

Classical Mechanics

Lecture 9

Today's Concepts:

- a) Energy and Friction
- b) Potential energy & force

Common Issues:

HW is harder than lecture

Need more practice materials

Don't know how to prepare for exam

Material is getting harder

Things we can do:

Do some HW problems in class

Provide practice materials to prepare for exam

Post formula sheet

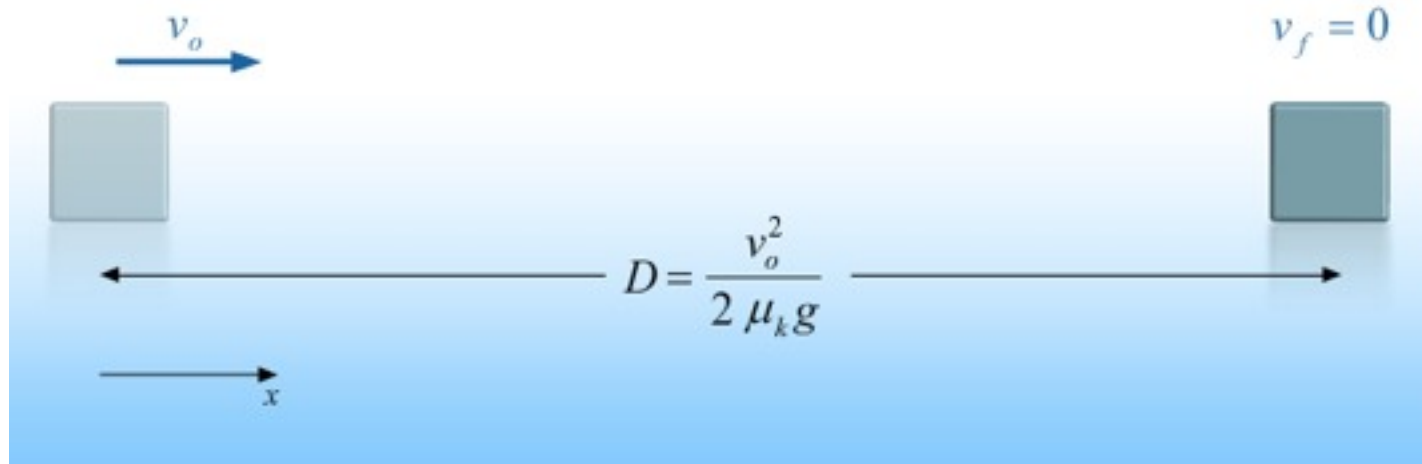
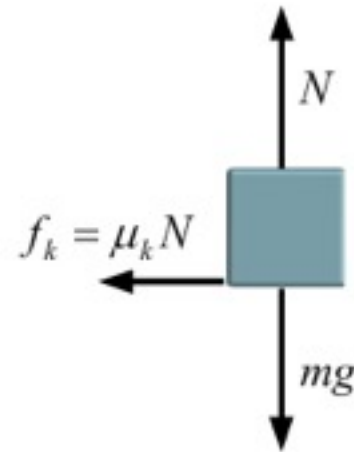
Make sure office hours are utilized

Macroscopic Work done by Friction

Work-Kinetic Energy Theorem

$$\Delta K = W_{Net}$$
$$-\frac{1}{2}mv_o^2 = -\mu_k mgD$$

Macroscopic Work
done by Friction



Macroscopic Work:

This is not a new idea – it’s the same “work” you are used to.

➔ $W = \int_a^b \vec{F} \cdot d\vec{l}$ Applied to big (i.e. macroscopic) objects rather than point particles (picky detail)

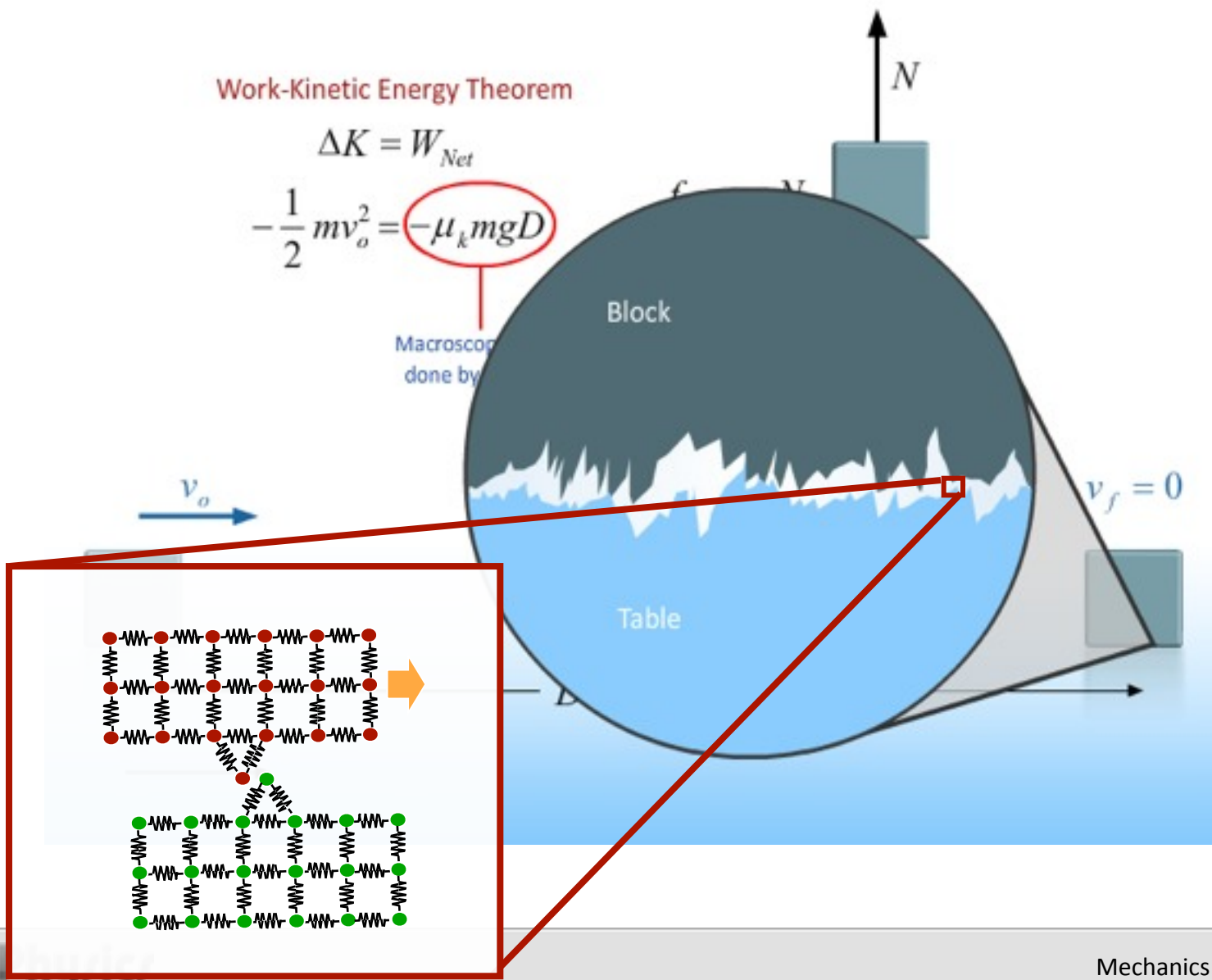
We call it “macroscopic” to distinguish it from “microscopic”.

