

# College Physics I: 1511

## Mechanics & Thermodynamics

Professor Jasper Halekas  
Van Allen Lecture Room 1  
MWF 8:30-9:20 Lecture

# Forces

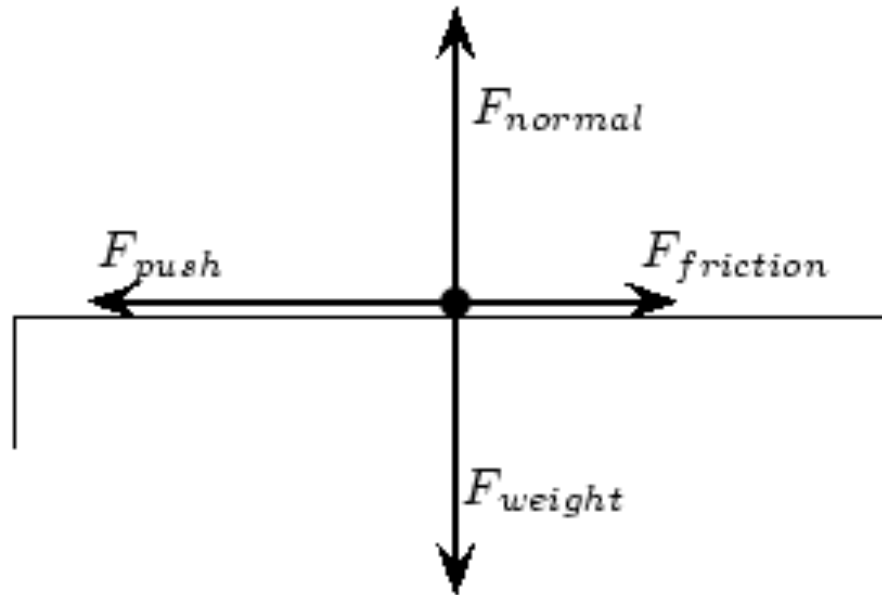
## Forces:

$$F_G = mg \text{ (@ surface)}$$

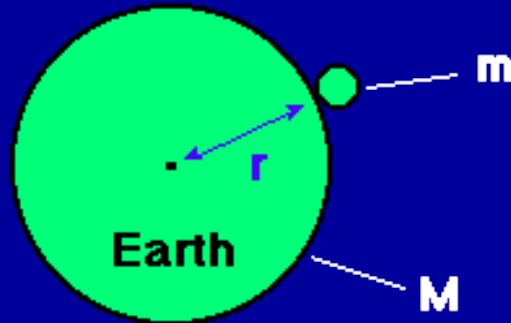
$$F_C = ma_c = \frac{mv^2}{r}$$

$$f_s^{MAX} = \mu_s F_N \quad f_k = \mu_k F_N$$

$$F_{spring} = -kx$$



# Gravity



$$\text{Weight} = F_g = G \frac{Mm}{r^2} = mg$$

The equation shows the relationship between weight, gravitational force, and acceleration due to gravity. The term  $G \frac{Mm}{r^2}$  is circled in red, and a red circle containing  $= g$  points to it. The final result  $mg$  is enclosed in a yellow box.

