Energy

LCHS

Work
Forms of Energy
Power
Conservation of Energy
Kepler's Laws of Motion
Simple Machines
Mechanical Advantage

- machine
- energy
- input force
- output force
- ramp
- gear
- screw
- rope and pulleys
- closed system
- work
- joule
- lever
- friction
- mechanical system
- simple machine
- potential energy
- kinetic energy
- radiant energy
- nuclear energy
- chemical energy
- mechanical energy
- mechanical advantage
- energy
- conservation of energy
- electrical energy
- input output
- input arm output
- arm
- fulcrum

Work

- Work can be done *by* you, as well as *on* you
  - Are you the *pusher* or the *pushee*
- Work is a measure of expended energy
  - Work makes you tired
- Machines make work easy (ramps, levers, etc.)
  - Apply less force over larger distance for same work
- Now instead of a force for how long in time we consider a force for how long in distance.
- The unit for work is the Newton-meter which is also called a Joule.

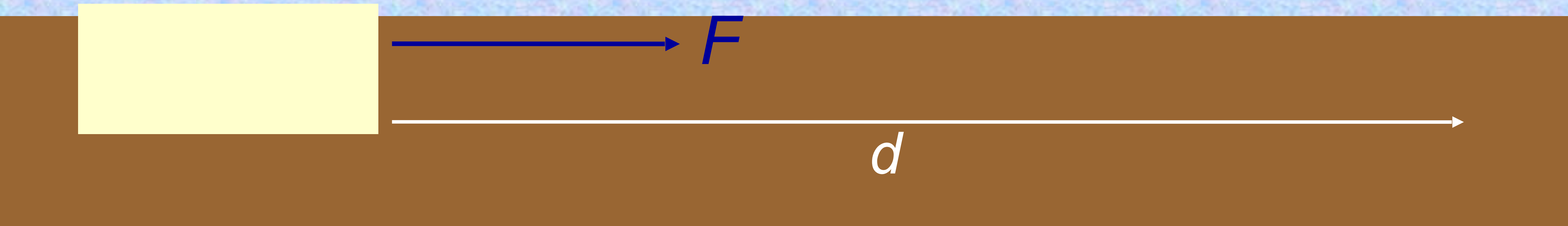
Work

The simplest definition for the amount of work a force does on an object is magnitude of the force times the distance over which it's applied:

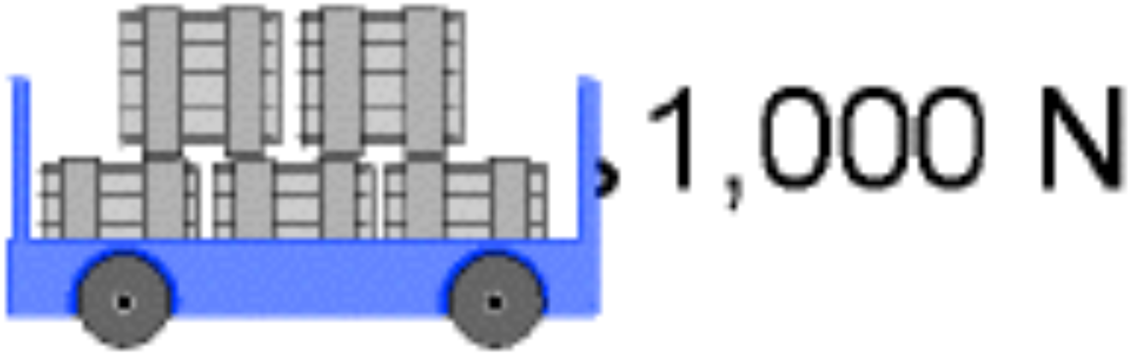
$$W = F\,d$$

This formula applies when:

- the force is constant
- the force is in the same direction as the displacement of the object