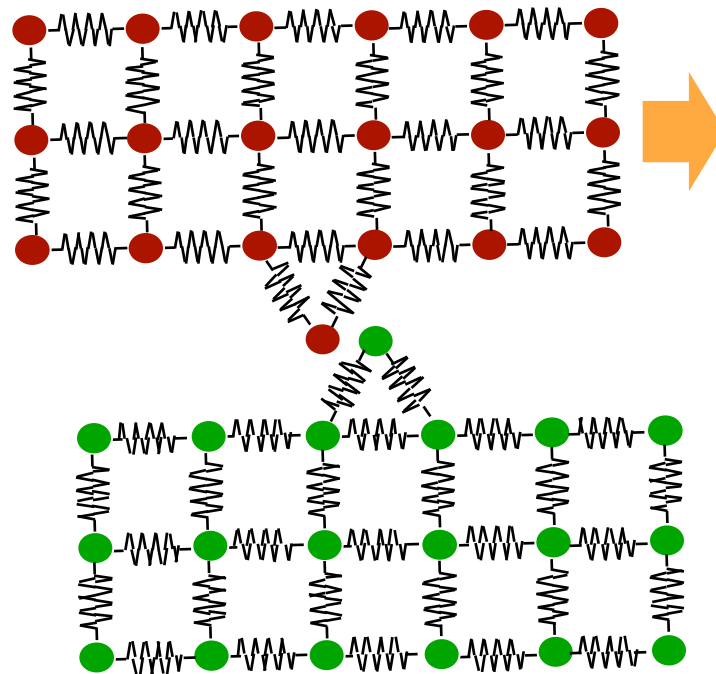
Work-Kinetic Energy Theorem

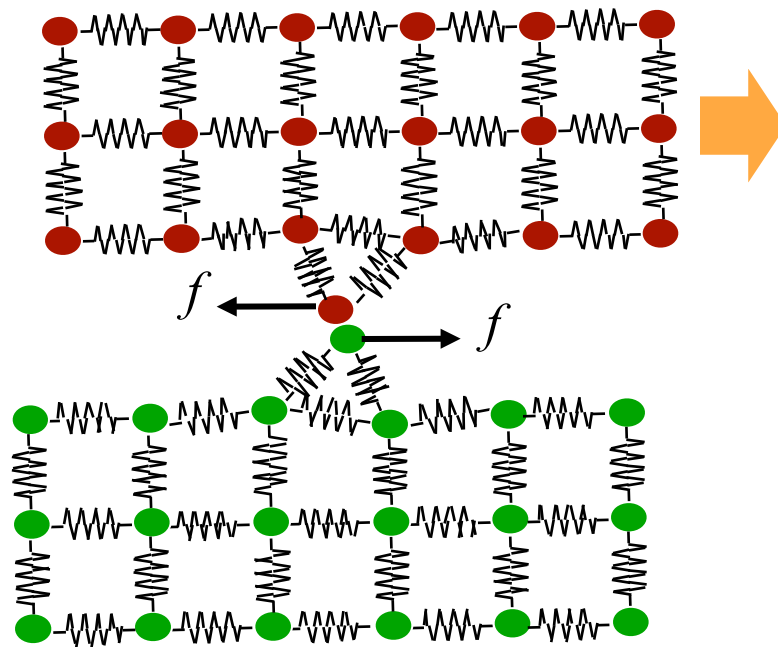
$$\Delta K = W_{Net}$$

$$-\frac{1}{2}mv_o^2 = -\mu_k mgD$$

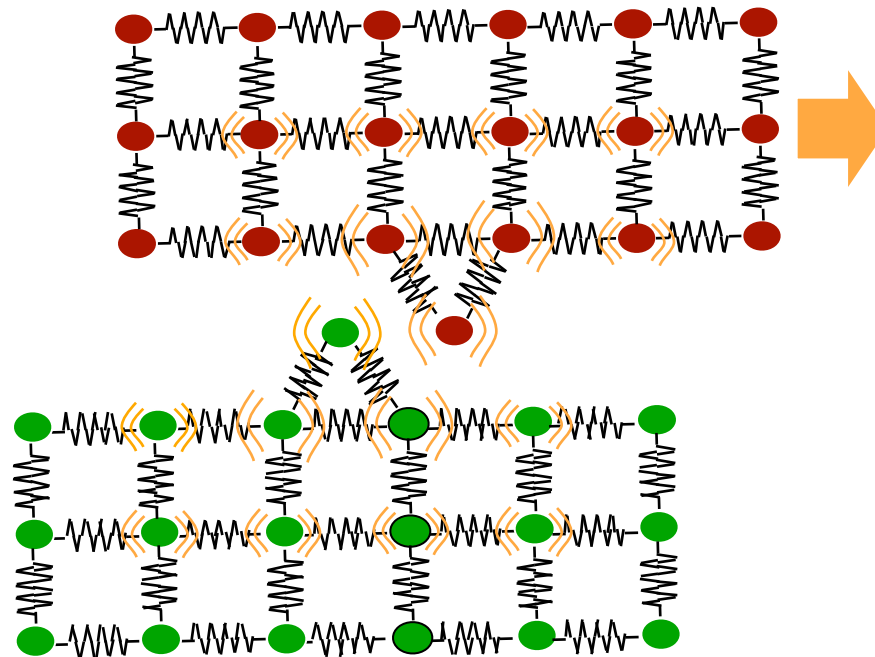
Macroscopic
done by







“Heat” is just the kinetic energy of the atoms!