**M** is the mass of the Earth

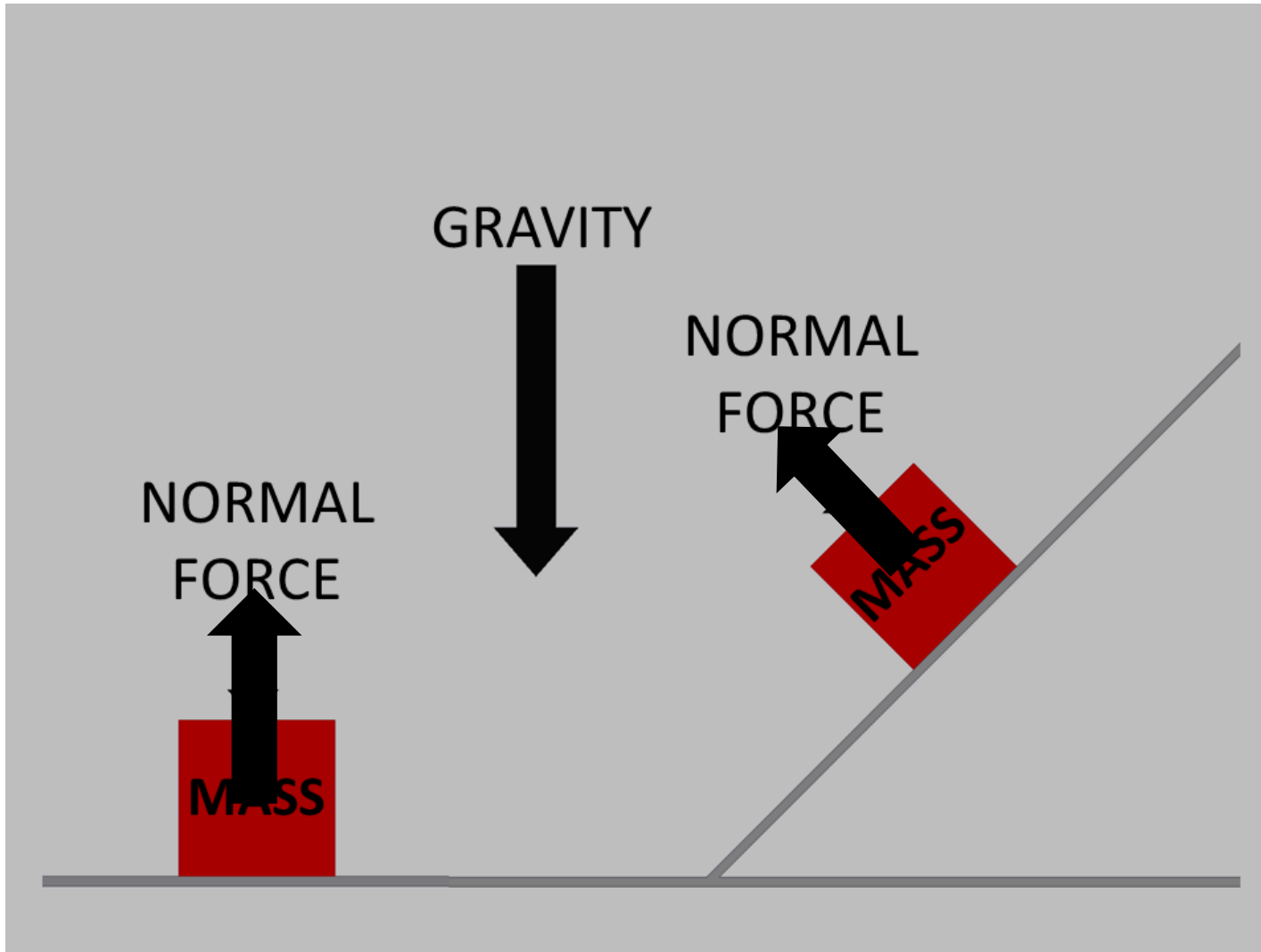
**m** is the mass of the object

**r** is the radius of the Earth

**g** is the acceleration due to gravity at the Earth's surface

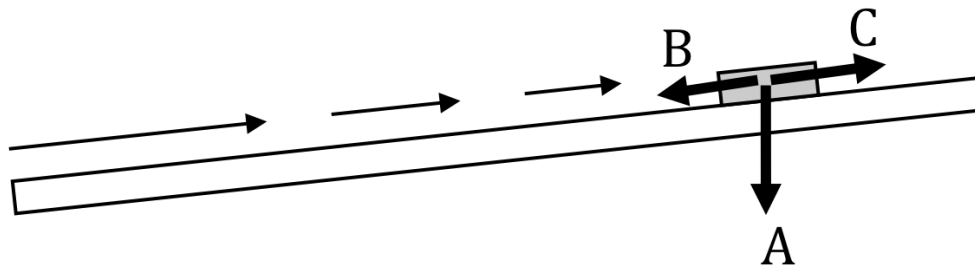
Only need to know gravity at surface for the test!

# Normal Forces



# Sample Question

A glider on a tilted air track is given a brief push uphill. The glider coasts up to near the top end, stops, and then slides back down.



When the glider is at the highest point of its path, its acceleration is..

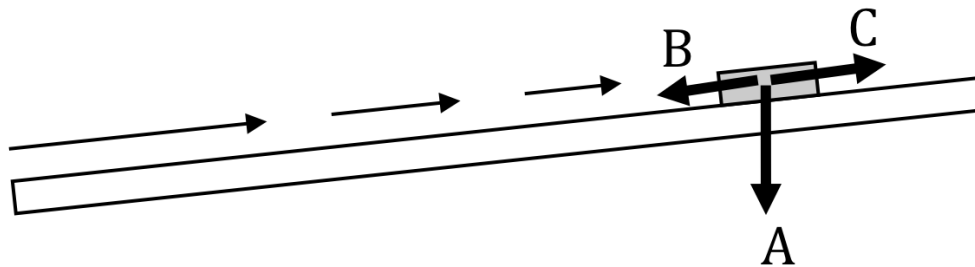
A: straight down

B: downward along the track

C: upward along the track

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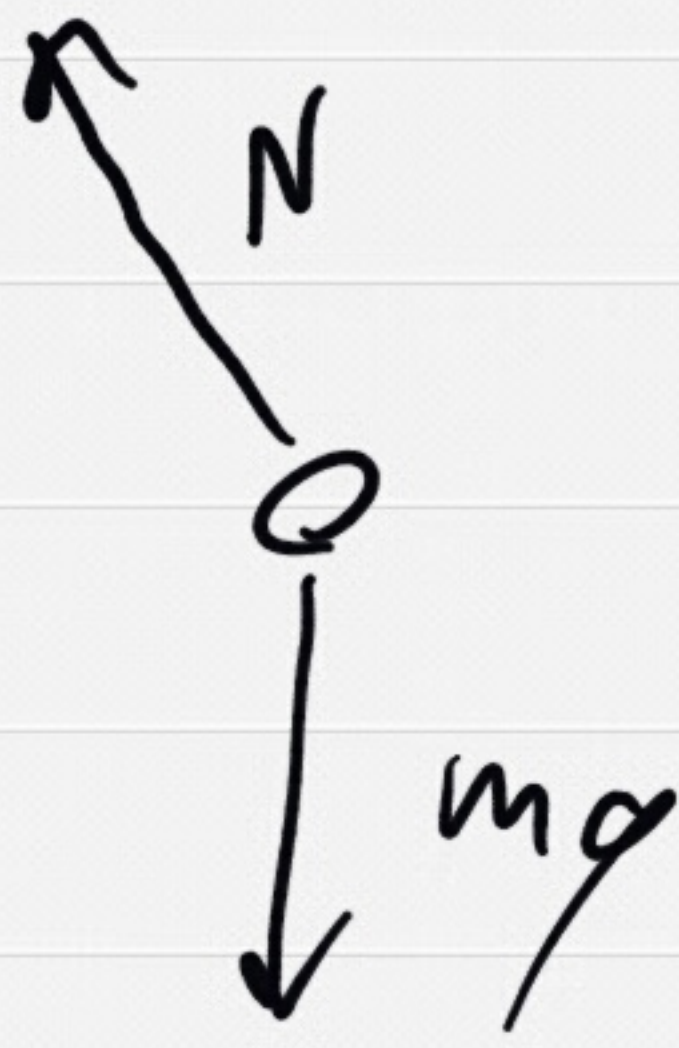