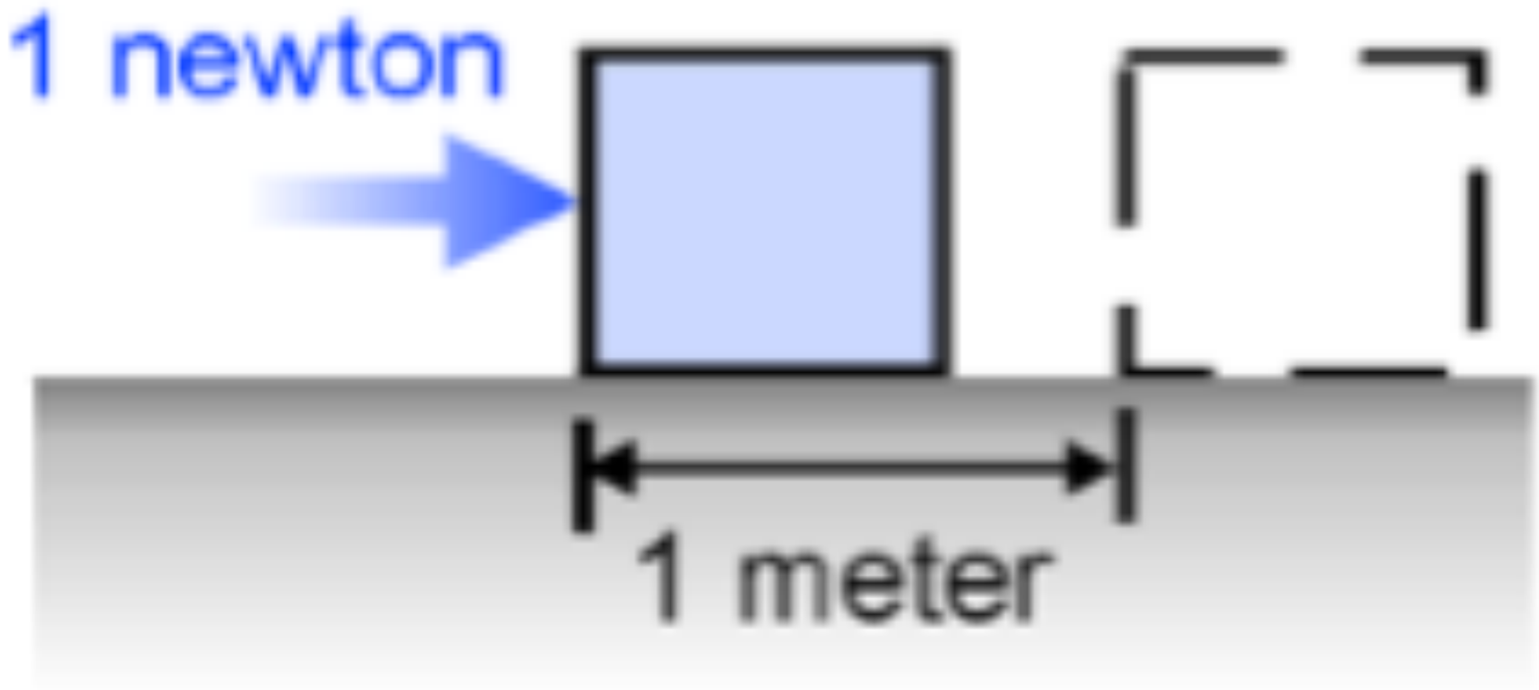
Work (force is parallel to distance)



$$W = F \times d$$

Work (joules) → W; Force (N) → F; Distance (m) → d

- **If you push a box with a force of one Newton for a distance of one meter, you have done exactly one joule of work.**