Do spinning Heat Demo

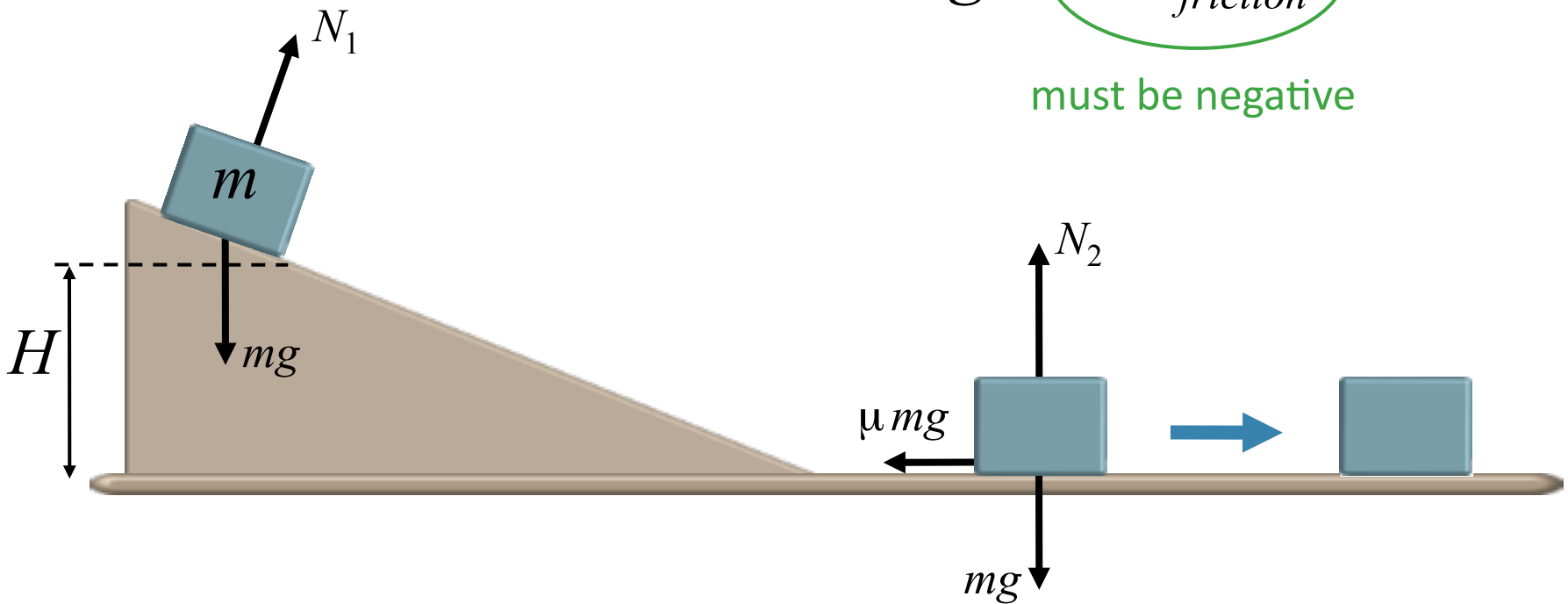
$$\Delta K = W_{tot} = W_{gravity} + W_{friction}$$



$$0 = W_{gravity} + W_{friction}$$

$$0 = mgH + W_{friction}$$

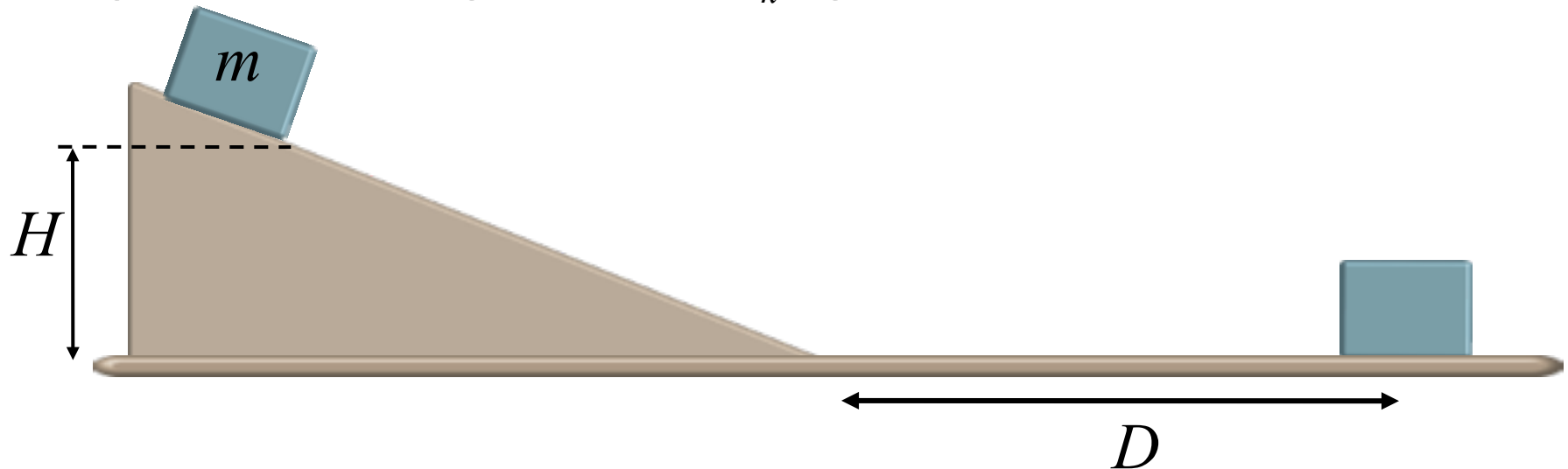
must be negative



Checkpoint

A block of mass m , initially held at rest on a frictionless ramp a vertical distance H above the floor, slides down the ramp and onto a floor where friction causes it to stop a distance r from the bottom of the ramp. The coefficient of kinetic friction between the box and the floor is μ_k . What is the macroscopic work done on the block by friction during this process?

