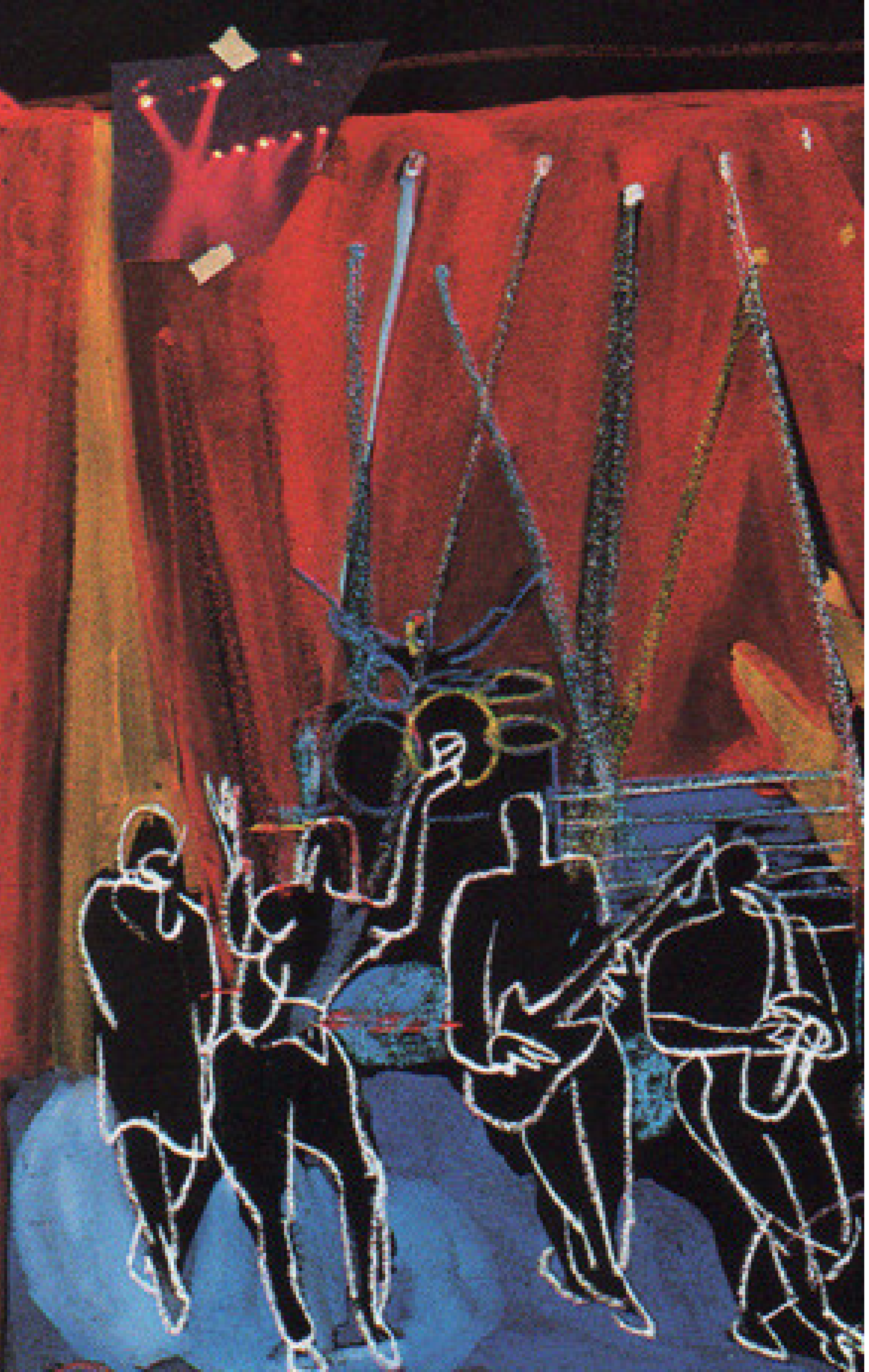


# PHY-141

# Basics of energy and its various forms

Luis Anchordoqui

# Outline

- Energy is probably the most important concept in physics because it pervades all the branches of this discipline

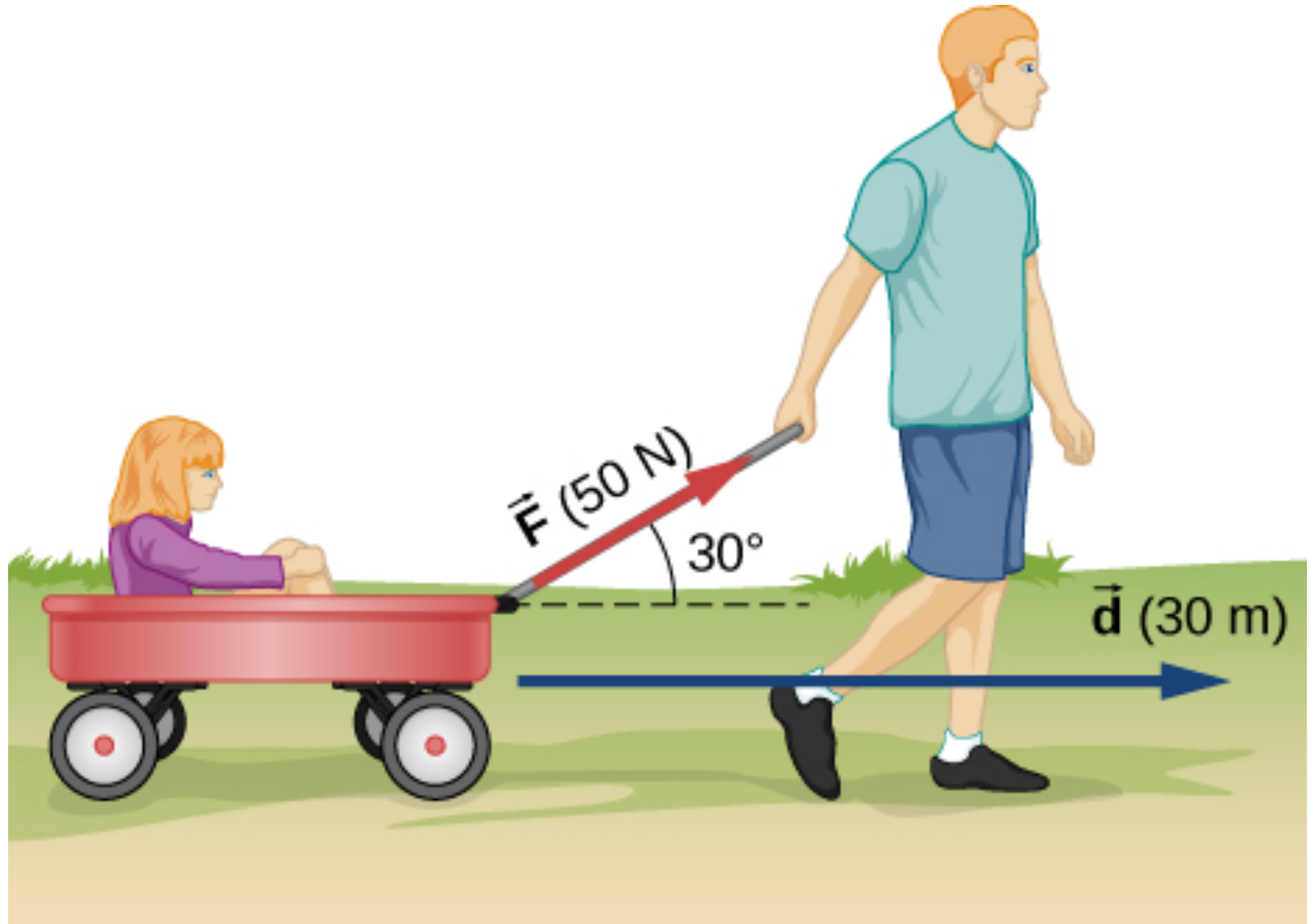
- One speaks of mechanical energy, gravitational energy, thermal energy, electric energy, sound energy, chemical energy, atomic energy, etc.

**But, what is energy?**

- Energy is the fundamental capacity to do work, drive motion, and produce heat or light, existing in kinetic (motion) and potential (stored) forms

# WORK

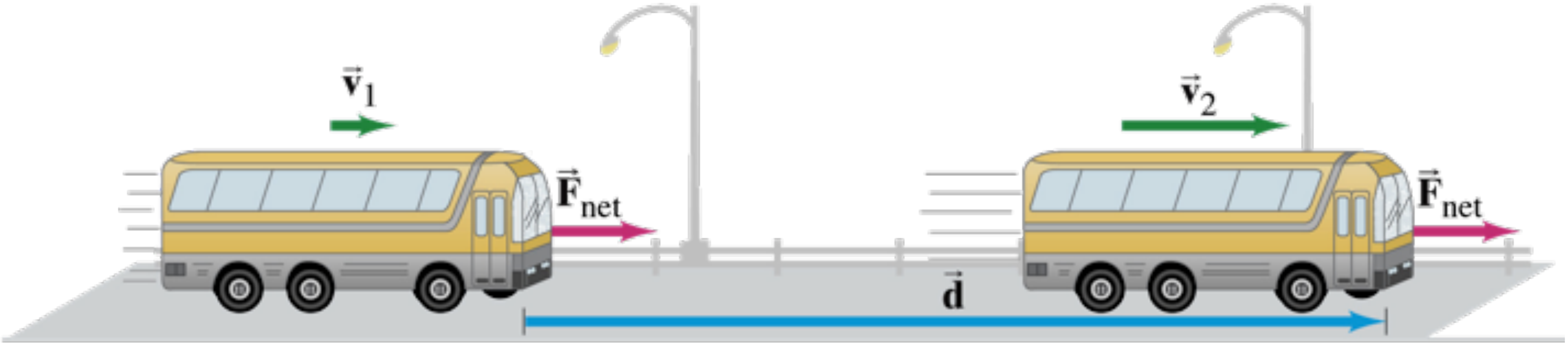
- Work is the measure of energy transfer that occurs when an object is moved over a distance by an external force
- Work is done only by the portion of the force that acts in the same direction as the object's movement
- For example, if you pull a wagon at an angle, only the *forward* part of your pull counts toward work; the part pulling *up* does no work if the wagon does not move upward