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A: straight down

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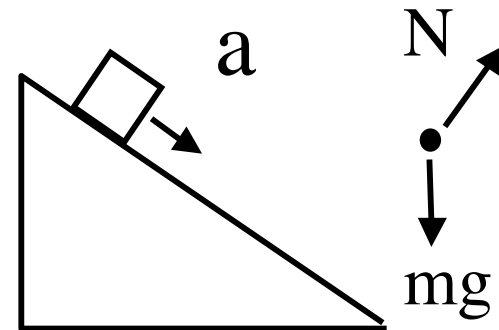
$$\vec{F}_{net} = m\vec{a}$$

so  $\vec{a}$  down along track

# Sample Question

- A mass  $m$  is accelerated down along a frictionless inclined plane. The magnitudes of the forces on the free-body diagram have not been drawn carefully, but the directions of the forces are correct. Which statement below must be true?

- A:  $mg > N$
- B:  $N > mg$
- C:  $N = mg$

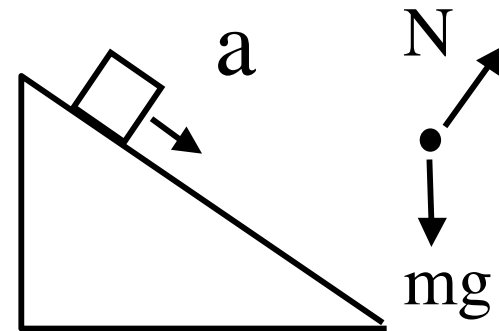


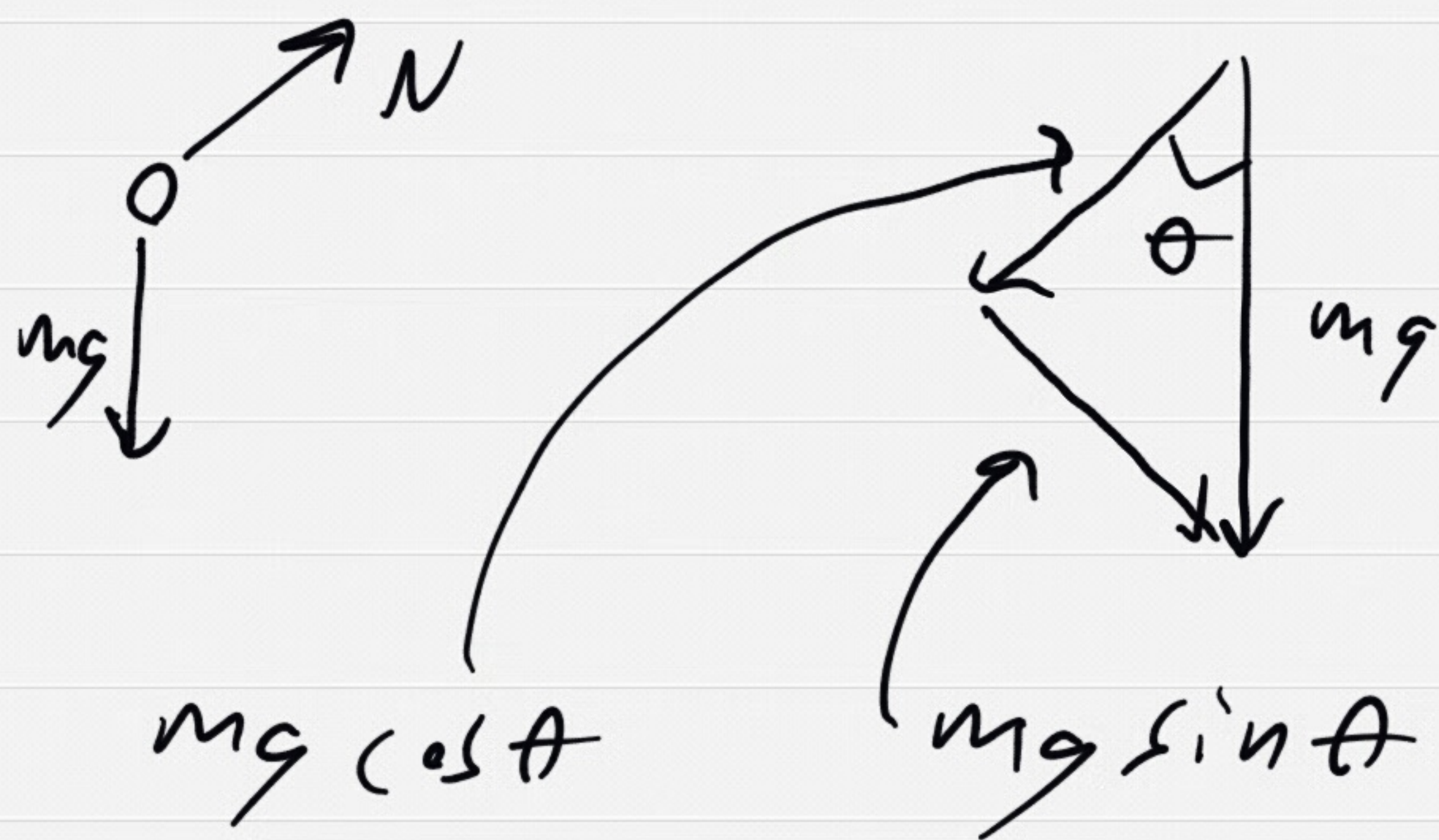


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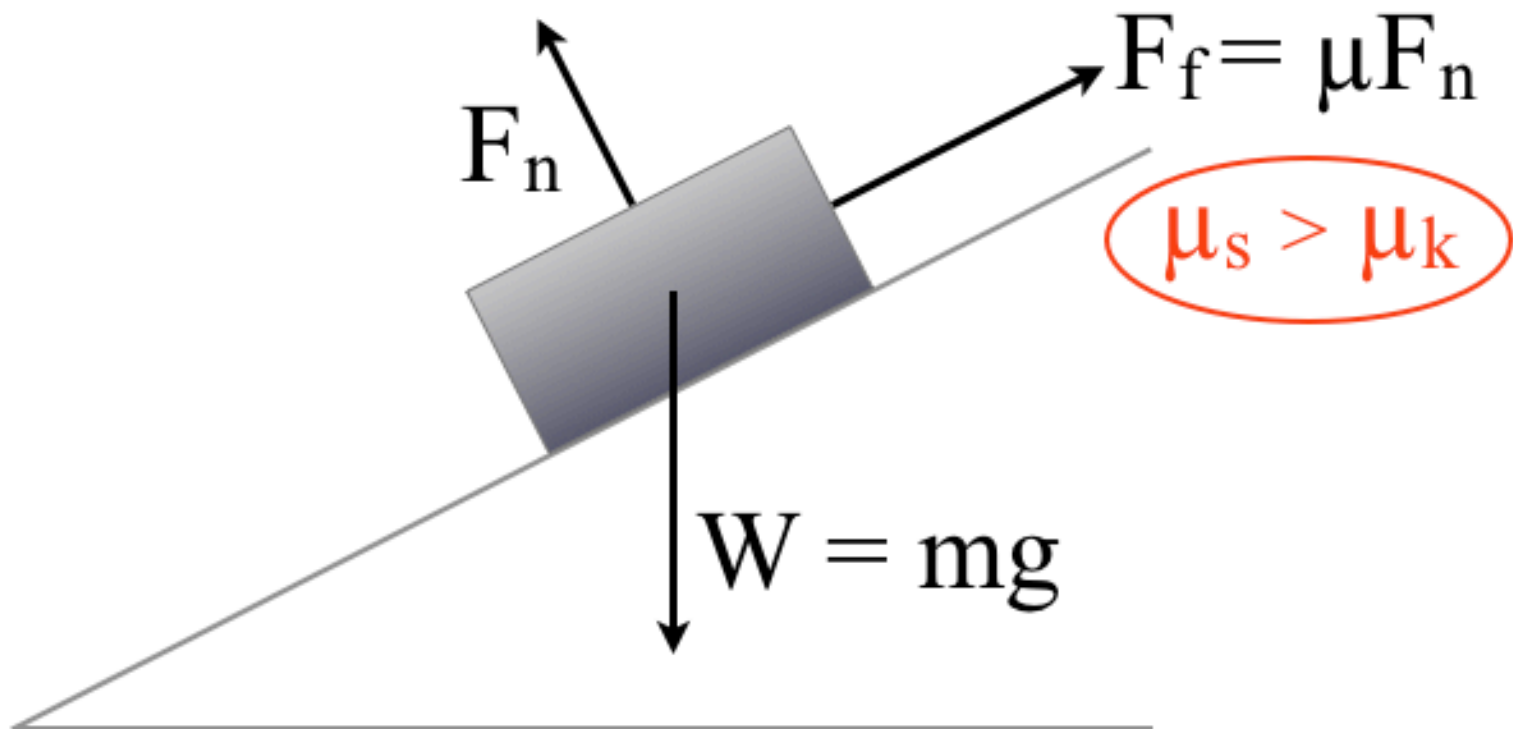




$N$  balances  $mg \cos \theta$

so  $N < mg$

# Friction



# Sample Question

I push (with force  $F_{\text{ext}}$ ) on a block (mass  $m$ ) which sits on the table.

The block is not moving, because there is static friction (coefficient  $\mu_s$ ).

What can you say for sure about the frictional force,  $f$  (frictional force of table on block)?