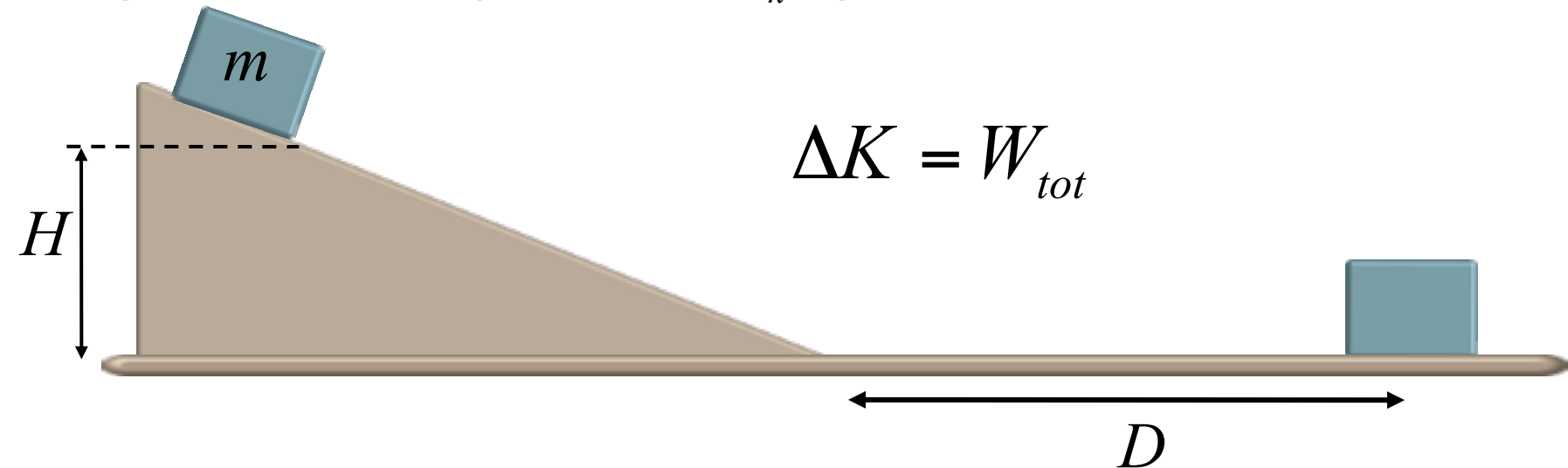
- A) mgH B) $-mgH$ C) $\mu_k mgD$ D) 0



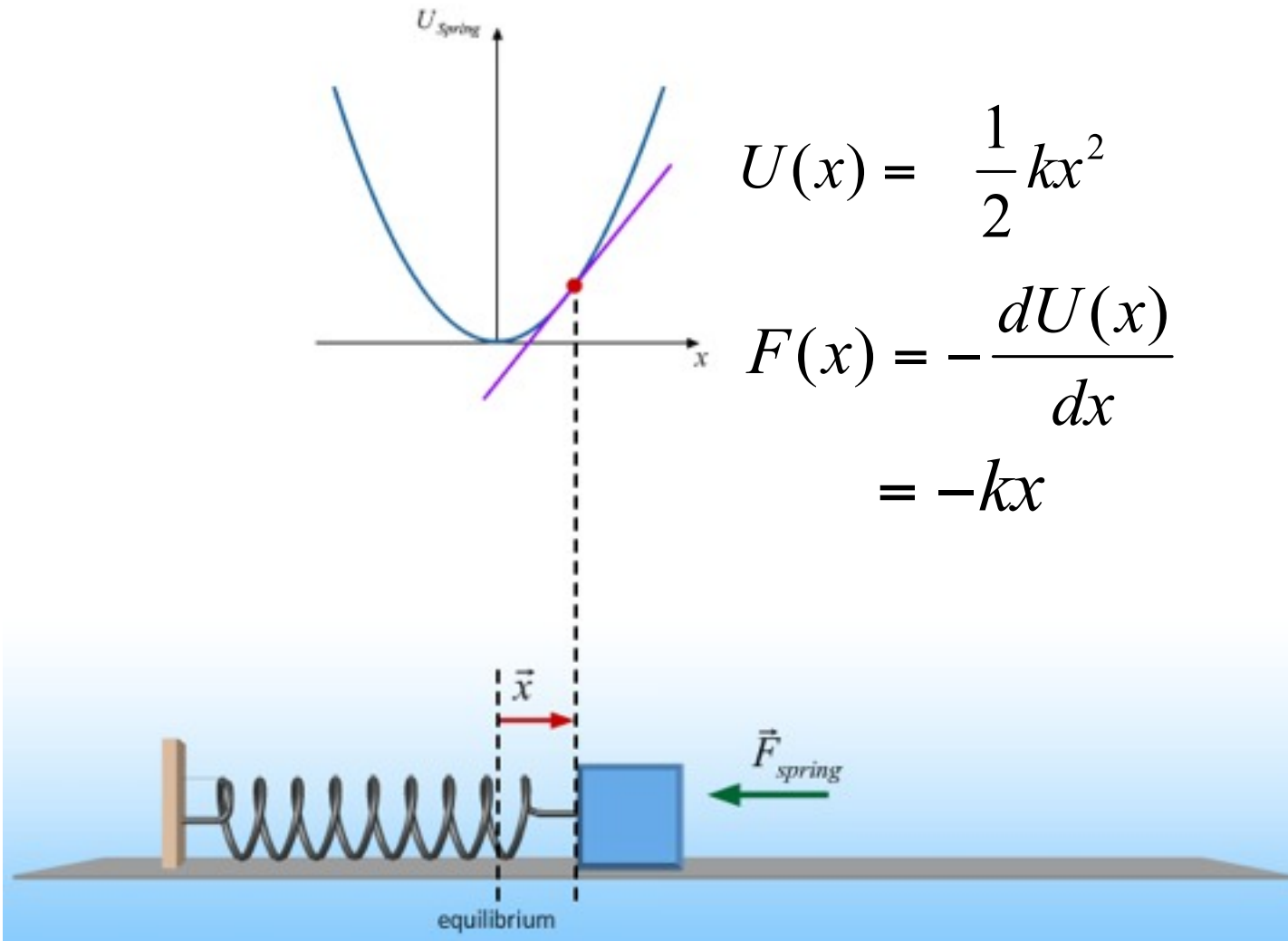
Checkpoint

A block of mass m , initially held at rest on a frictionless ramp a vertical distance H above the floor, slides down the ramp and onto a floor where friction causes it to stop a distance D from the bottom of the ramp. The coefficient of kinetic friction between the box and the floor is μ_k . What is the **total** macroscopic work done on the block by all forces during this process?