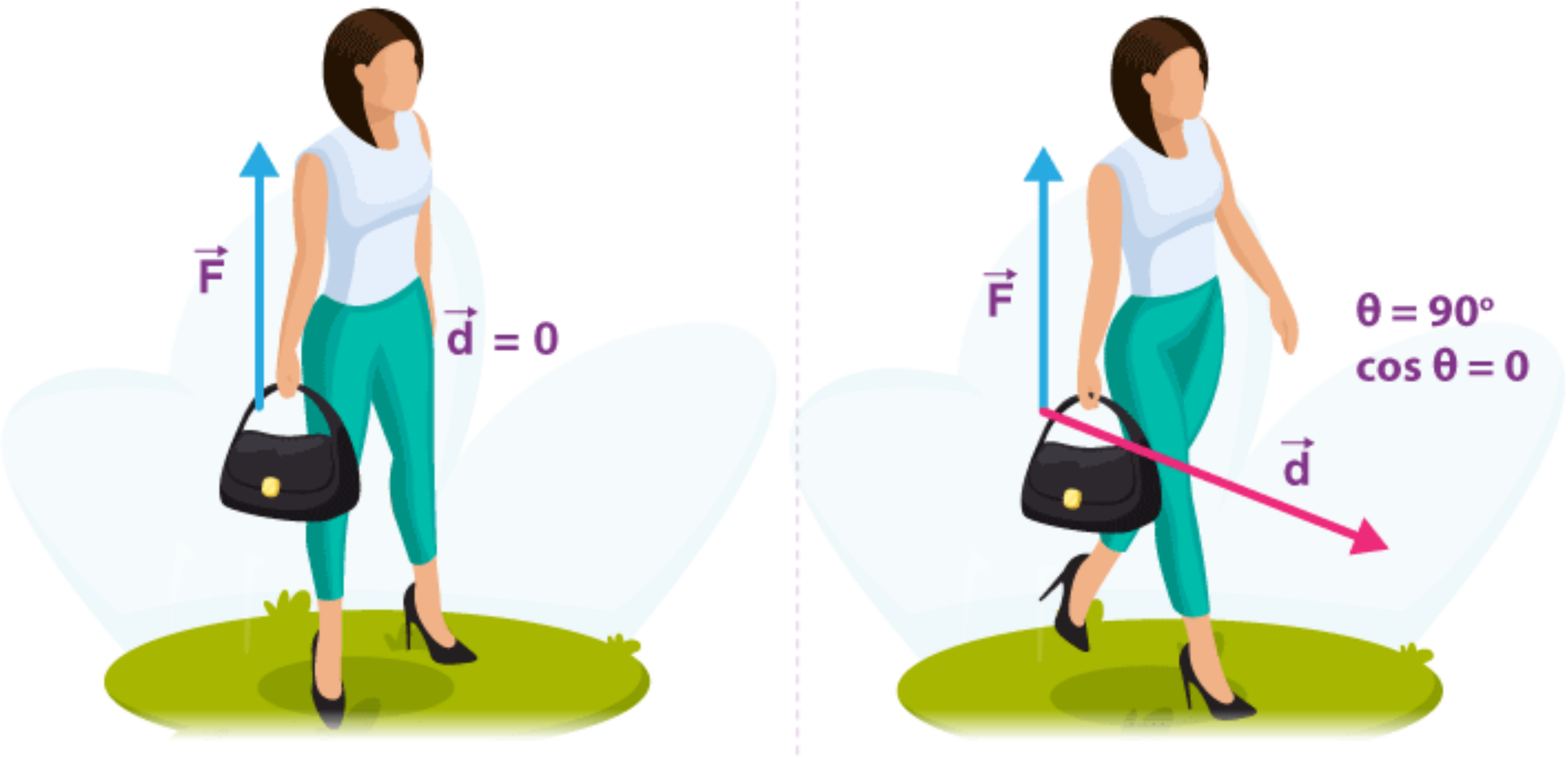
- If force $F$ and movement are in the same direction, work is simply

$$W = Fx$$

where $x$ is the displacement of the object



- If the force is perpendicular to the movement, the work done by that specific force is zero



➢ If the force opposes the movement, the work is negative because energy is being removed from the object ☛ $W = -Fx$

➢ If the system in question is the TRAIN, then the Green Man exerts an external force on the system


NEGATIVE WORK

**The joule (J) is the SI derived unit for energy, defined as the work done by a force of one newton acting over a distance of one meter**

$$(\mathrm{J} = \mathrm{N} \cdot \mathrm{m})$$

# KINETIC ENERGY

- Kinetic energy is the energy a body possesses as a result of its motion

- It is formally defined as the work needed to accelerate a body from rest to its current velocity


$V_{\text{initial}} = 0$

$V_{\text{final}}$

# KINETIC ENERGY

- **In Newtonian mechanics, this work (and thus the kinetic energy) is equal to:**

$$E_{\text{kinetic}} = \frac{1}{2}mv^2$$ **where $m$ is the object's mass and $v$ its speed**

- **Having gained this energy during its acceleration, the body mantains this kinetic energy unless its speed changes**

- **Negative work of the same magnitude would be required to return the body to a state of rest from that velocity**

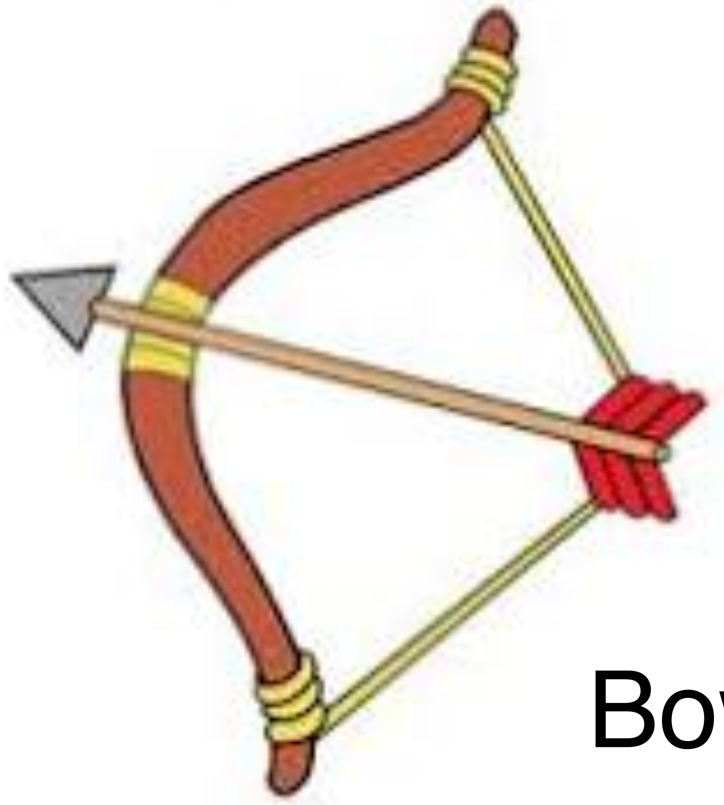
# POTENTIAL ENERGY

- **Potential energy is energy stored in an object due to its position, configuration, or state**
- **It is a property of a system, representing the potential for that system to perform work**

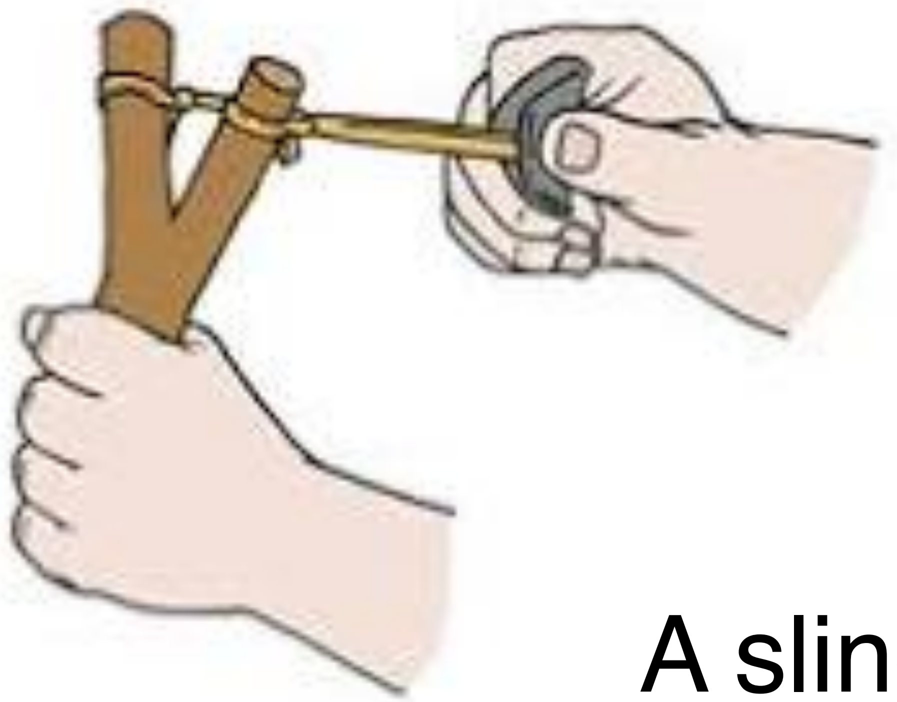
Roller coaster at its highest point

Dam holding and releasing water

Apples on a tree



Bow and arrow

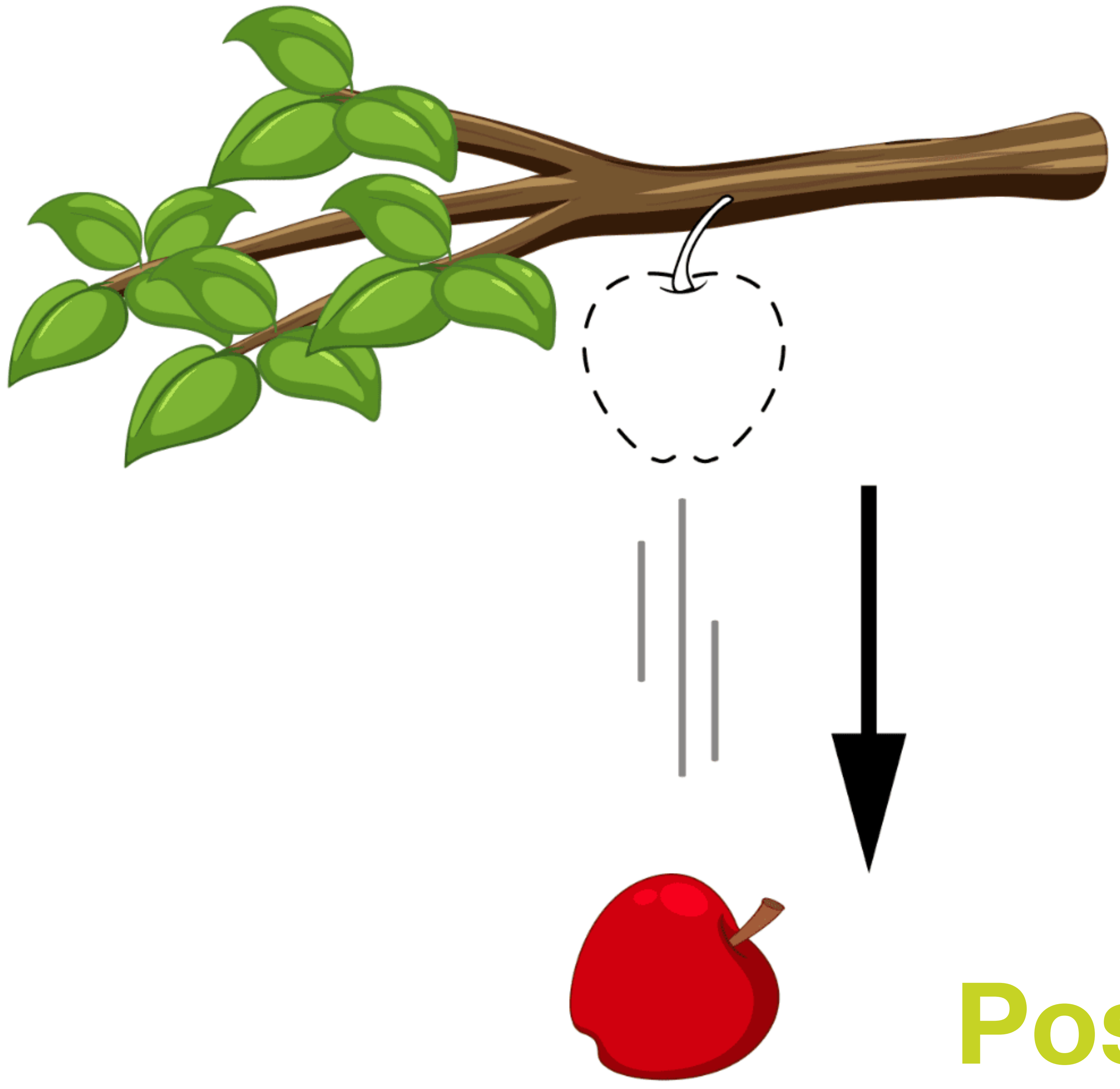


A slingshot being pulled

# GRAVITATIONAL POTENTIAL ENERGY

- The gravitational potential energy is stored due to an object's height in a gravitational field
- Near the surface of the Earth, it is calculated as $E_{\text{gravitational}} = mgh$

  where $m$ is the object's mass, $h$ its height, and $g$ is the gravitational acceleration