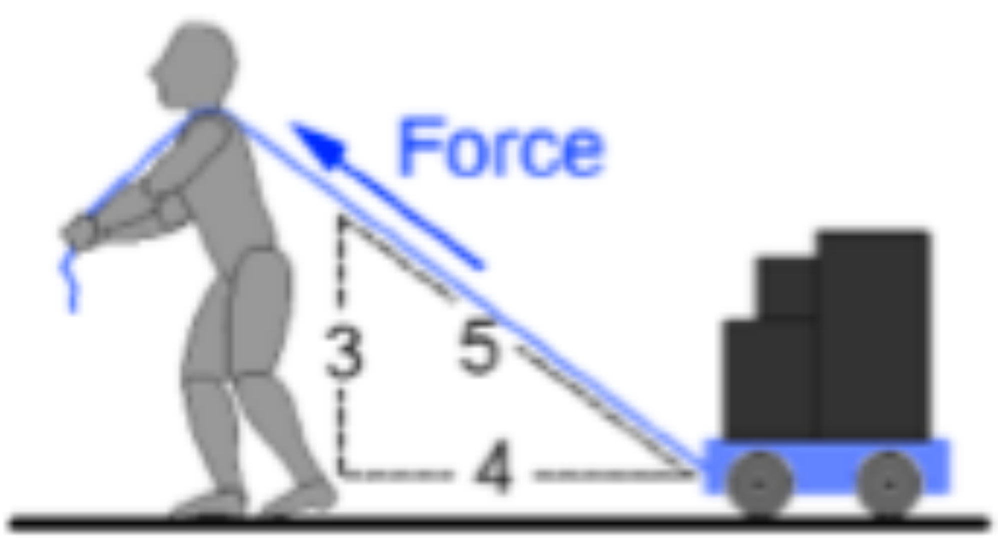
- In Physics, work has a very specific meaning.
- In Physics, work represents a <u>measurable change</u> in a system, caused by a <u>force.</u>

Work (force at angle to distance)

Force (N)

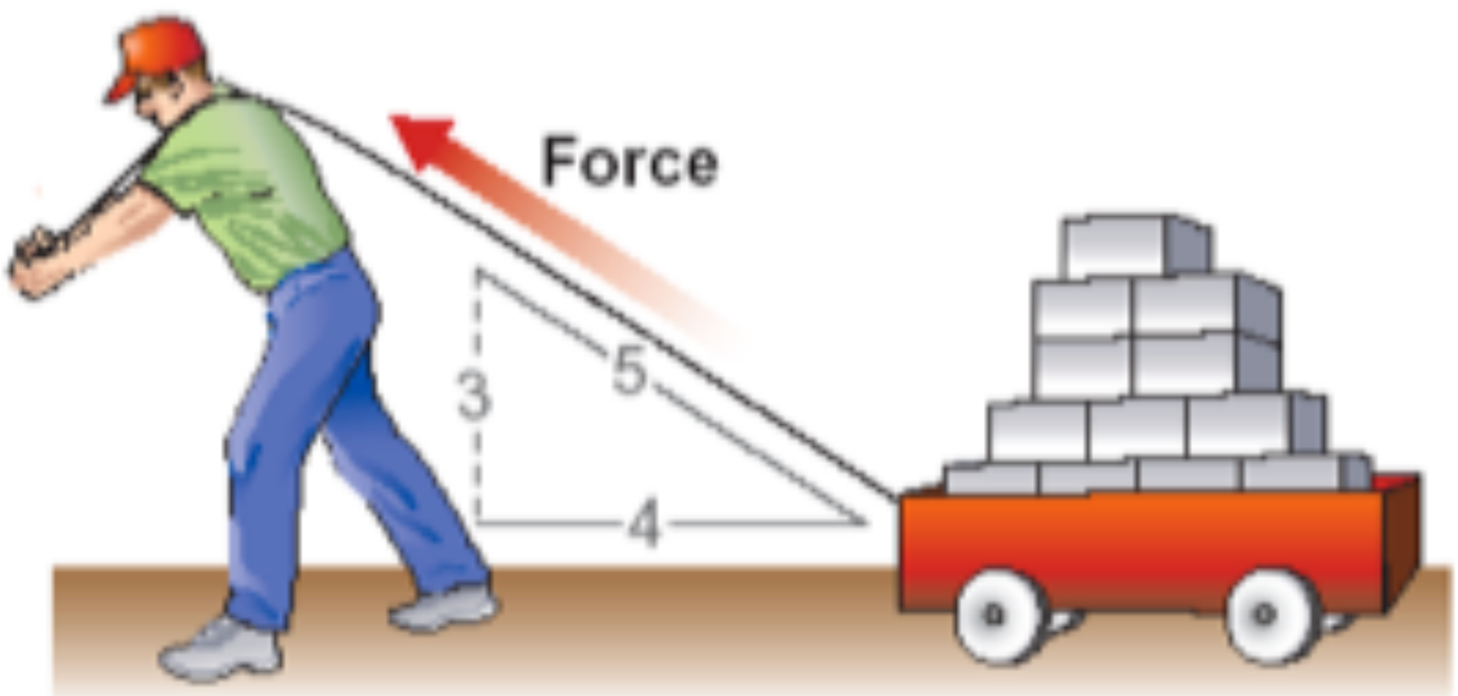
Work (joules) → $W = Fd\cos(\phi)$ ← Angle