- A) mgH B) $-mgH$ C) $\mu_k mgD$ D) 0



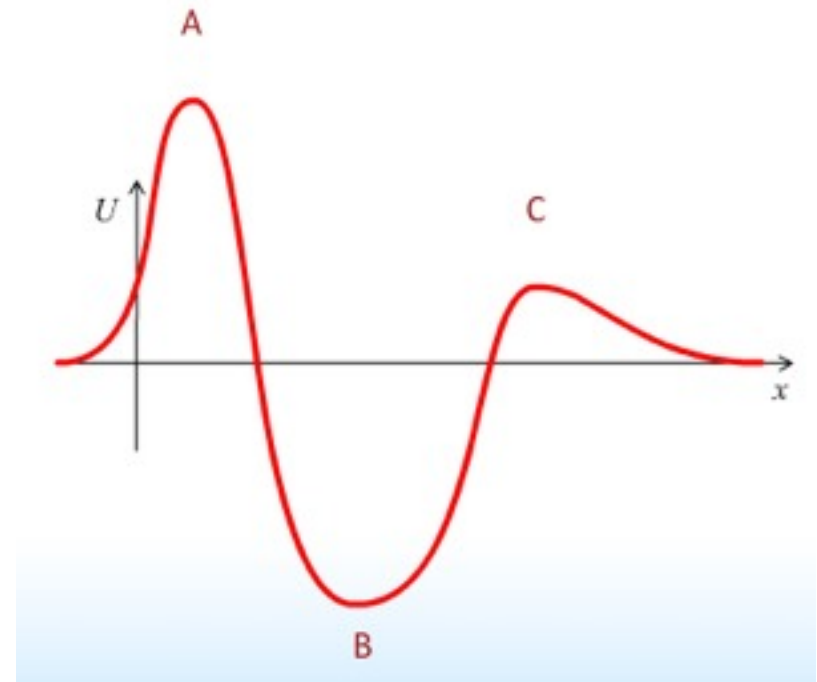
Potential Energy vs. Force



Potential Energy vs. Force

$$F(x) = -\frac{dU(x)}{dx}$$

	P.E. Function U	Force \vec{F}
Gravity (Near Earth)	$mgh + U_o$	$m\vec{g}$
Gravity (General Expression)	$-G\frac{m_1m_2}{r} + U_o$	$-G\frac{m_1m_2}{r^2}\hat{r}$
Spring	$\frac{1}{2}kx^2 + U_o$	$-k\vec{x}$



Demo

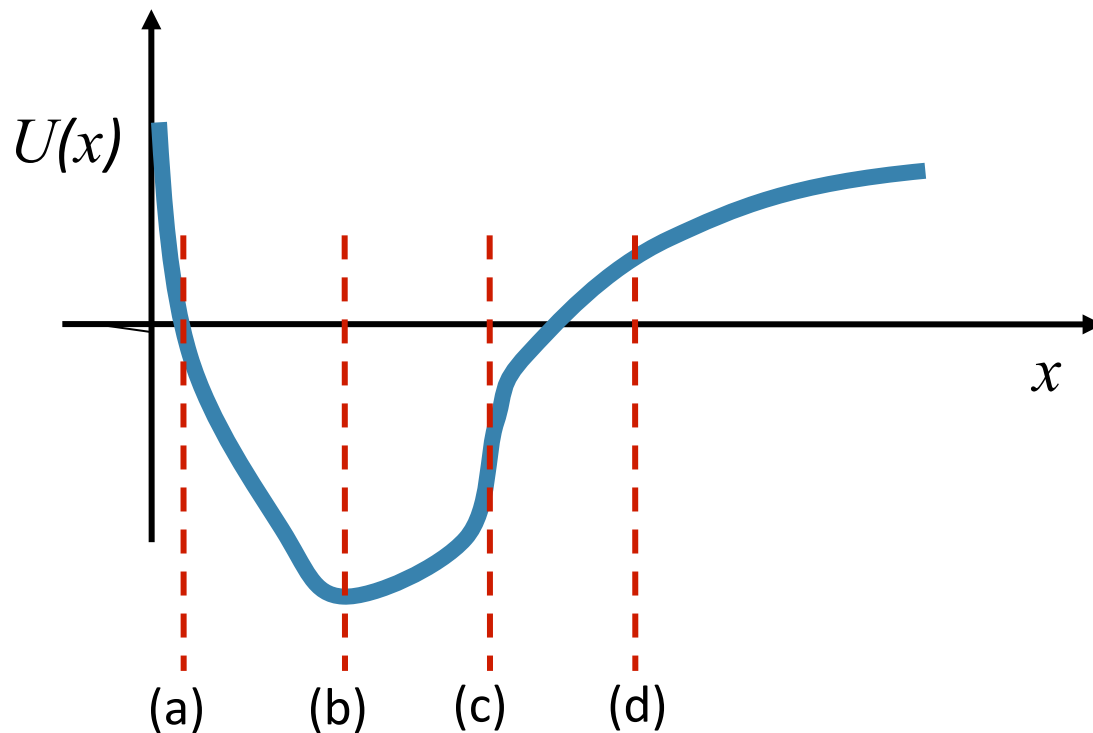
Clicker Question



Suppose the potential energy of some object U as a function of x looks like the plot shown below.