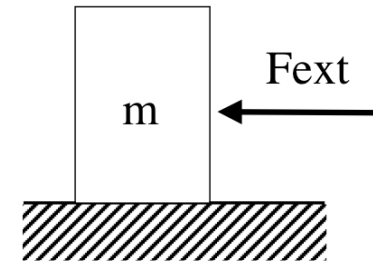
**A:**  $f = \mu_s mg$

**B:**  $f = F_{\text{ext}}$

**C:**  $f > F_{\text{ext}}$

**D:**  $f < F_{\text{ext}}$

**E:** Not enough information (or, MORE than one of the above)

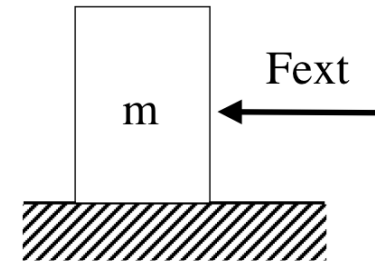


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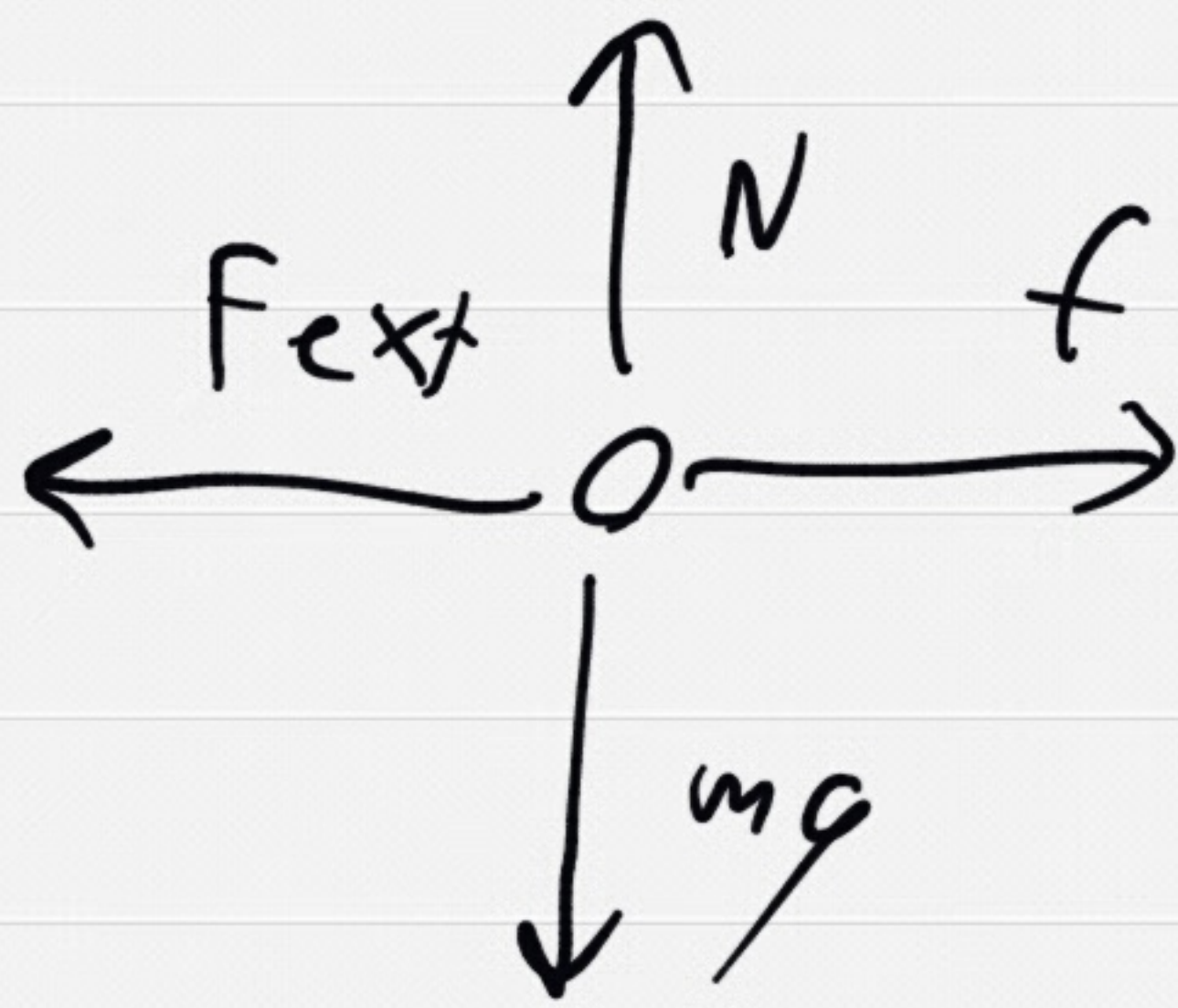
**A:**  $f = \mu_s mg$