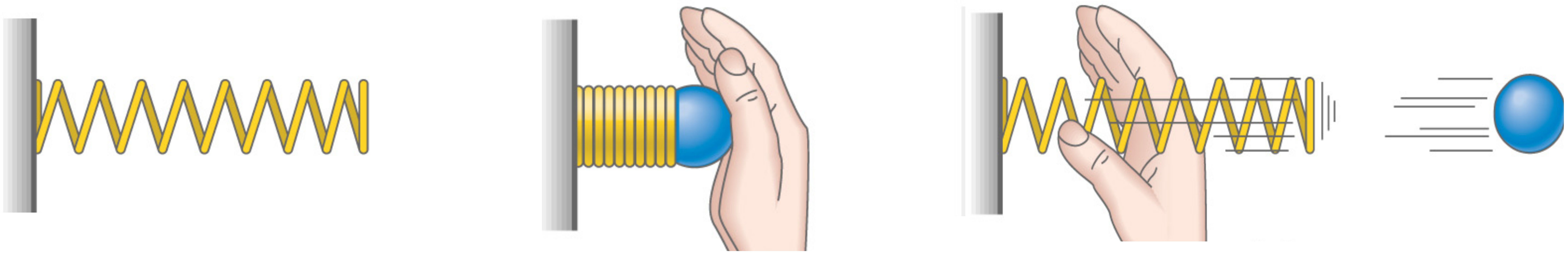



Position in a Gravitational Field

# ELASTICAL POTENTIAL ENERGY

- The elastic potential energy is stored in objects that can be compressed or stretched, like springs

- It is given by $E_{\text{elastic}} = \frac{1}{2}kx^2$, where $k$ is the spring constant and $x$ is the displacement

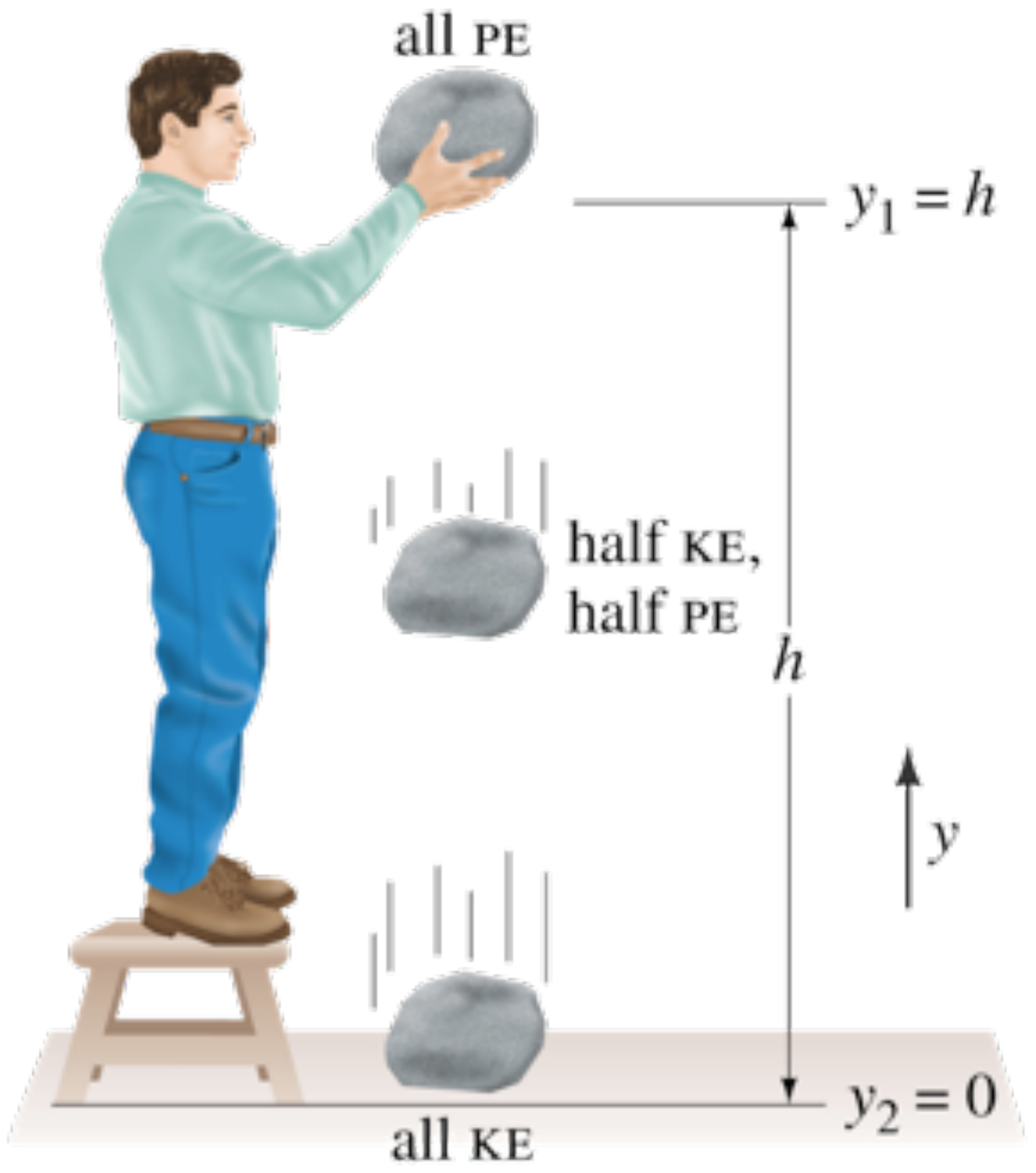


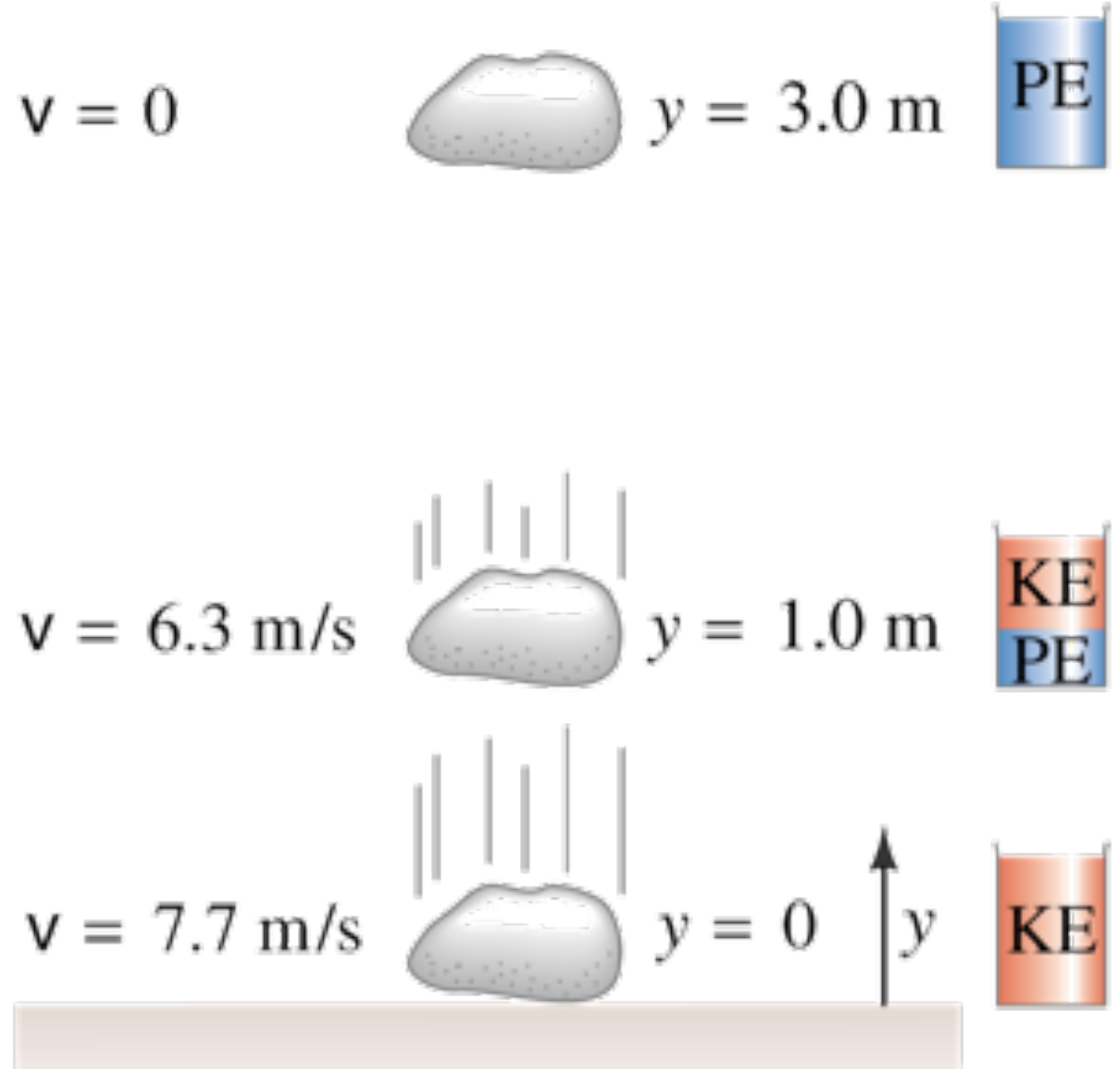
# CONSERVATION OF MECHANICAL ENERGY

- In an ideal system without friction or air resistance the total mechanical energy (kinetic + potential) stays constant, allowing energy to convert between kinetic and potential forms but never changing the total sum,