Where is the force on the object zero?

- A) (a) B) (b) C) (c) D) (d)



$$F(x) = -\frac{dU(x)}{dx}$$

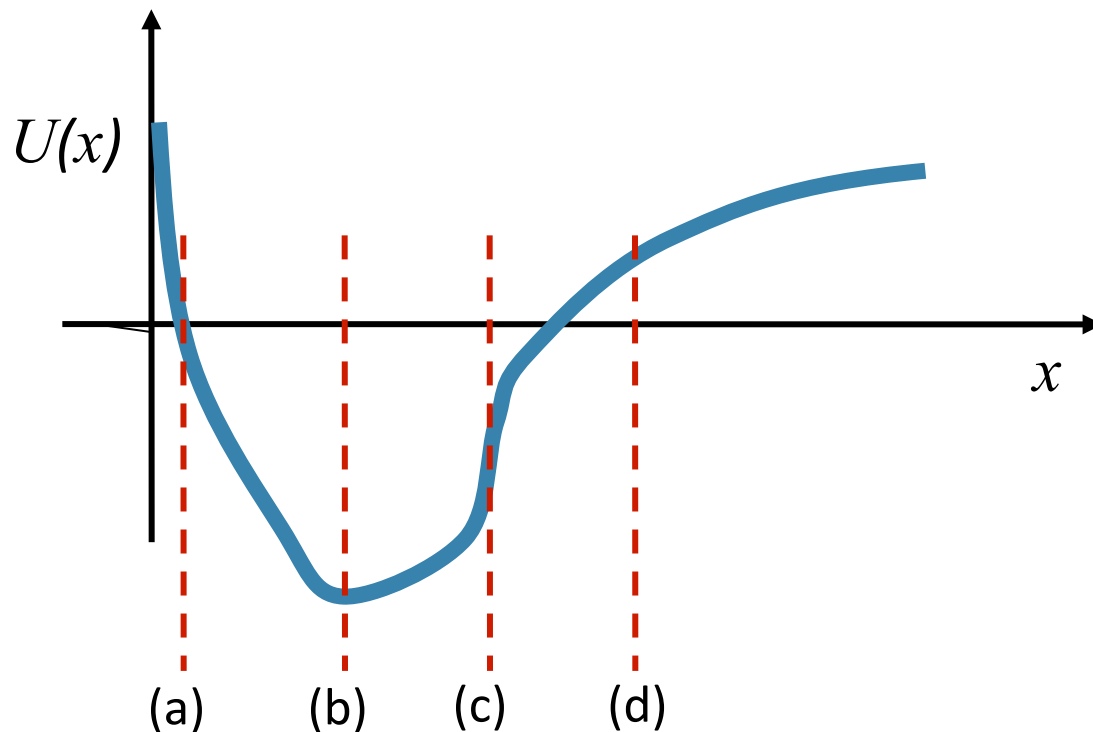
Clicker Question



Suppose the potential energy of some object U as a function of x looks like the plot shown below.

Where is the force on the object in the $+x$ direction?

- A) To the left of (b) B) To the right of (b) C) Nowhere



$$F(x) = -\frac{dU(x)}{dx}$$

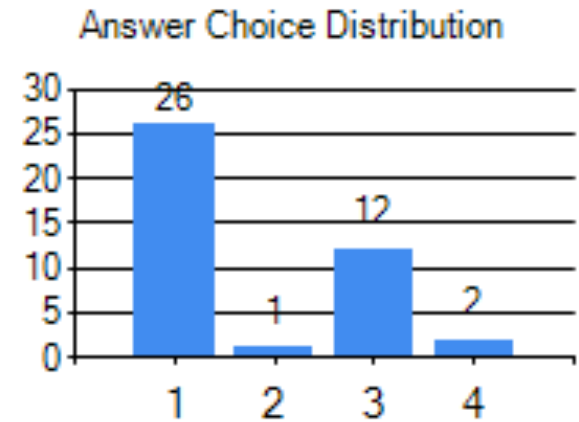
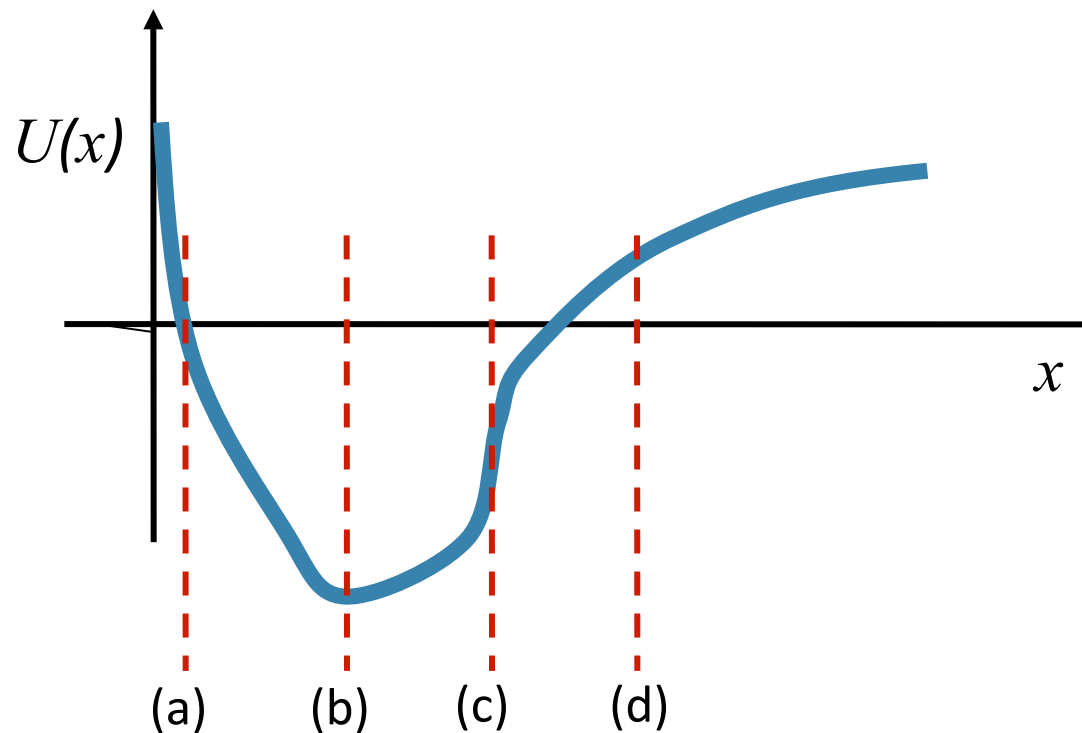
CheckPoint



