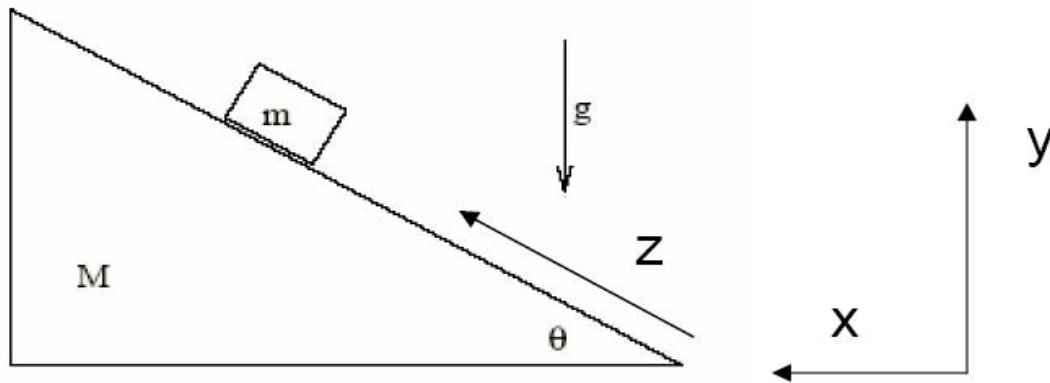


## Classical Mechanics (Escape Velocity) Problem 1

Suppose the Moon were to have the same mass as the Earth, and you are trying to throw one of your physics books from the Earth to the Moon. With what minimum velocity must the book leave the surface of the Earth? Neglect the relative motion of the Earth and the Moon, and the Earth's rotation. The mass of the Earth is  $M_E = 6.0 \cdot 10^{24}$  kg, the radius of the Earth is  $6.4 \cdot 10^6$  m, and the distance from the center of the Earth to the center of the Moon is  $R_{EM} = 3.8 \cdot 10^8$  m. Compare your answer to the escape velocity from Earth alone. The gravitational constant is  $G = 6.67 \cdot 10^{-11}$  N m<sup>2</sup>/kg<sup>2</sup>.

## Classical Mechanics Problem 2

A wedge of mass  $M=4.5$  kg sits on a horizontal surface. Another mass  $m=2.3$  kg sits on the sloping side of the wedge. The incline is at an angle  $\theta=31.7$  degrees with respect to the horizontal, and  $g=9.8$  m/s<sup>2</sup>. All surfaces are frictionless. The mass  $m$  is released from rest on mass  $M$ , which is also initially at rest. Use Lagrangian mechanics and the suggested coordinates to determine the vector values of the accelerations of both  $M$  and  $m$  once the mass is released.



## Classical Mechanics Problem 3

A pencil of length  $L$  is held vertically with its point on a desk and then allowed to fall over. Assuming that the point does not slip, find the speed of the eraser just as it strikes the desk. Compare this with the speed that would result from free fall from a height equal to the length of the pencil.

## Classical Mechanics

### Problem 4

Consider the Earth as a frame rotating about its axis with frequency  $\omega$ . Particles are then subject to the Coriolis force given by  $\vec{F} = -2m(\vec{\omega} \times \vec{v}_r)$ , where  $\vec{v}_r$  is the velocity of the particle relative to the frame and  $m$  is the mass of the particle. Choose the  $z$ -axis along the upwards vertical direction, and the  $y$ -axis pointing North, and the  $x$ -axis to the East. Assume you are in the Northern hemisphere at a colatitude  $\theta$  (angle of the  $z$ -axis with respect to  $\vec{\omega}$ ).

- (a) a particle moves under the influence of gravity and the Coriolis force. Write the equations of motion in the  $x$ ,  $y$ , and  $z$  directions. Use the approximation that the component of velocity in the  $z$  direction is much larger than the components in the  $x$  and  $y$  directions, i.e.  $|v_z| \gg |v_x|, |v_y|$ .
- (b) the particle is dropped at rest from a height  $h$  above the ground, and it arrives at the ground with a speed  $v_0 = \sqrt{2gh}$ . Find the magnitude and direction of the Coriolis deflection.
- (c) the particle is now thrown vertically upward with an initial speed  $v_0$  so that it reaches the maximum height  $h$  [the same height as in part (b)], and then falls back to the ground. find the magnitude and direction of the Coriolis deflection.
- (d) Compare your results for parts (b) and (c).