PHYS 4A – Spring 2024 – Final

2 Hours – Scientific calculator allowed

Lecture Notes, Books, Mobile Phones, Tablets, or Laptops are not allowed.

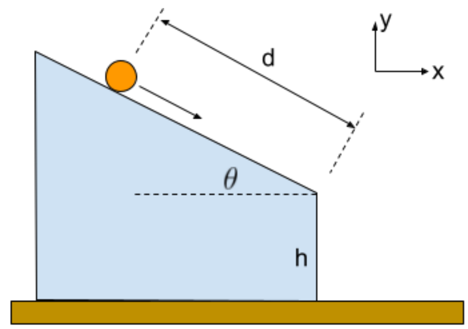
Question:	1	2	3	4	5	Total
Points:	5	10	10	5	10	40
Bonus Points:	2	2	2	0	2	8
Score:						

1. A rock is dropped vertically from a cliff and falls under the influence of gravity. A second rock is released 1.00 s later. *Ignore air friction.*

   (a) (5 points) How many seconds after the *first* rock is dropped, will the distance between two rocks be equal to 10.0 m?

   (b) (2 points (bonus)) Calculate the *relative velocity* of the first rock to the second rock when they are 10.0 m apart.

2. A uniform cylinder of mass $m = 2.00\,\mathrm{kg}$ and radius R, initially at rest, *rolls* down a roof with a *rough surface*. The inclination is $\theta = 30.0°$ and the total distance is $d = 20.0\,\mathrm{m}$. ($I_{\mathrm{CM}} = mR^2/2$) *Hint: You don't need the value of R for the calculations below.*



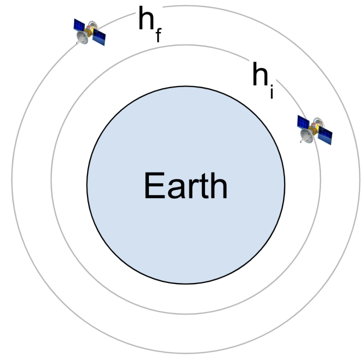
(a) (3 points) Calculate the change in potential energy as the cylinder travels the distance d on the roof.

(b) (4 points) Calculate the total kinetic energy, the rotational kinetic energy, and the translational kinetic energy of the cylinder as it's leaving the edge of the roof.

(c) (3 points) What is the velocity vector $\vec{\mathbf{v}}_{\text{CM}}$ of the center of mass of the cylinder as it's leaving the edge of the roof in the coordinate frame shown on the graph?

(d) (2 points (bonus)) If the edge of the roof is $h = 8.00\,\text{m}$ above the ground, how far from the building will the cylinder fall?

3. A satellite of mass $m = 800\,\text{kg}$ is orbiting the earth at an altitude of $h_i = 600\,\text{km}$ in a circular orbit. We want to move this satellite to a circular orbit at an altitude of $h_f = 4300\,\text{km}$. This is a two-stage process with a first burn to reach the transfer orbit and a second burn to reach the final orbit. *Remember:* $R_E = 6380\,\text{km}$



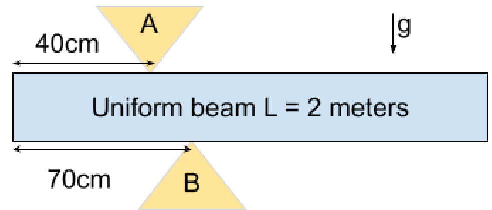
   (a) (4 points) What is the total amount of energy injected to do this?

   (b) (3 points) This manoeuver would require two steps with an elliptical transfer orbit inbetween. What is the length of the semi-major axis of this transfer orbit expressed in kilometers?

   (c) (3 points) What is the orbital period of the satellite in the final position? Give your answer in minutes.

(d) (2 points (bonus)) How long does the satellite stay on the transfer orbit before the second rocket burn? Give your answer in minutes.

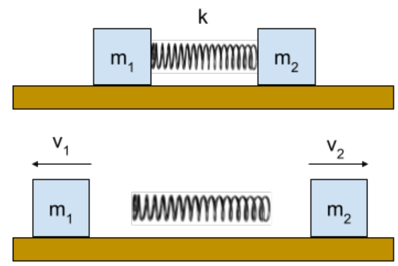
4. A *uniform* beam of mass $m = 100\,\text{kg}$ and length $L = 2.00\,\text{m}$ is being supported at two points $x_A = 40.0\,\text{cm}$ and $x_B = 70.0\,\text{cm}$ measured from one end of the beam.



(a) (2 points) Draw a free-body diagram of the beam and indicate and label all the forces.

(b) (3 points) Calculate the forces F_A, and F_B that the supports **A** and **B** exert on the beam.

5. Two objects of masses $m_1 = 2.00\,\text{kg}$ and $m_2 = 1.00\,\text{kg}$ are connected with a massless spring of $k = 4000\,\text{kg/s}^2$ and are resting on a *frictionless* surface. Initially, the spring is compressed by 10.0 cm and gets released.



   (a) (3 points) What is the total energy of the system before the spring is released?

   (b) (2 points) What is the total momentum of the system before and after the spring is released?

   (c) (5 points) What are the velocities of each block with respect to the table after the spring is released?

(d) (2 points (bonus)) What is the velocity of the spring after the objects m_1 and m_2 have lost contact with the spring? *Hint: Consider the velocity of each end of the spring just before it loses contact with the objects.*