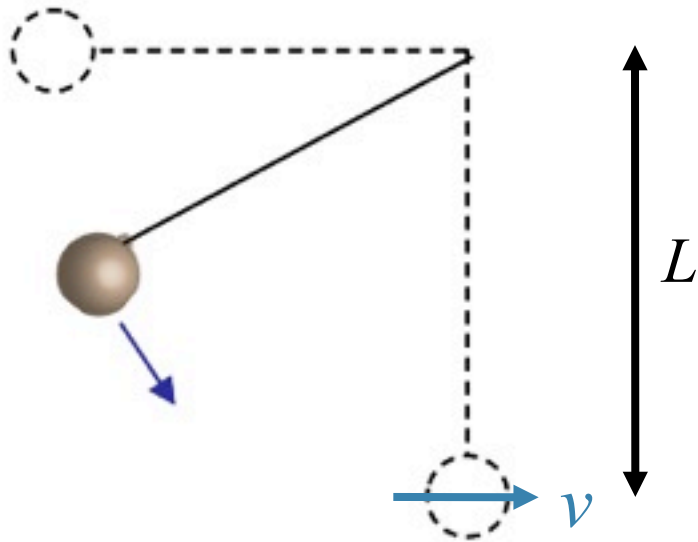
Suppose the potential energy of some object U as a function of x looks like the plot shown below.

Where is the force on the object biggest in the $-x$ direction?

- A) (a) B) (b) C) (c) D) (d)



$$F(x) = -\frac{dU(x)}{dx}$$

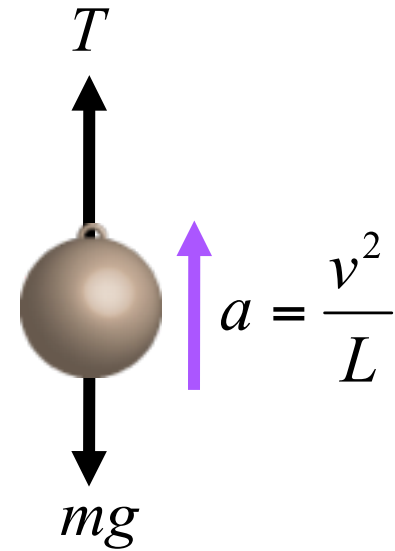
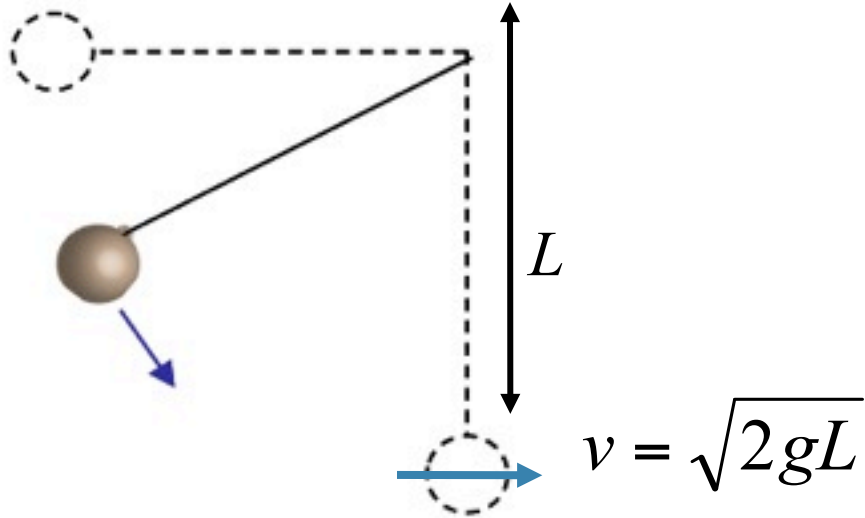


A mass $m = 5.8$ kg hangs on the end of a massless rope $L = 1.97$ m long. The pendulum is held horizontal and released from rest.