Distance (m)

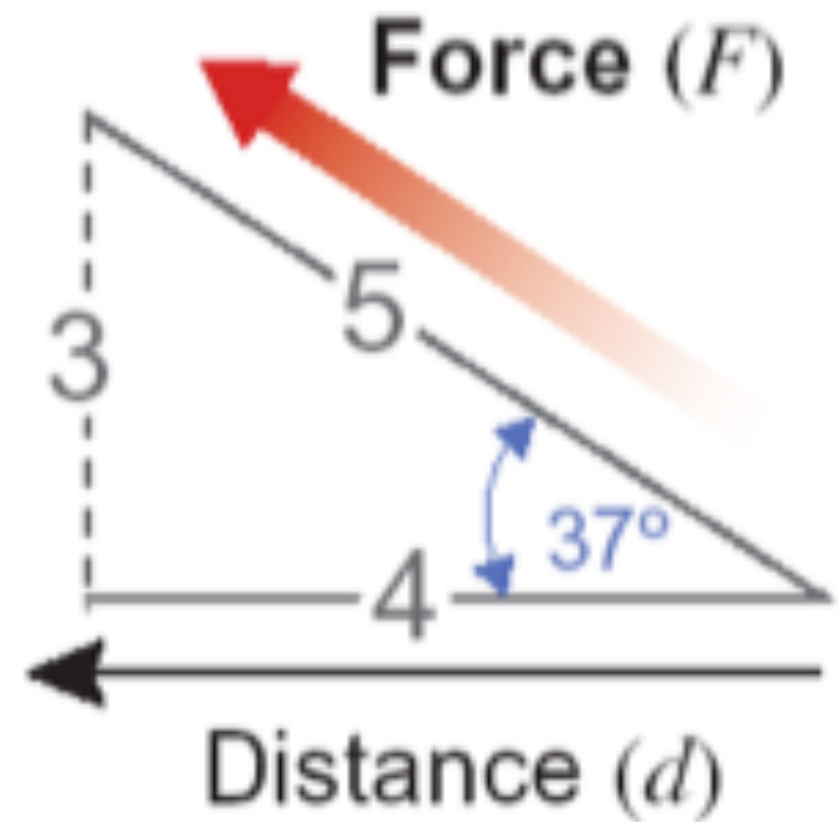


Force at an Angle to the Distance

PROBLEM



ANALYSIS



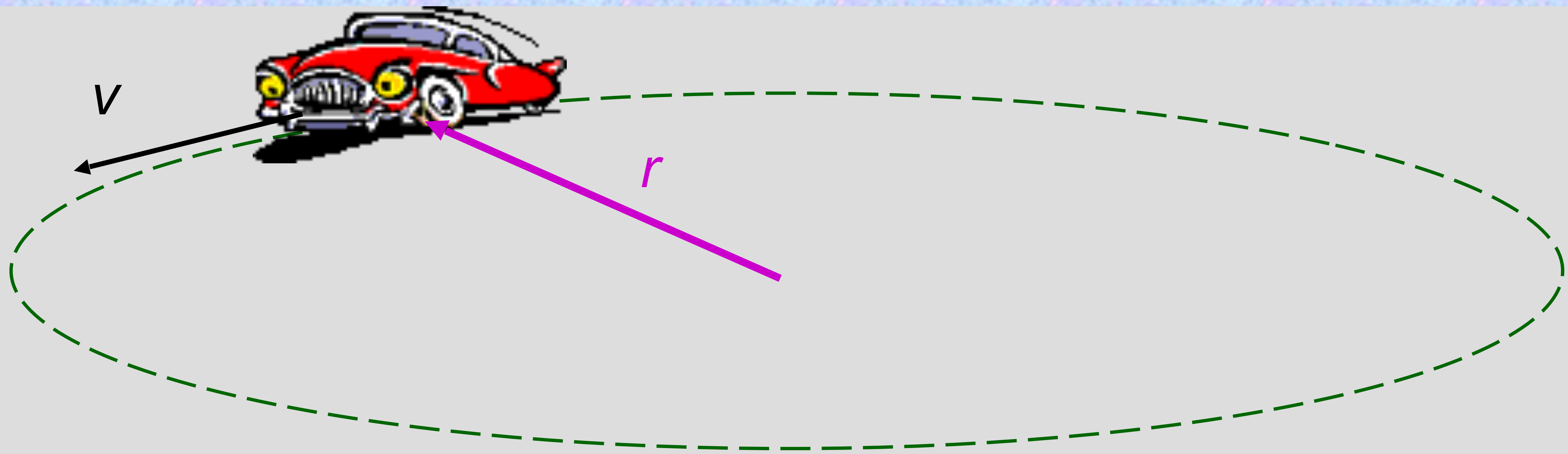
SOLUTION

$$W = Fd \times \left(\frac{4}{5}\right) = Fd \cos 37^\circ$$

Work: Circular Motion Example