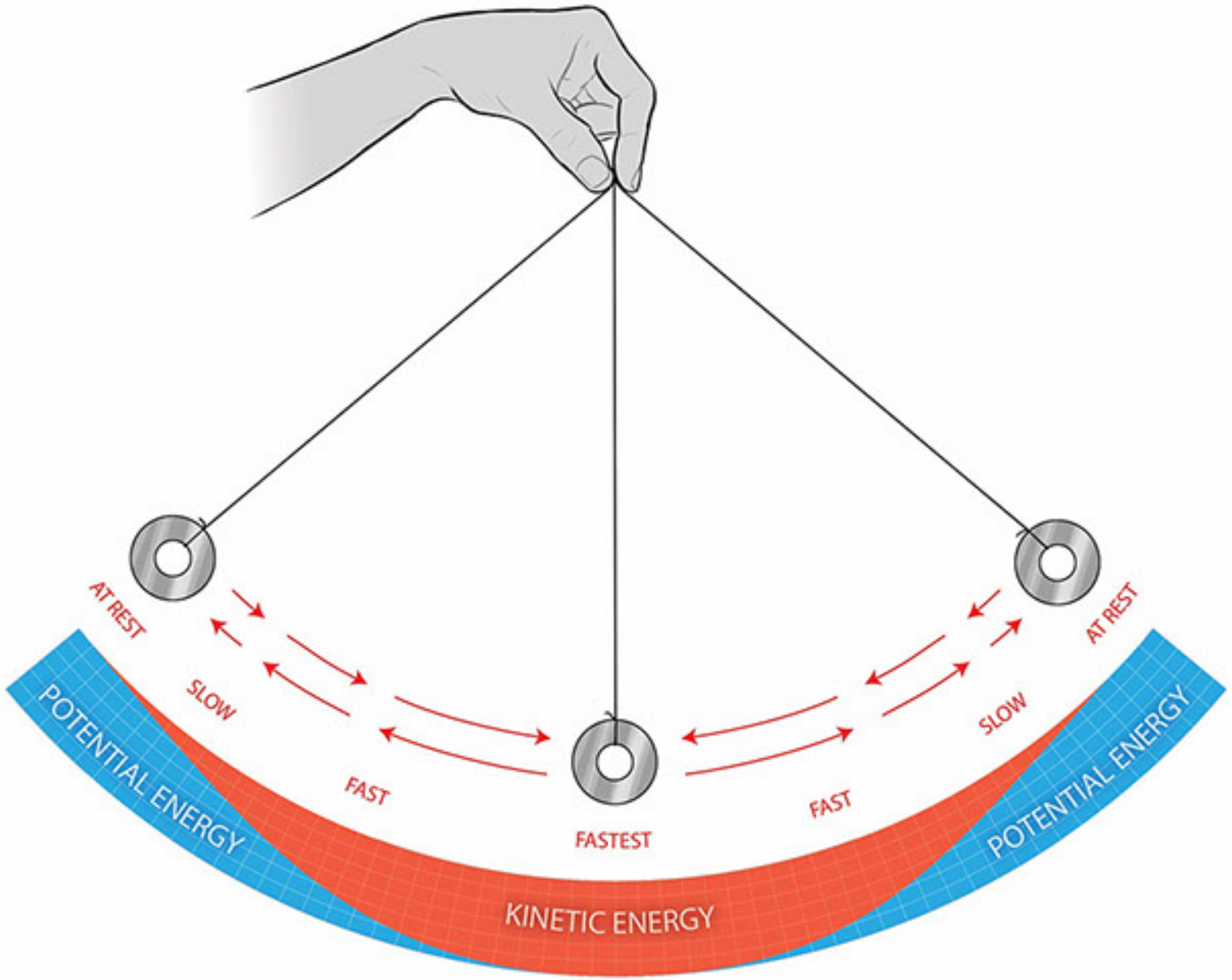
$$\Delta E_{\text{kinetic}} + \Delta E_{\text{potential}} = 0$$

- This means that mechanical energy is never *lost*; it simply converts from one form to another



- A swinging pendulum constantly swaps energy
- It has maximum potential energy at its highest points and maximum kinetic energy at its lowest



# WORK DONE ON A SKIER

- You and your friend are at a ski resort with two ski runs a beginner's run and an expert's run
- Both runs begin at top of ski lift and end at finish line at bottom of same lift
- Let $h$ be vertical descent for both runs
- Beginner's run is longer and less steep than expert's run
- You and your friend, who is a much better skier than you, are testing some experimental frictionless skis
- To make things interesting you offer a wager that if she takes expert's run and you take beginner's run, her speed at finish line will not be greater than your speed at finish line
- Forgetting that you studied physics she accepts bet
- Conditions are that you both start from rest at top of lift and both of you coast for entire trip

**Who wins bet? (Assume air drag is negligible)**

# WORK DONE ON A SKIER (CONT'D)

- Final speed depends only on $h$ which is same for both runs
- Both of you will have same final speed

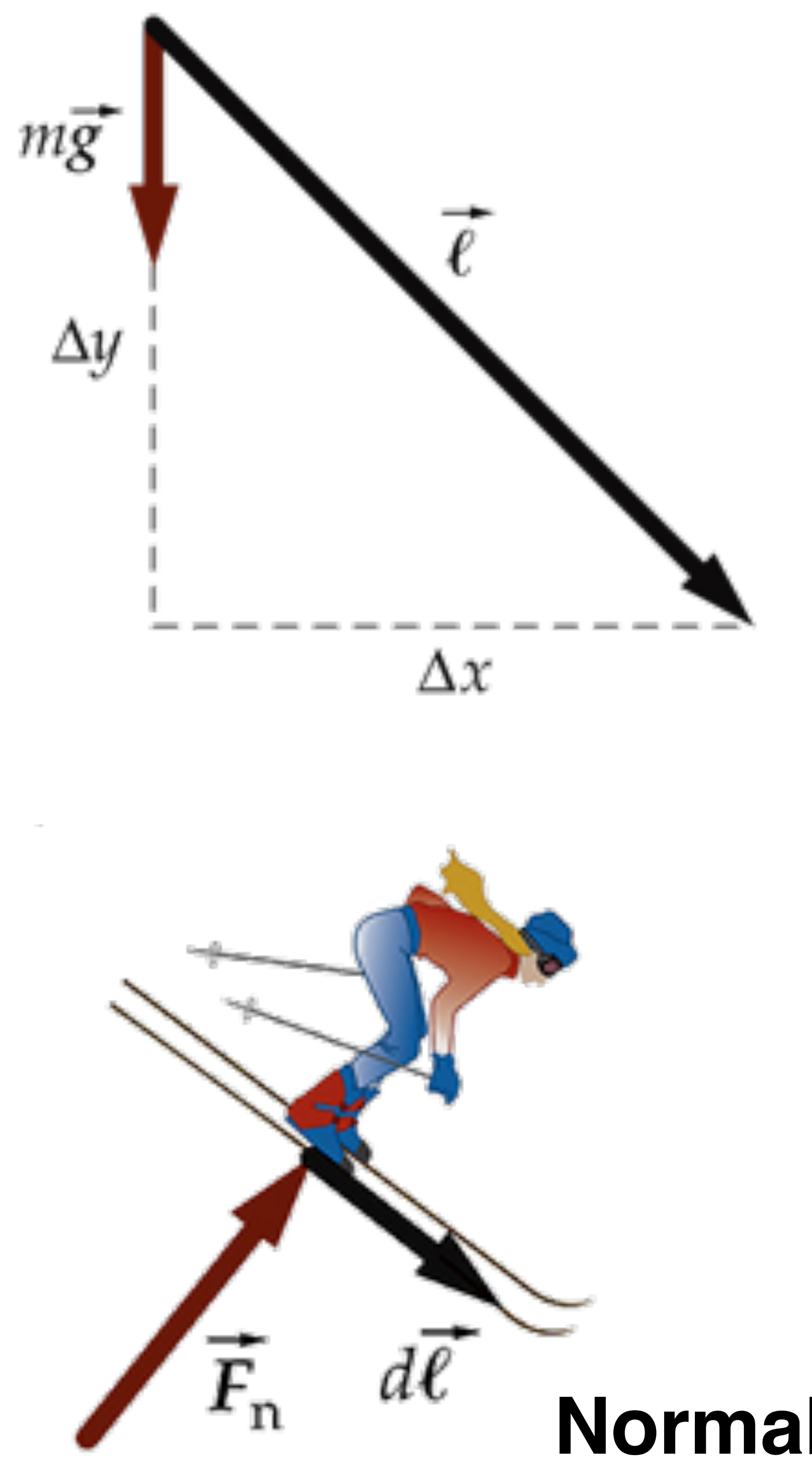
TOP $E_{\text{gravitational}} = mgh$

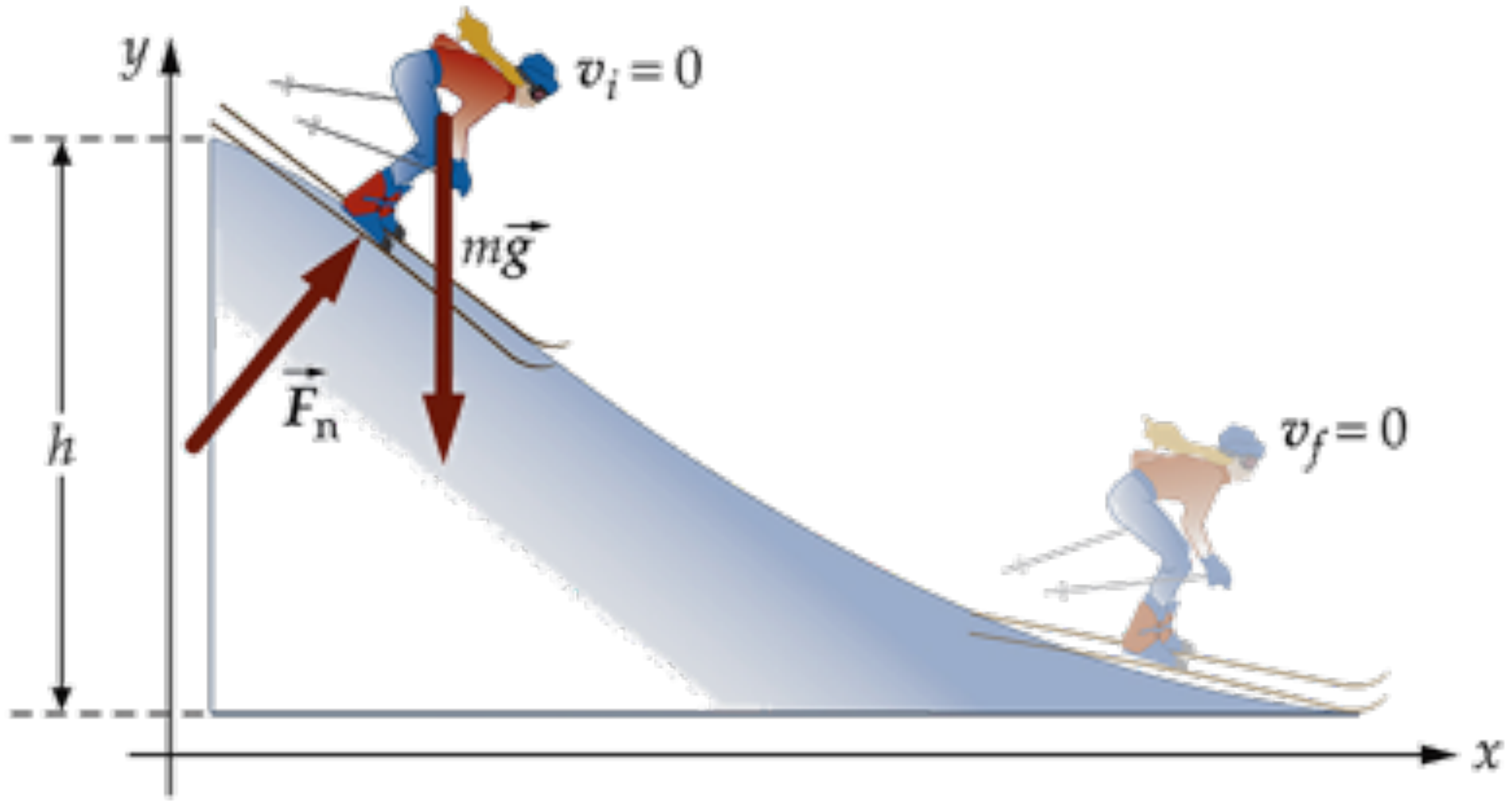
BOTTON $E_{\text{kinetic}} = \frac{1}{2}mv^2$

$$E_{\text{kinetic}} = E_{\text{gravitational}}$$

$$mgh = \frac{1}{2}mv^2$$

$$v = \sqrt{2gh}$$




**Normal force** ☛ support force exerted by a surface on an object resting on it, acting perpendicular (or "normal") to the surface to prevent the object from passing through it

**YOU WIN!!!**

# POWER

**Power is rate at which work is done**

$$\text{average power} = \langle P \rangle = \frac{\text{work}}{\text{time interval}} = \frac{\text{energy transformed}}{\text{time interval}}$$

**In SI system, units of power are watts:**

$$1\text{W} \;=\; 1\ \text{J/s}$$

**Difference between walking and running up these stairs is power – change in gravitational potential energy is same**

Which of the following best describes potential energy?

A. The energy of an object due to its motion
B. The energy of an object due to its position or condition
C. The energy of an object due to its temperature
D. The energy of an object due to its mass

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Which of the following is an example of potential energy?