1) How fast is the mass moving at the bottom of its path? m/s

Conserve Energy from initial to final position

$$mgL = \frac{1}{2}mv^2 \longrightarrow v = \sqrt{2gL}$$

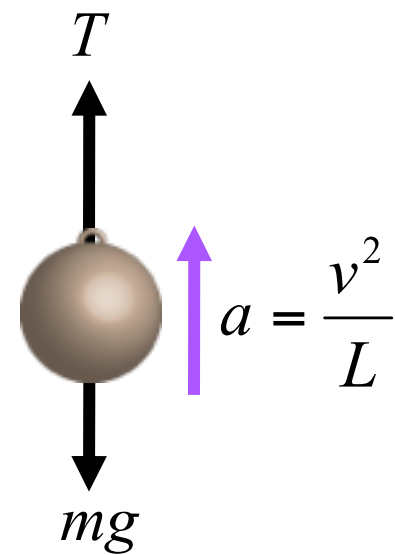
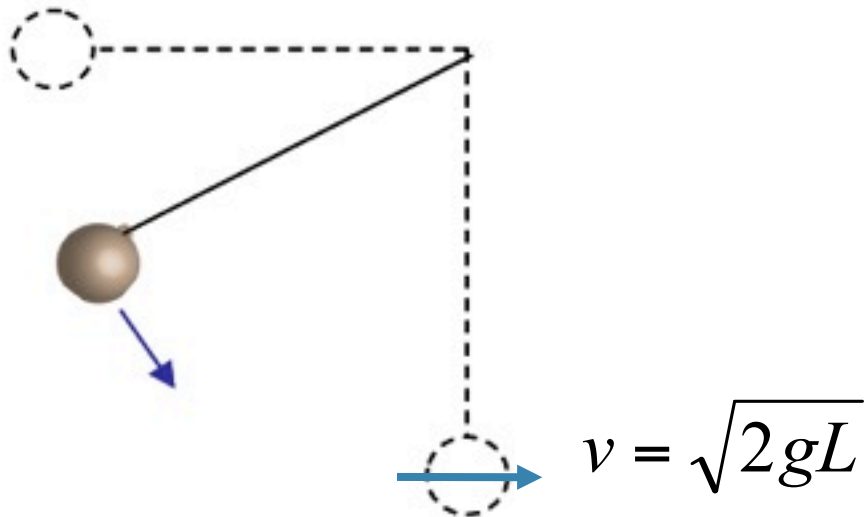


A mass $m = 5.8$ kg hangs on the end of a massless rope $L = 1.97$ m long. The pendulum is held horizontal and released from rest.

1) How fast is the mass moving at the bottom of its path? m/s

2) What is the magnitude of the tension in the string at the bottom of the path? N

$$T - mg = \frac{mv^2}{L} \quad \rightarrow \quad T = mg + \frac{mv^2}{L}$$



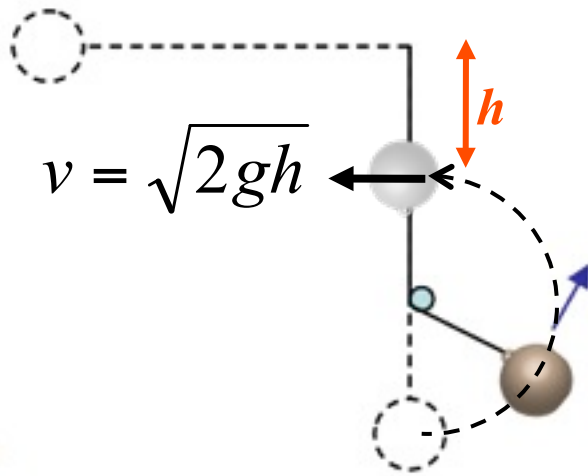
A mass $m = 5.8$ kg hangs on the end of a massless rope $L = 1.97$ m long. The pendulum is held horizontal and released from rest.

1) How fast is the mass moving at the bottom of its path? m/s

2) What is the magnitude of the tension in the string at the bottom of the path? N

3) If the maximum tension the string can take without breaking is $T_{\max} = 500$ N, what is the maximum mass that can be used? (Assuming that the mass is still released from the horizontal and swings down to its lowest point.) kg

$$T = mg + \frac{mv^2}{L} \quad \longrightarrow \quad T = mg + \frac{m2gL}{L} \quad \longrightarrow \quad T = 3mg$$



4) 🕒

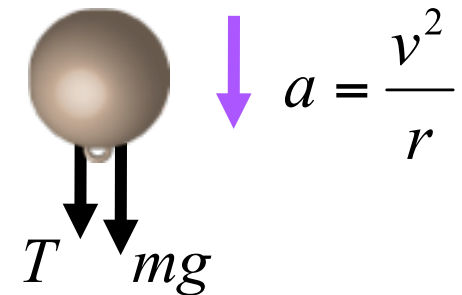
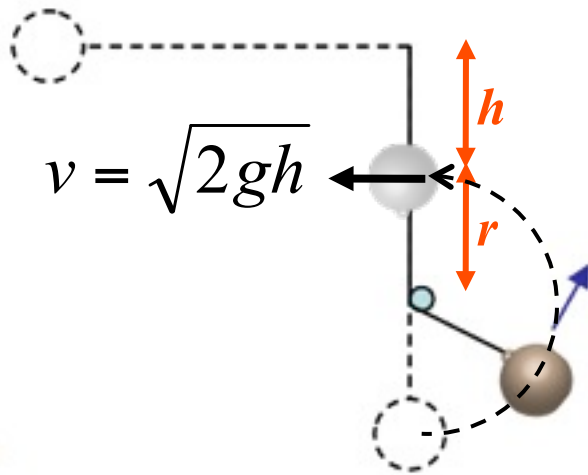
Now a peg is placed $4/5$ of the way down the pendulum's path so that when the mass falls to its vertical position it hits and wraps around the peg. As it wraps around the peg and attains its maximum height it ends a distance of $3/5 L$ below its starting point (or $2/5 L$ from its lowest point).

How fast is the mass moving at the top of its new path (directly above the peg)?

 m/s

Conserve Energy from initial to final position.

$$mgh = \frac{1}{2}mv^2 \quad \rightarrow \quad v = \sqrt{2gh}$$



4) 🕒

Now a peg is placed $4/5$ of the way down the pendulum's path so that when the mass falls to its vertical position it hits and wraps around the peg. As it wraps around the peg and attains its maximum height it ends a distance of $3/5 L$ below its starting point (or $2/5 L$ from its lowest point).

How fast is the mass moving at the top of its new path (directly above the peg)?

m/s

5) 🕒

Using the original mass of $m = 5.8$ kg, what is the magnitude of the tension in the string at the top of the new path (directly above the peg)? N

$$T + mg = \frac{mv^2}{r} \quad \rightarrow \quad T = \frac{mv^2}{r} - mg$$