A '69 Thunderbird is cruising around a circular track. Since it's turning a centripetal force is required. What type of force supplies this centripetal force?

answer:



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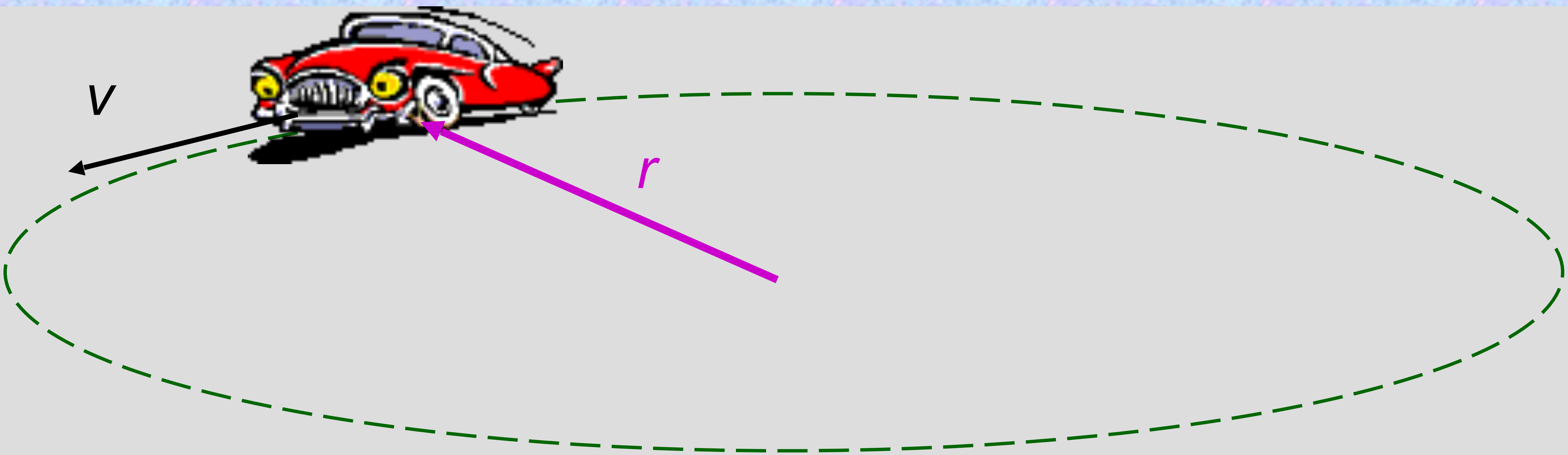
friction

How much work does this force do?