A. A car driving on the highway

B. A falling rock

C. A stretched rubber band

D. A rolling ball

Which of the following is an example of potential energy?

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When a roller coaster moves down a hill, what energy transformation occurs?

A. Potential energy is converted to kinetic energy
B. Kinetic energy is converted to potential energy
C. Thermal energy is converted to kinetic energy
D. Potential energy is converted to chemical energy

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If an object's speed doubles, its kinetic energy:

A. Doubles

B. Is cut in half

C. Quadruples

D. Remains the same

[Hint: $E_{\text{kinetic}} = \frac{1}{2}mv^2$ ]

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Which of the following is true about a rollercoaster at the top of a hill?

A. It has low potential energy
B. It has high potential energy
C. It has maximum kinetic energy
D. It has no energy

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What factors determine an object's gravitational potential energy?

A. Speed and mass

B. Mass and height

C. Velocity and time

D. Height and speed

[Hint: $E_{\text{gravitational}} = mgh$ ]

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A book sits on a shelf. Which type of energy does it possess?

A. Kinetic energy
B. Potential energy
C. Neither
D. Both

A book sits on a shelf. Which type of energy does it possess?

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The total energy of a system (in the absence of friction) is:

A. Always decreasing
B. Always increasing
C. The sum of kinetic and potential energy
D. Only kinetic energy

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## What type of energy does a drawn bow have?

A. Kinetic energy

B. Potential energy

C. Both kinetic and potential energy

D. Neither kinetic nor potential energy

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An object is thrown straight up. Which of the following is true about the sign of work done by the gravitational force while the object moves up and then down?

A. Work is positive on the way up, work is positive on the way down

B. Work is negative on the way up, work is negative on the way down

C. Work is negative on the way up, work is positive on the way down

D. Work is positive on the way up, work is negative on the way down

E. Work is zero the way up, work is zero on the way down

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A bullet penetrates a wooden block and loses its velocity by a half. What is the ratio between the initial kinetic energy of the bullet and kinetic energy when the bullet leaves the block?

A. 1/2

B. 1/4

C. 2/1

D. 4/1

E. 16/1

[Hint: $E_{\text{kinetic}} = \frac{1}{2}mv^2$ ]

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E. 16/1

A block of mass $m$ is pulled over a distance $d$ by an applied force $F$ which is directed in parallel to the displacement. How much work is done on the block by the force $F$?

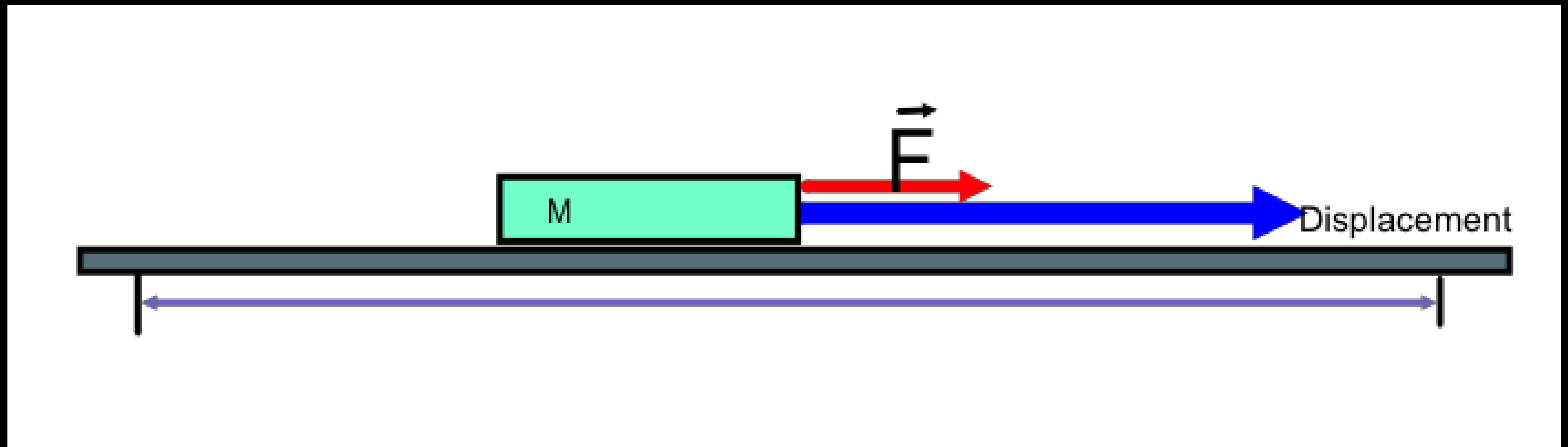
A. $mFd$

B. ZERO

C. $Fd$

D. $F/d$

E. $-Fd$



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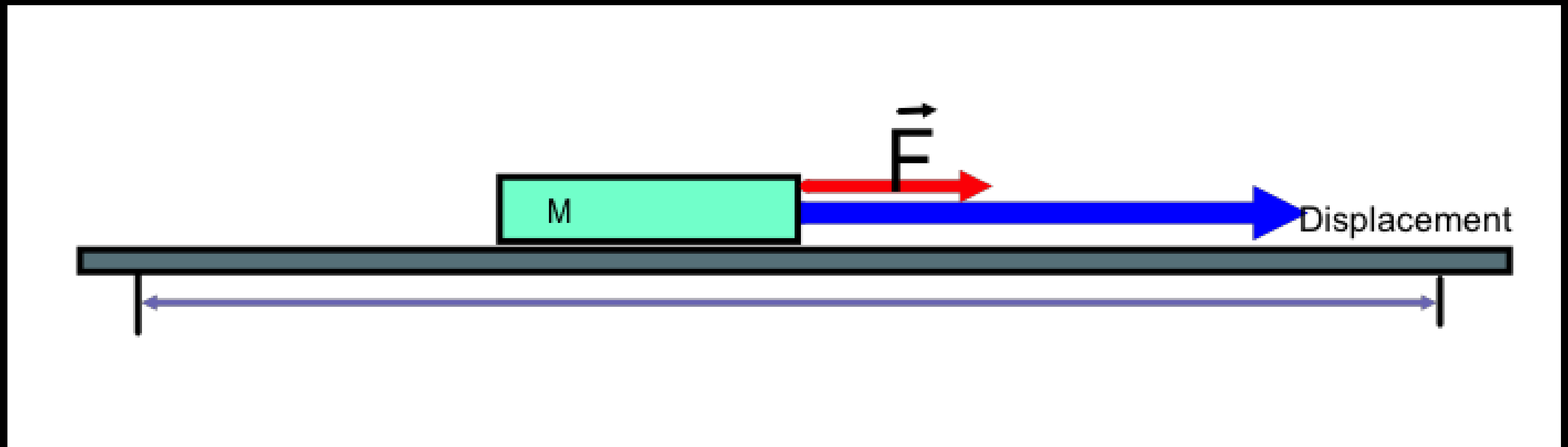

A block of mass $m$ is moved over a distance $d$ . An applied force $F$ is directed perpendicularly to the block's displacement. How much work is done on the block by the force $F$?

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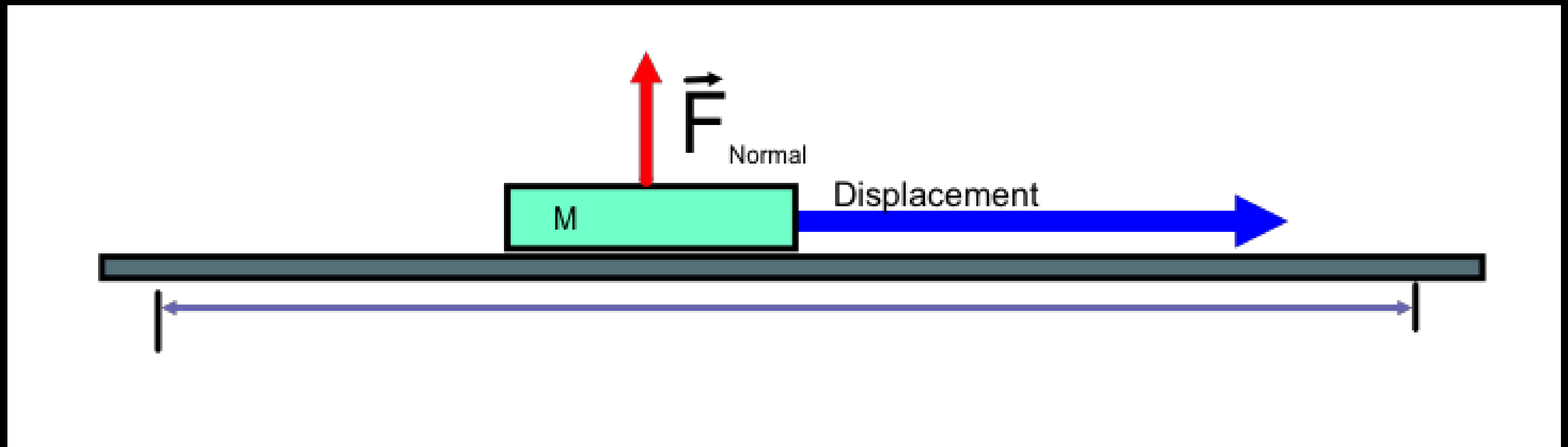

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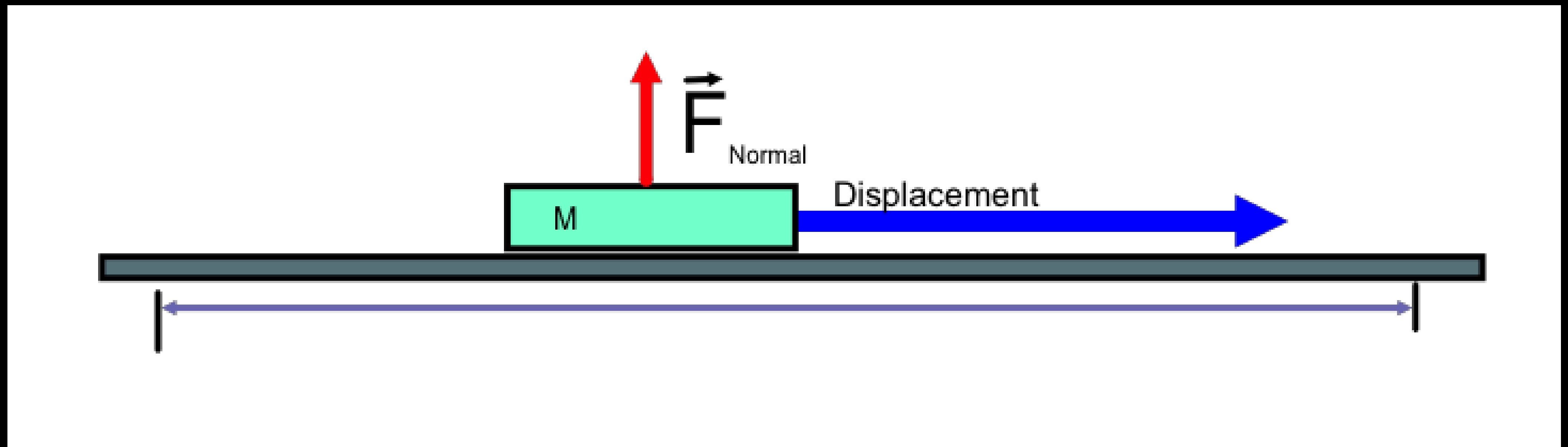

A block of mass $m$ is moved over a distance $d$ . An applied force $F$ is opposite to the block's displacement. How much work is done on the block by the force $F$?