**B:**  $f = F_{\text{ext}}$

**C:**  $f > F_{\text{ext}}$

**D:**  $f < F_{\text{ext}}$

**E:** Not enough information (or, MORE than one of the above)



$$\boxed{f = F_{\text{ext}}} \quad \text{since } a = 0$$

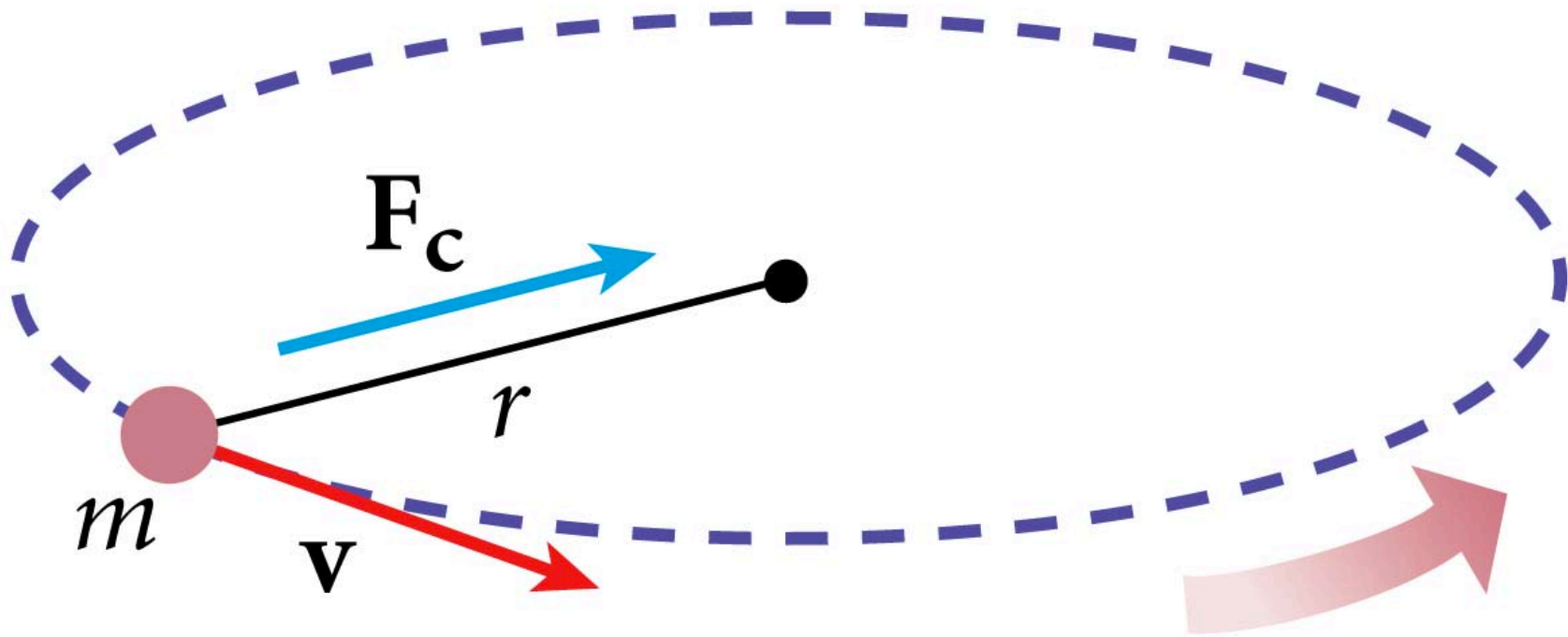
$$\begin{aligned} f_{\text{max}} &= \mu_s F_N \\ &= \mu_s mg \end{aligned}$$

but  $f$  can be less than  $f_{\text{max}}$  if not needed to balance  $F_{\text{ext}}$

# Centripetal Force

Rotational Motion:

$$\theta = s/r \quad a_c = \frac{v^2}{r}$$



# Work and Energy

## Work & Energy:

$$KE_{trans} = \frac{1}{2}mv^2$$

$$E = KE + PE$$

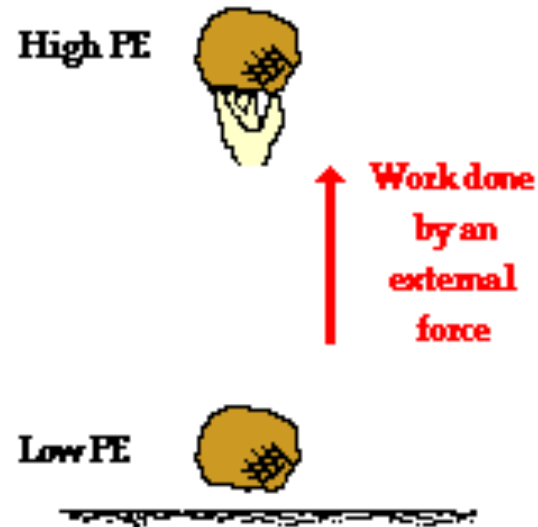
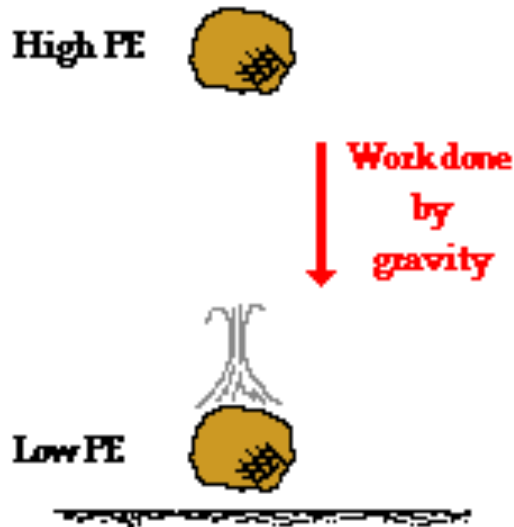
$$\Delta KE = W_{net}$$

