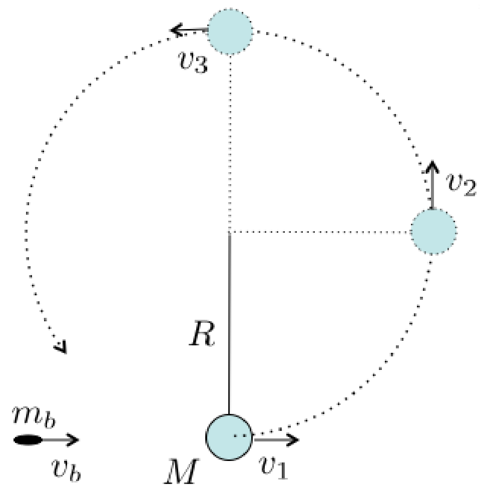
9. **Balllistic Spinner** A bullet of mass $m_b = 0.01$ kg is moving with initial velocity $v_b = 160$ m/s and strikes a pendulum of mass $M = 0.3$ kg hanging from a massless string of length $R = 50$ cm. The bullet sticks in the pendulum so this is an inlastic collision, and the pendulum swings around the circle after the collision.

   (a) What is the velocity v_1 of the pendulum/bullet just after the bullet lodges in the pendulum, in m/s? (5.16 m/s)

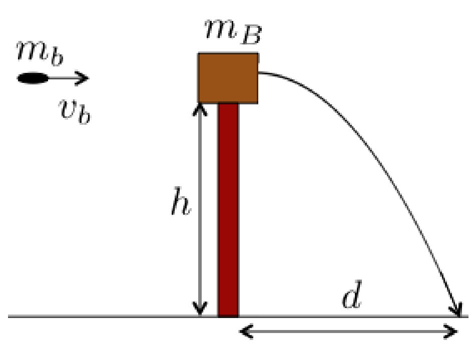
   (b) Use conservation of energy to find the velocities v_2 and v_3 of the pendulum in the diagram, in m/s. (4.10 m/s; 2.65 m/s)

   (c) What is the maximum tension T on the pendulum string? (19.55 N)

   (d) What are the magnitude and direction of the total acceleration acting on the mass at the location marked by v_2? (35.02 m/s^2, 16.3° down from -$\hat{y}$ axis.)



10. **Bullet Speed from Elastic Collision**
   A wooden block with mass $m_B = 1.0$ kg is put on top of a fencepost with a height of $h = 2.0$ m. The bullet (mass $m_b = .010$ kg) strikes the block with initial velocity $v_b = 300$ m/s from a perfectly horizontal direction and bounces off of it, with a final velocity pointing to the left. The collision is completely elastic.

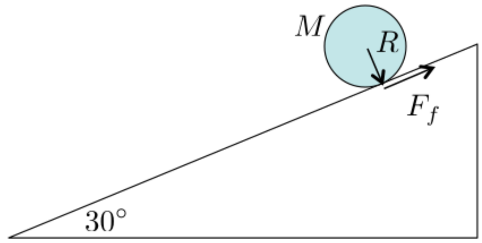


   (a) Use conservation of energy and conservation of momentum to find the velocities of the bullet and block just after the collision.

   (b) Use conservation of energy to find the final velocity of the block as it hits the ground.

   (c) Use projectile motion calculations to find the distance from the post that the block hits the ground, d.

11. **Rolling Motion**



A uniform sphere of radius R and mass M is placed at the top of a plane inclined at an angle of θ. The coefficient of friction between the plane and the ball is μ. Gravity acts vertically downward as in most inclined plane problems.

The answers to this problem are equations in terms of these unknowns. The formula for the rotational inertia of a solid sphere rotating around its center is $I = \frac{2}{5}MR^2$.

(a) Calculate the force of friction F_f between the ball and plane in Newtons (this force of friction points up the plane), and calculate the torque τ that F_f exerts on the sphere.

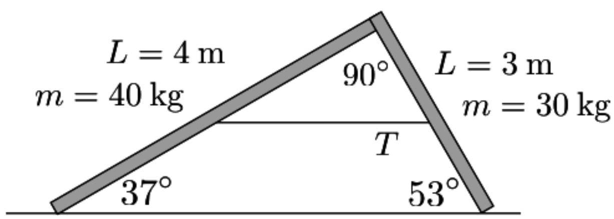
(b) What is the angular acceleration α of the sphere as it rolls down the plane?

(c) What is the linear acceleration a of the sphere's center as it rolls down the plane?

(d) If there is no friction, what is the linear acceleration a of the sphere's center as it slides down the plane?

(e) What relationship between μ and θ will produce the same acceleration of the ball whether it's rolling or sliding?
(a) $\mu = \frac{1}{5}\tan\theta$ (b) $\mu = \frac{2}{5}\tan\theta$ (c) $\mu = \tan\theta$ (d) $\mu = \frac{5}{2}\tan\theta$ (e) $\mu = 5\tan\theta$

12. **The Dreaded Statics Problem**



Two ladders, 4m and 3m long and 40kg and 30kg mass respectively, are hinged together and tied together by a horizontal rope of length 2.5m so the hinge makes a 90° angle as shown in the above figure. Each ladder's center of mass is at its midpoint, and the rope connects their centers of mass. The floor is frictionless, and assume Earth's gravity.

(a) What is the normal upward force from the floor acting on the left ladder, in Newtons? On the right ladder, in Newtons?

(b) What is the tension T in the rope, in Newtons?

(c) What is the magnitude of the force that each ladder exerts on the other at the hinge, in Newtons?

(d) If a weight of 90N is suspended from the hinge, what is the new tension T of the rope, in Newtons?