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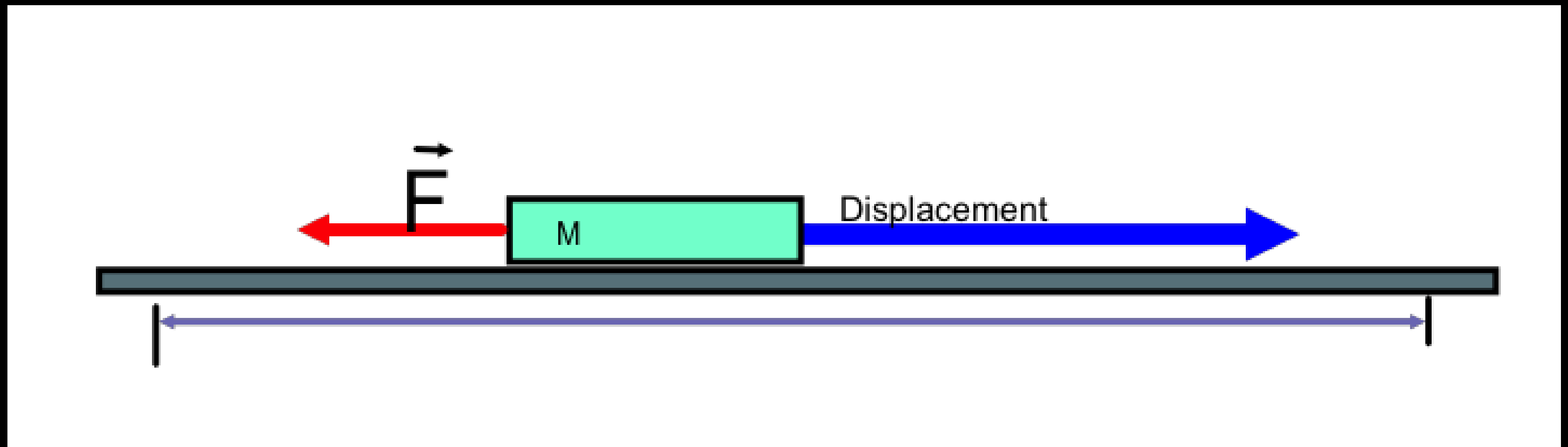

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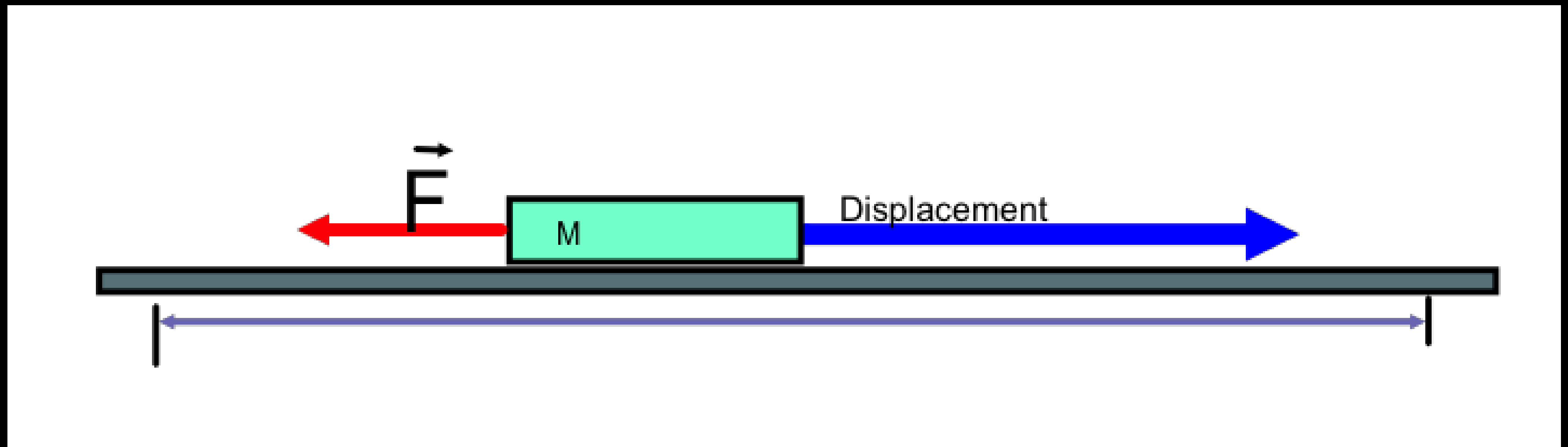

A truck driver is trying to push a loaded truck with an applied force. Unfortunately, his attempt was unsuccessful the truck stays stationary no matter how hard the driver pushes. How much work is done by the driver?

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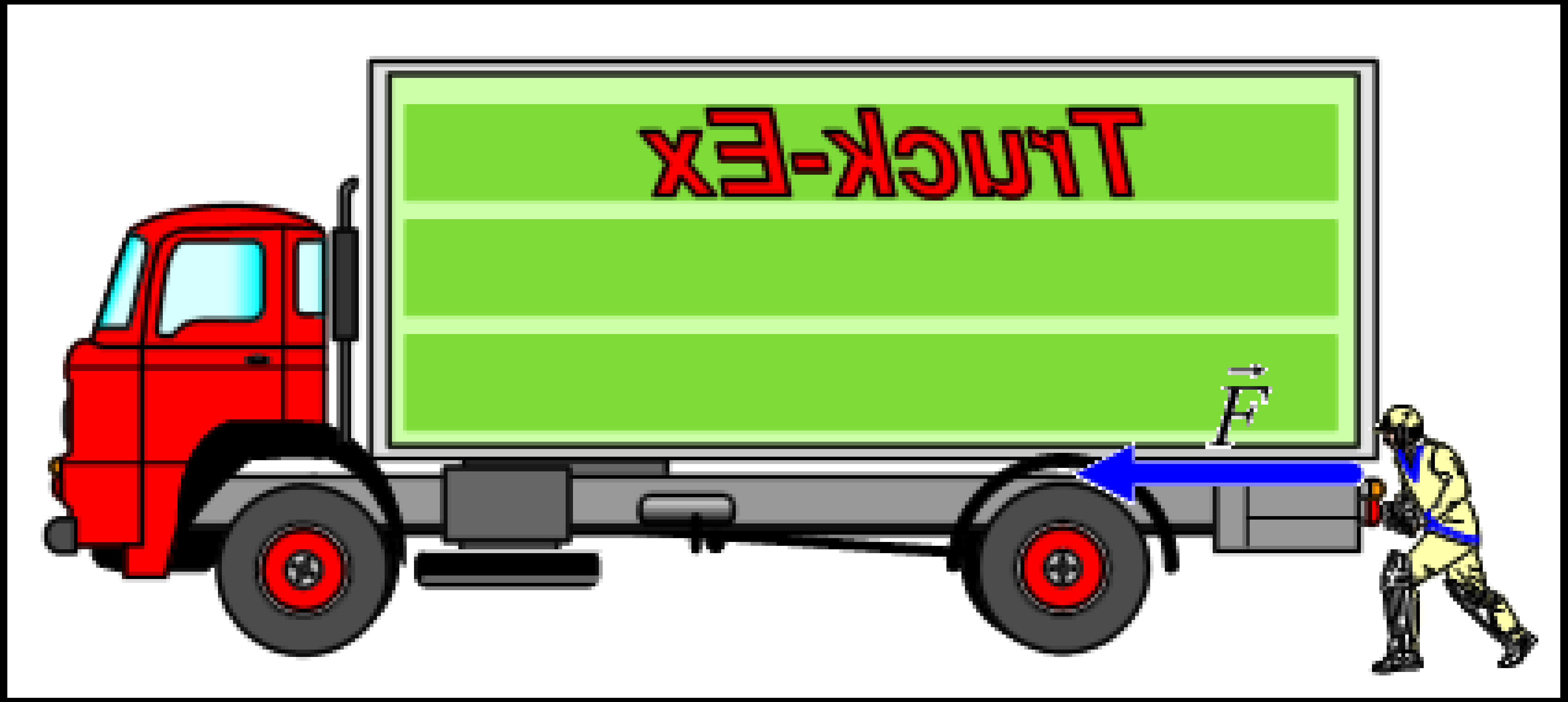

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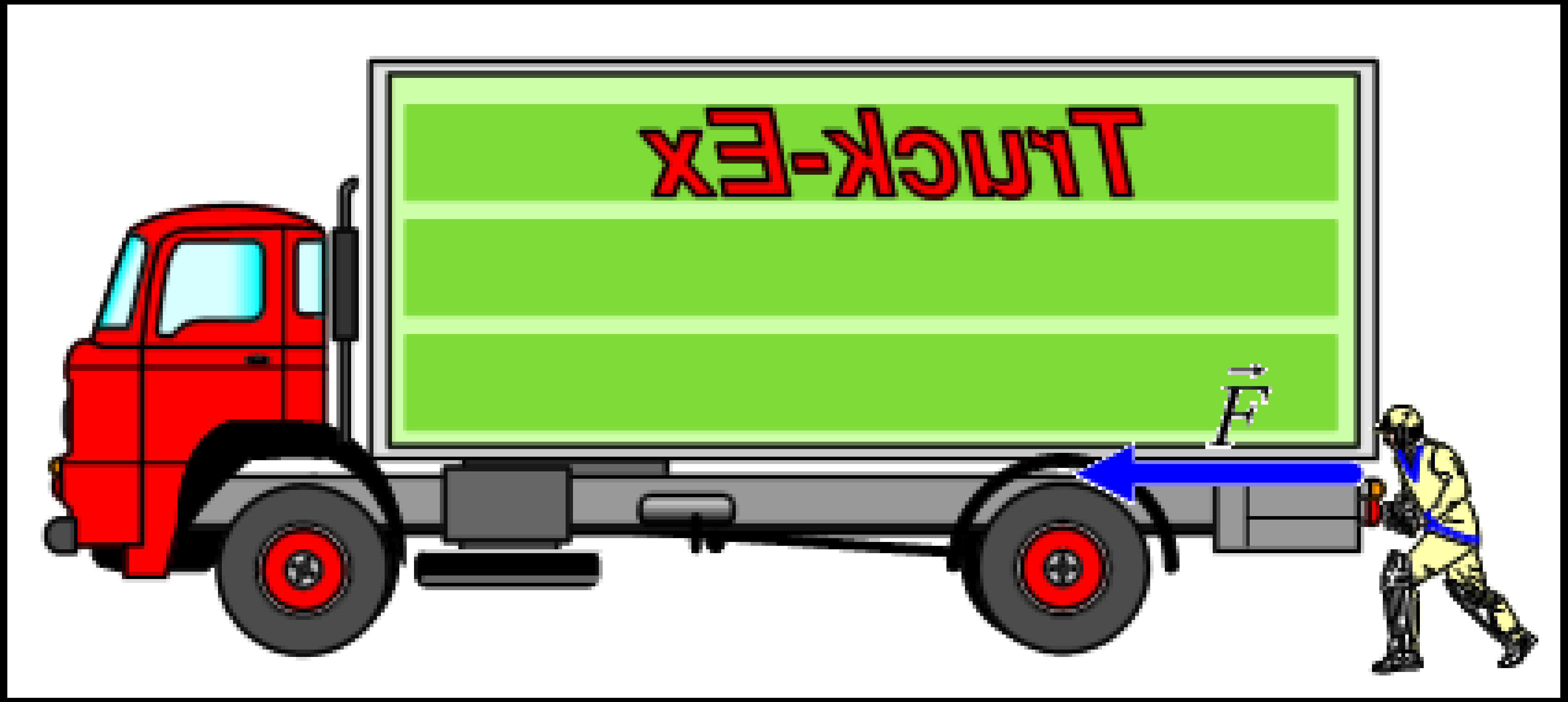

A spacecraft moves around Earth in a circular orbit with a constant radius $d$. How much work is done by the gravitational force on the spacecraft during one revolution?