$$\Delta E = W_{nc}$$

$$PE_G = mgh$$

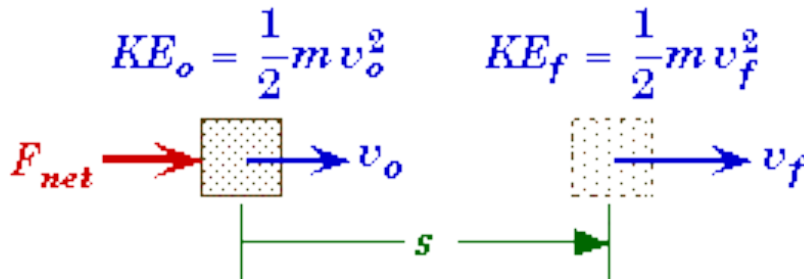
$$PE_{spring} = \frac{1}{2}kx^2$$

$$W = \vec{F} \cdot \Delta\vec{r} = |\vec{F}||\Delta\vec{r}| \cos \theta_{Fdr}$$





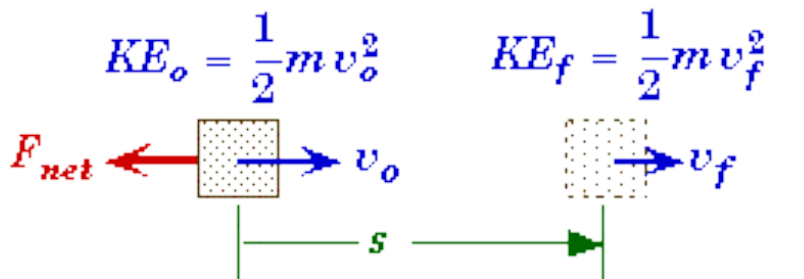
# Work and Energy



The diagram shows a block moving to the right. A red arrow labeled  $F_{net}$  points to the right, and a blue arrow labeled  $v_o$  also points to the right. A green arrow labeled  $s$  indicates the displacement to the right. A second dashed block is shown further to the right with a blue arrow labeled  $v_f$  pointing to the right.

$$KE_o = \frac{1}{2} m v_o^2 \quad KE_f = \frac{1}{2} m v_f^2$$
$$W_{net} = F_{net} s \cos(0^\circ) = +F_{net} s$$

$W_{net} > 0$   
 $\Delta v > 0$   
 $KE_f > KE_o$



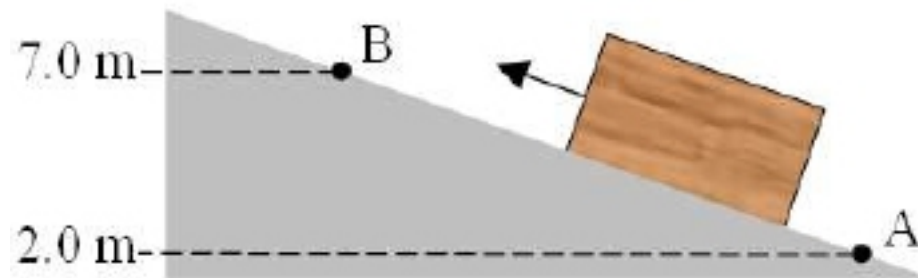
The diagram shows a block moving to the right. A red arrow labeled  $F_{net}$  points to the left, and a blue arrow labeled  $v_o$  points to the right. A green arrow labeled  $s$  indicates the displacement to the right. A second dashed block is shown further to the right with a blue arrow labeled  $v_f$  pointing to the right.

$$KE_o = \frac{1}{2} m v_o^2 \quad KE_f = \frac{1}{2} m v_f^2$$
$$W_{net} = F_{net} s \cos(180^\circ) = -F_{net} s$$

$W_{net} < 0$   
 $\Delta v < 0$   
 $KE_f < KE_o$

# Sample Question

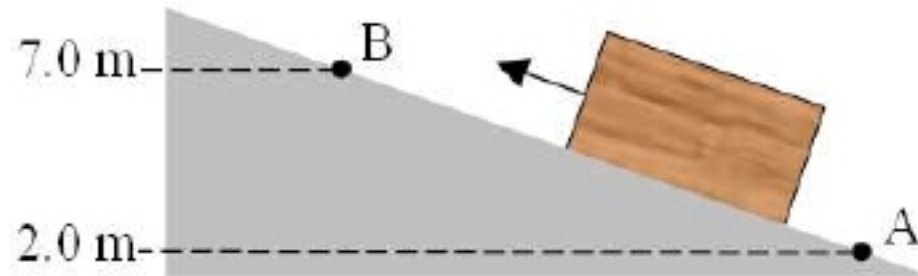
- A 12-kg crate is pushed up an incline from point A to point B as shown in the figure. What is the change in the gravitational potential energy of the crate? Assume  $g = 10 \text{ m/s}^2$ .



- A. -600 J
- B. -1200 J
- C. +1200 J
- D. This cannot be determined without knowing the angle of the incline.
- E. +600 J

# Sample Question

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- A.  $-600 \text{ J}$
- B.  $-1200 \text{ J}$
- C.  $+1200 \text{ J}$
- D. This cannot be determined without knowing the angle of the incline.
- E.  $+600 \text{ J}$

$$\Delta PE_g = mgh$$

$$= 12 \cdot 10 \cdot 5$$

$$= \boxed{600 \text{ J}}$$

# Sample Question

- A woman stands on the edge of a cliff and throws a stone vertically *downward* with an initial speed of 10 m/s. The instant before the stone hits the ground below, it has 450 J of kinetic energy. If she were to throw the stone horizontally outward from the cliff with the same initial speed of 10 m/s, how much kinetic energy would it have just before it hits the ground?
  - A. 950 J
  - B. 50 J
  - C. 100 J
  - D. 450 J
  - E. 800 J