Work: Circular Motion Example

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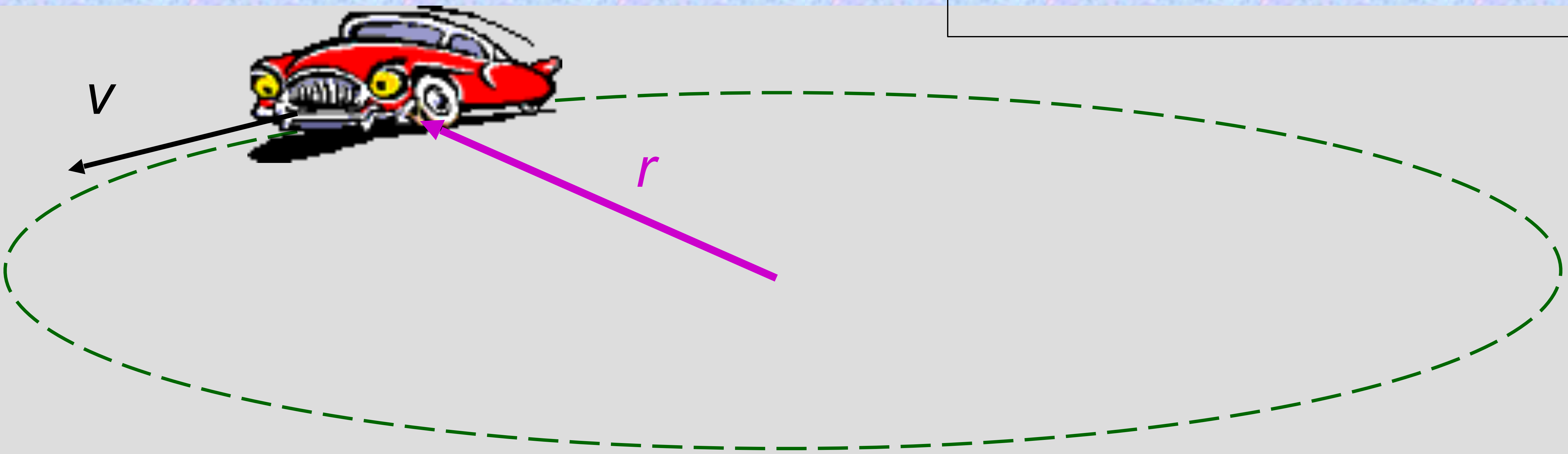
answer:

friction

How much work does this force do?

answer:

None, since the centripetal force is always perpendicular to the car’s motion.



Question

How much work is required to push a desk 15 m across a floor with a force of 100 N?

A) 6.7 J

B) 115 J

C) 85 J

D) 1500 J

Question

Pushing a crate 10 m across a floor with a force of 250 N requires ______ J of work?

A) 2500 J

B) 25 J

C) 250 J

D) .25 J

Questions:

- How much work is done when a weight lifter lifts a barbell weighing 1000 Newtons 1.5 meters above the ground?

Questions:

- How much work is done when a weight lifter pushes on a stationary wall with a force of 1000 Newtons for 15 seconds?

Question

- A 10 N weight is lifted 5 m. A 20 N weight is lifted 2.5 m. Which lifting required the most work?

(a) 10 N weight
(b) 20 N weight
(c) same work for each lifting
(d) not enough information is given to work the problem

Question

Two cars, A and B, travel as fast as they can to the top of a hill. If their masses are equal and they start at the same time, which one does the most work if A gets to the top first?