A. $F_{\text{gravitation}} d$

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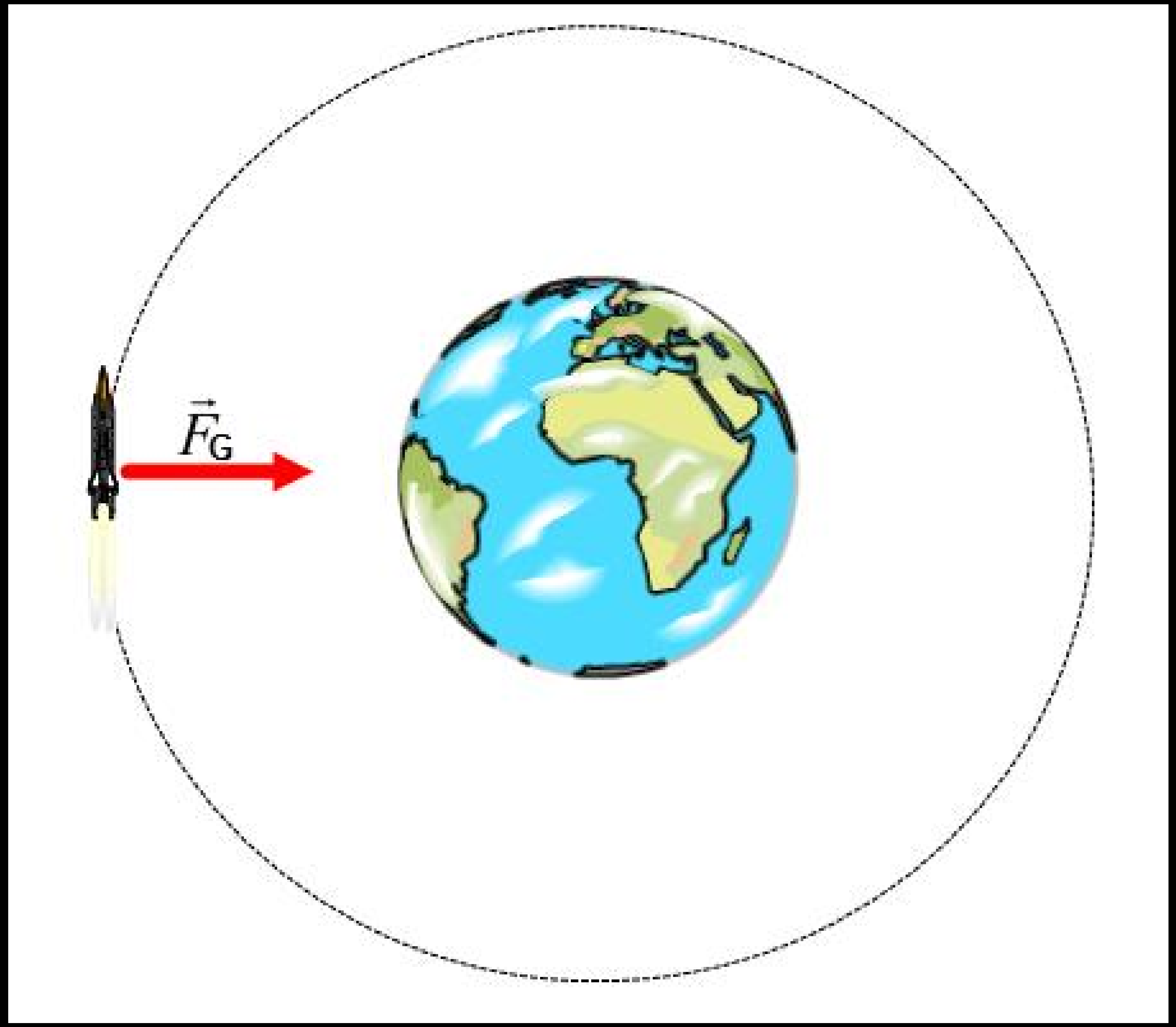
C. $mgd$

D. $\frac{1}{2}mv^2$

E. ZERO



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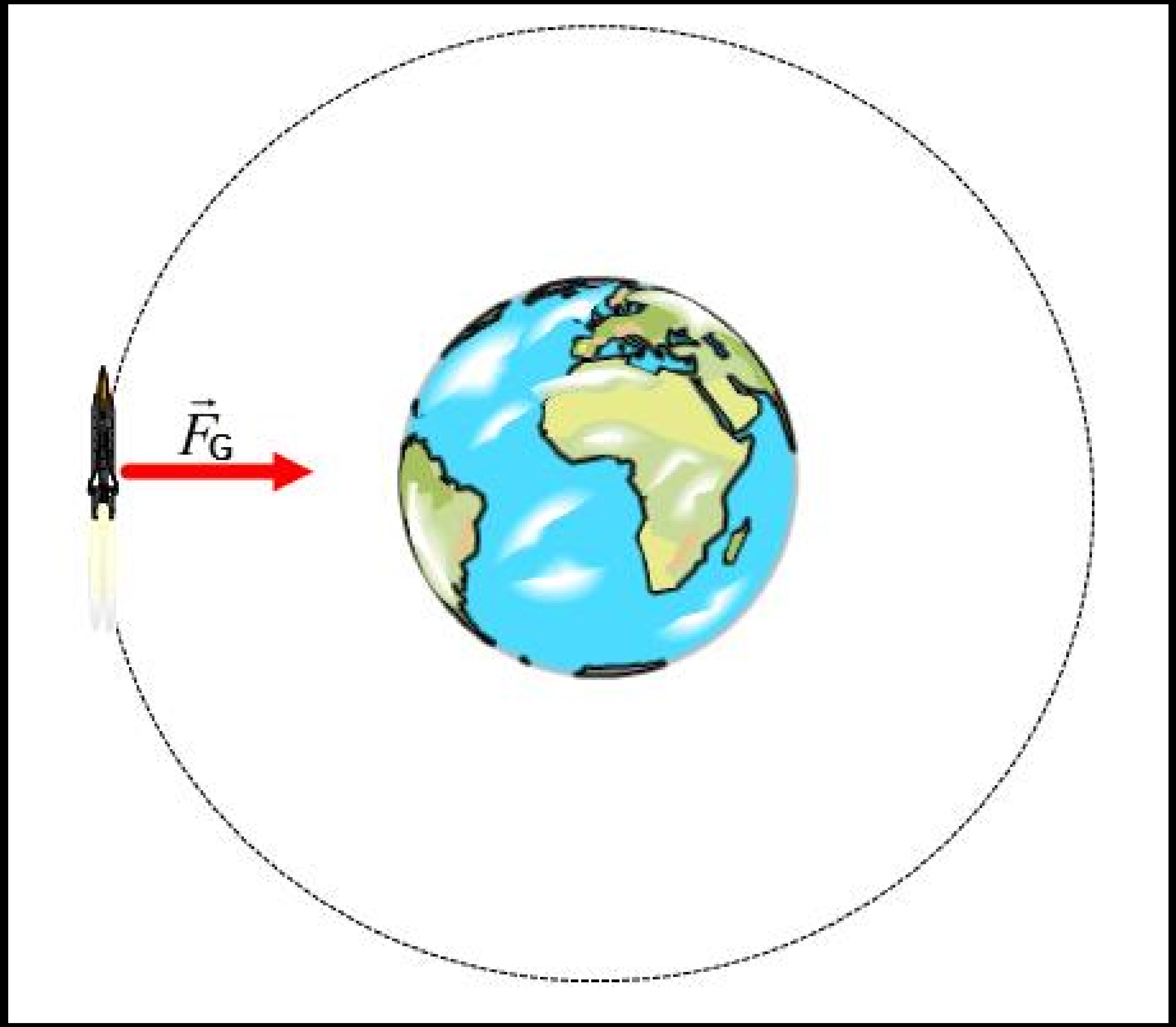


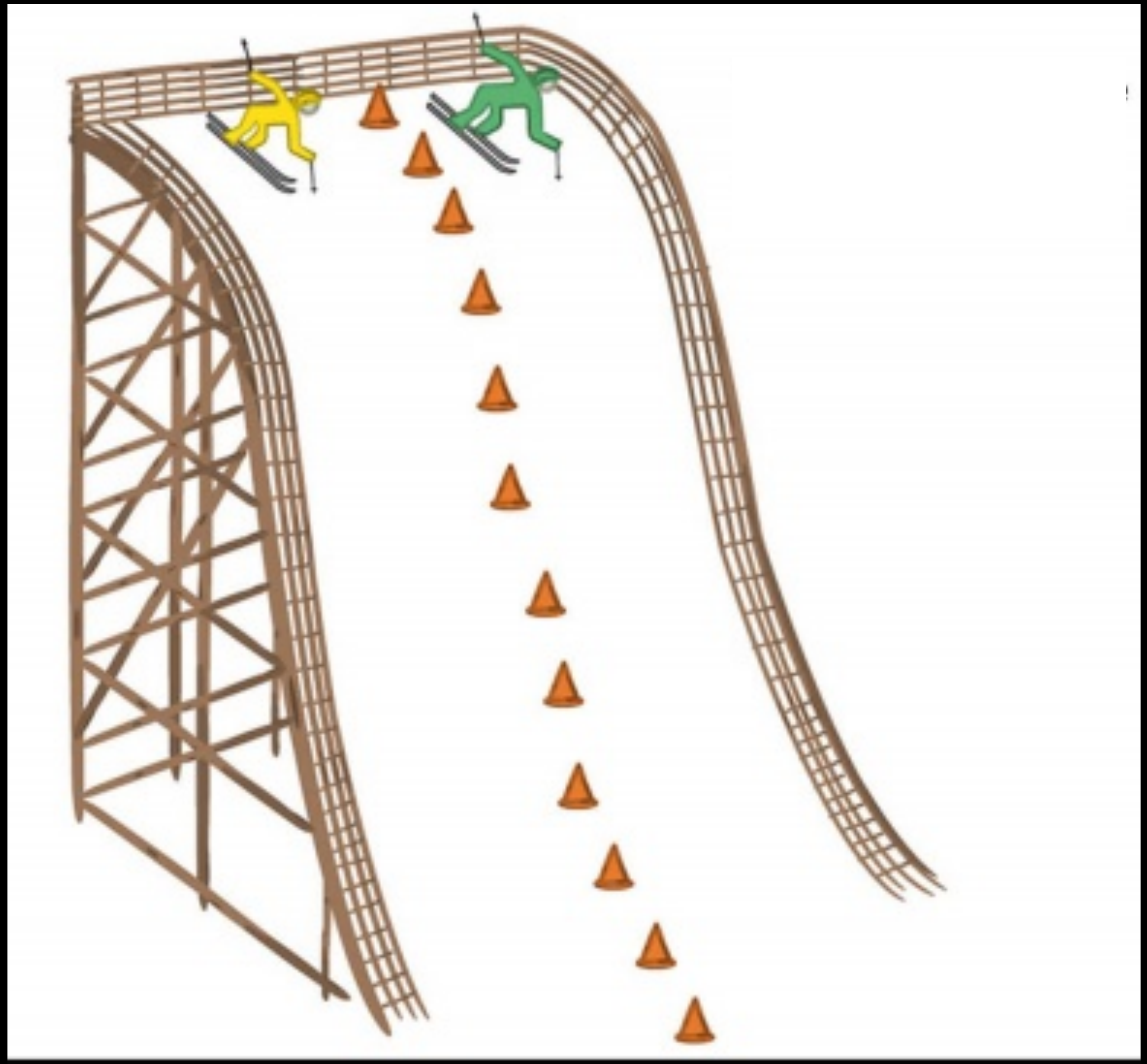
The green skier has more gravitational potential energy because he has a more mass. Which statement gives the correct result at the bottom of the hill?