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  - A. 950 J
  - B. 50 J
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  - D. 450 J
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$$E = KE + PE = \text{const.}$$

$$E_0 = \frac{1}{2}mv_0^2 + mgy_0$$

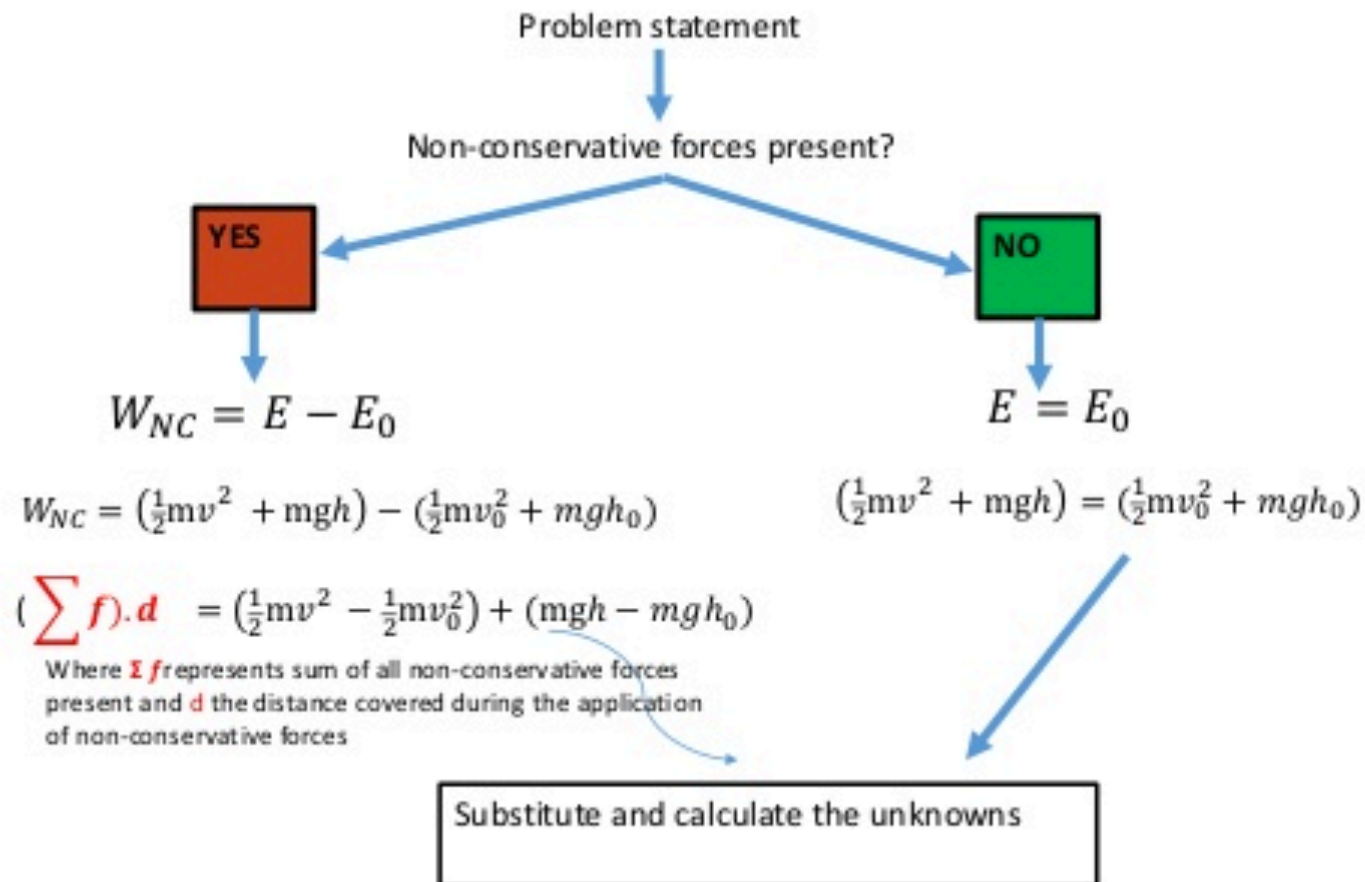
$$E_1 = E_0$$

$$= \frac{1}{2}mv_f^2 + mgy_f$$

$KE_f$  same in both cases

# Work and Energy: Non-Conservative

## Problem solving strategy





# Sample Question

- An automobile approaches a barrier at a speed of 20 m/s along a level road. The driver locks the brakes at a distance of 50 m from the barrier. What minimum coefficient of kinetic friction is required to stop the automobile before it hits the barrier? Assume  $g = 10 \text{ m/s}^2$ .
- A. 0.5  
B. 0.6  
C. 0.4  
D. 0.7  
E. 0.8

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C. 0.4

D. 0.7

E. 0.8

$$\begin{aligned}\Delta E &= W_{nc} = F \Delta r \cos \theta_{Fr} \\ &= -F_f \Delta x \\ &= -\mu mg \cdot 50\end{aligned}$$

$$\begin{aligned}\Delta E &= \Delta KE + \Delta PE \\ &= \Delta \left( \frac{1}{2} m v^2 \right) \\ &= \frac{1}{2} m v_f^2 - \frac{1}{2} m v_0^2 \\ &= -\frac{1}{2} m v_0^2\end{aligned}$$

$$\begin{aligned}\text{So } -\frac{1}{2} m v_0^2 &= -\mu mg \cdot 50 \\ &= -500 \cdot \mu \cdot m\end{aligned}$$

$$\text{or } -\frac{1}{2} v_0^2 = -500 \mu$$

$$\mu = \frac{\frac{1}{2} v_0^2}{500} = \frac{\frac{1}{2} \cdot 400}{500}$$

$$= \boxed{0.4}$$