(a) A
(b) B
(c) they do the same amount of work

Do Work Problems

Forms of Energy

When work is done on an object the amount of energy the object has as well as the types of energy it possesses could change. Here are some types of energy you should know:

- Kinetic energy
- Rotational Kinetic Energy
- Gravitational Potential Energy
- Elastic Potential Energy
- Chemical Potential Energy
- Mass itself

- Electrical energy
- Light
- Sound
- Other waves
- Thermal energy

Gravitational Potential Energy

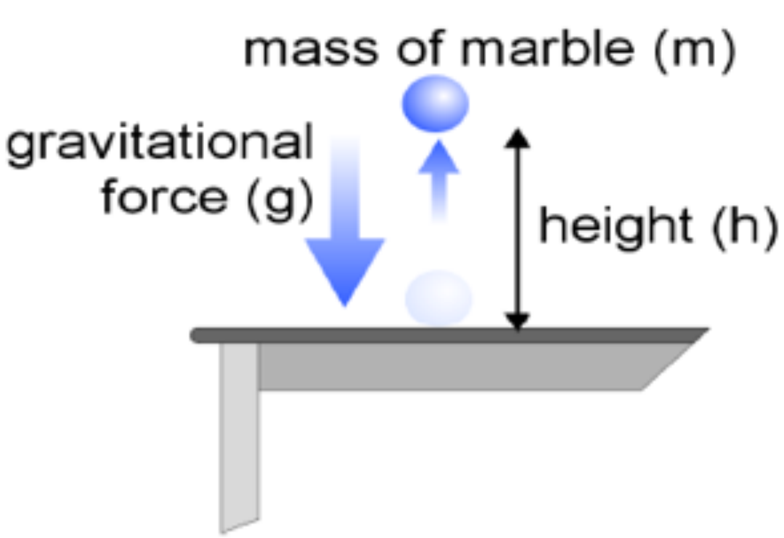
- Gravitational potential energy is the energy stored in an object as the result of its vertical position or height.

- The energy is stored as the result of the gravitational attraction of the Earth for the object.

Gravitational Potential Energy

Objects high above the ground have energy by virtue of their height. This is potential energy (the gravitational type). If allowed to fall, the energy of such an object can be converted into other forms like kinetic energy, heat, and sound. Gravitational potential energy is given by:

$$U = mgh$$



Gravitational Potential Energy

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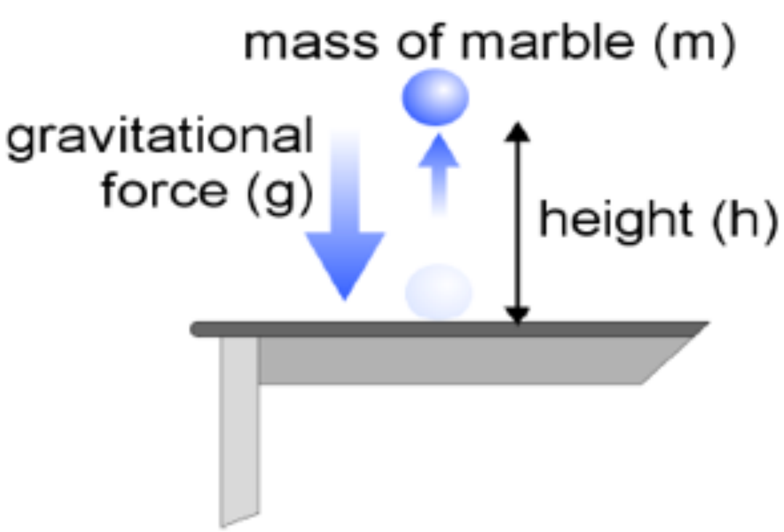
$$U = m g h$$

The equation shows that . . .



- the **more** mass a body has
- or the **stronger** the gravitational field it's in
- or the **higher** up it is

the **more** gravitational potential energy it's got.