A. Kinetic energy > Kinetic energy

B. Kinetic energy > Kinetic energy

C. Kinetic energy = Kinetic energy

Gravitational potential energy



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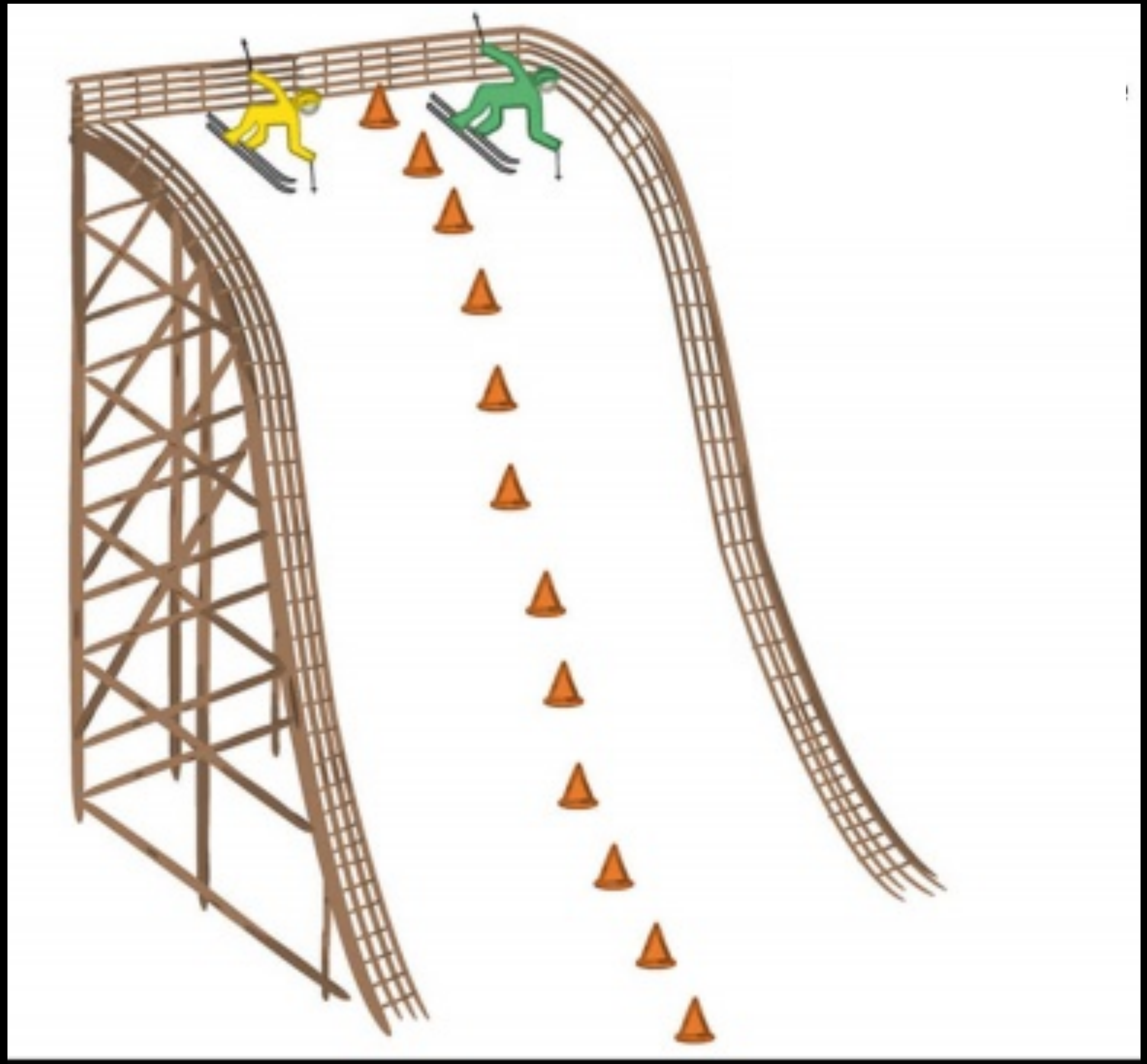

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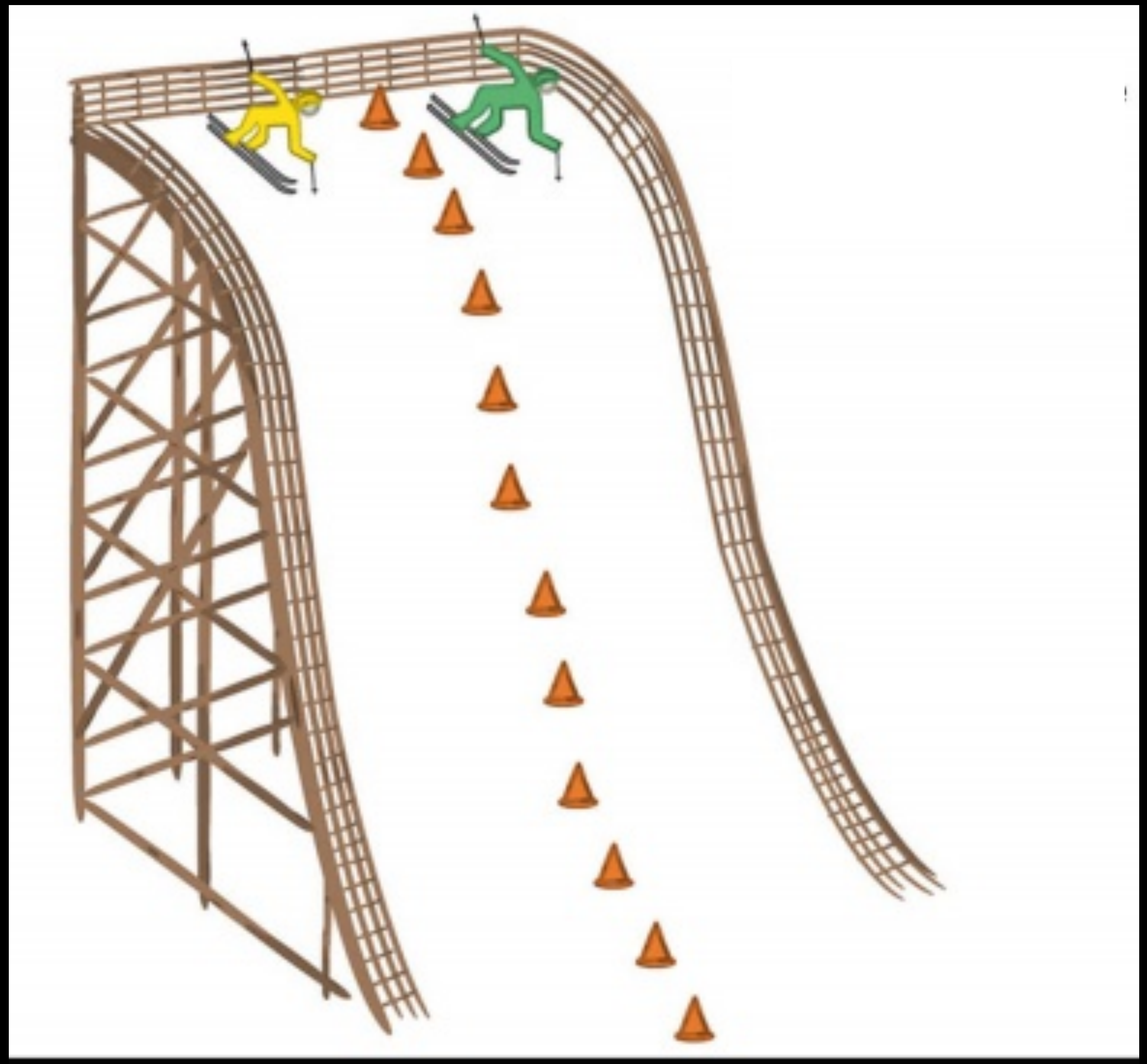


A. Speed > Speed

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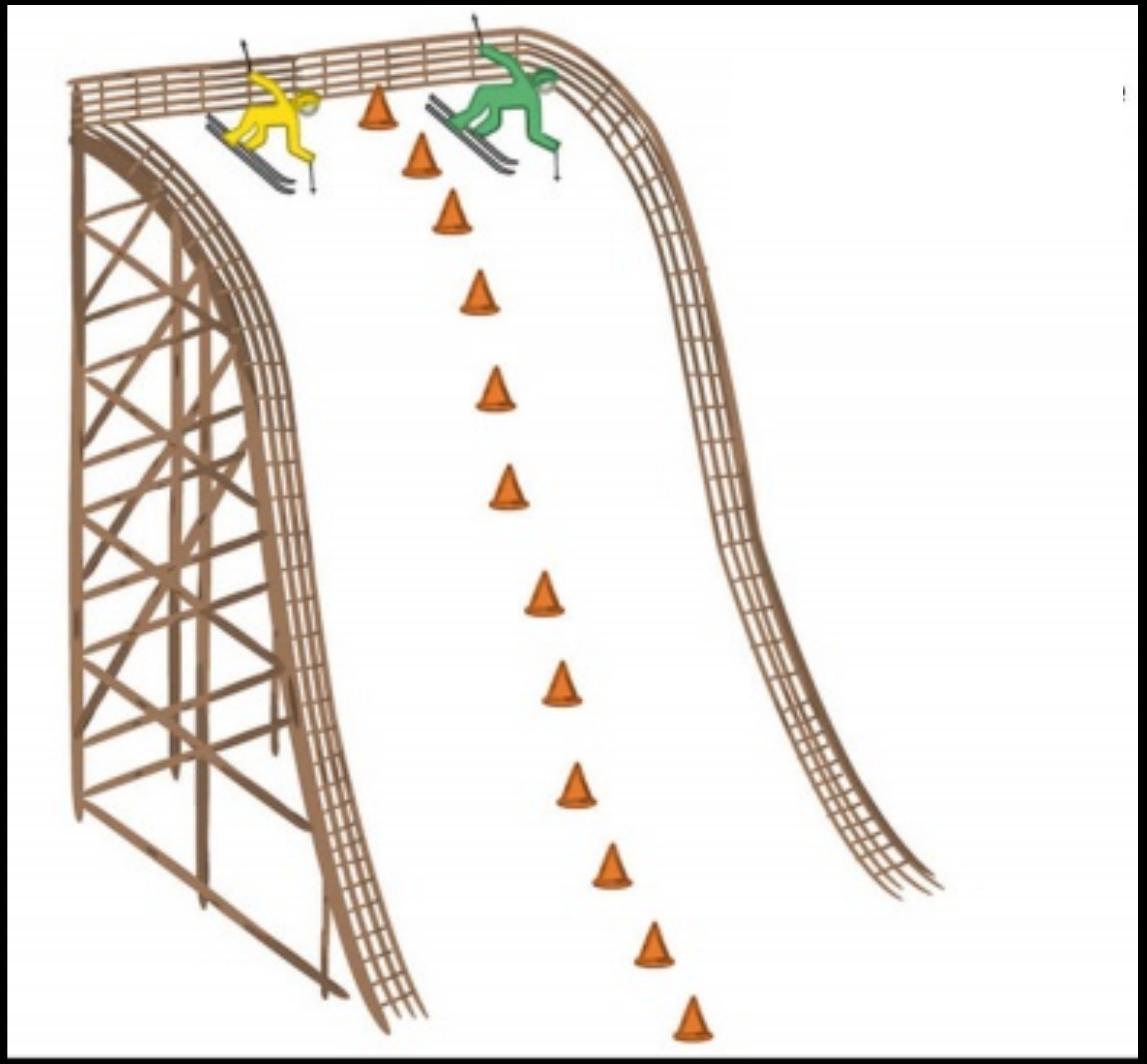
Gravitational potential energy



Kinetic energy

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