Work done against gravity

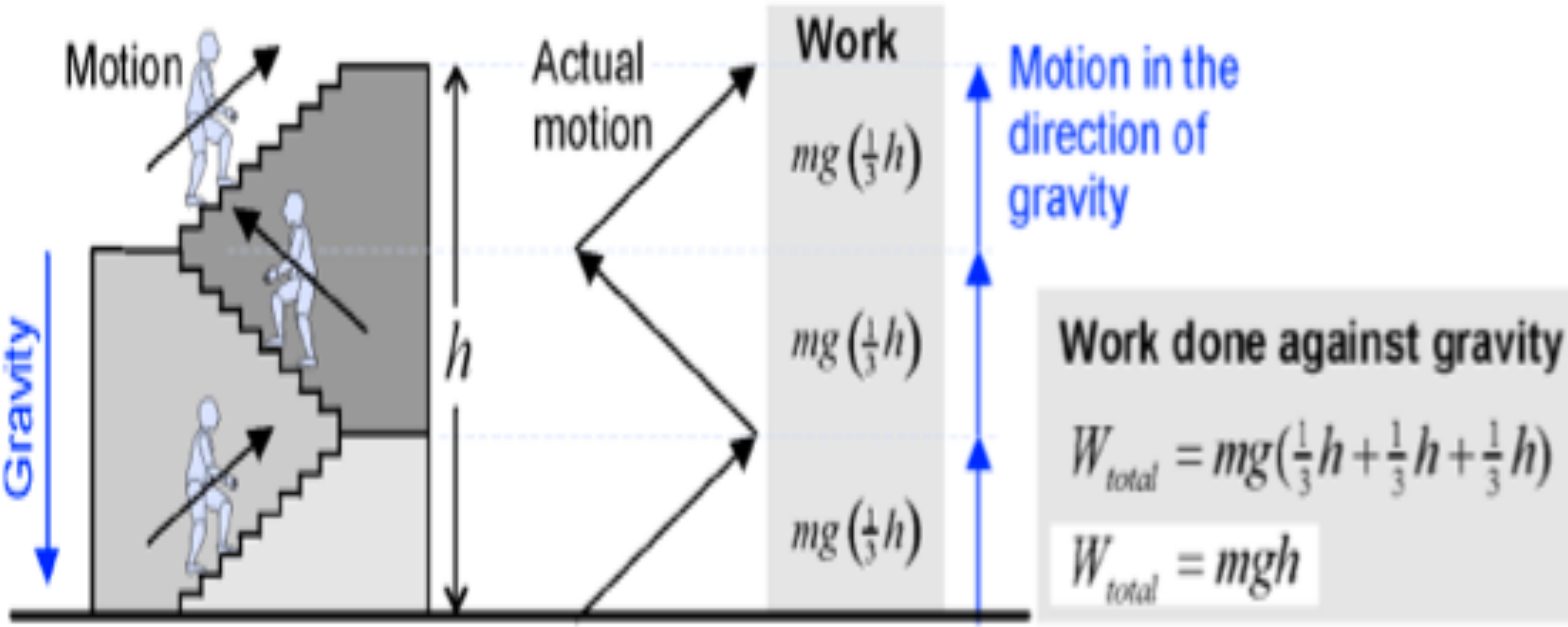
Mass (kg)

Height object raised (m)

Work (joules) → $W = mgh$

Gravity (m/sec^2)

Path doesn't matter



SI Potential Energy Units

From the equation $U = mgh$ the units of gravitational potential energy must be:

$$\text{kg} \cdot (\text{m/s}^2) \cdot \text{m} = (\text{kg} \cdot \text{m/s}^2) \cdot \text{m} = \text{N} \cdot \text{m} = \text{J}$$

This shows the SI unit for potential energy is the Joule, as it is for work and all other types of energy.

Reference point for *U* is arbitrary

Gravitational potential energy depends on an object's height, but how is the height measured? It could be measured from the floor, from ground level, from sea level, etc. It doesn't matter what we choose as a reference point (the place where the potential energy is zero) so long as we are consistent.

Example: A 190 kg mountain goat is perched precariously atop a 220 m mountain ledge. How much gravitational potential energy does it have?

continued on next slide

Reference point for *U* is arbitrary

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Example: A 190 kg mountain goat is perched precariously atop a 220 m mountain ledge. How much gravitational potential energy does it have?

$$U = mgh = (190)\,(9.8)\,(220) = 409\,640 \text{ J}$$

This is how much energy the goat has with respect to the ground below. It would be different if we had chosen a different reference point.

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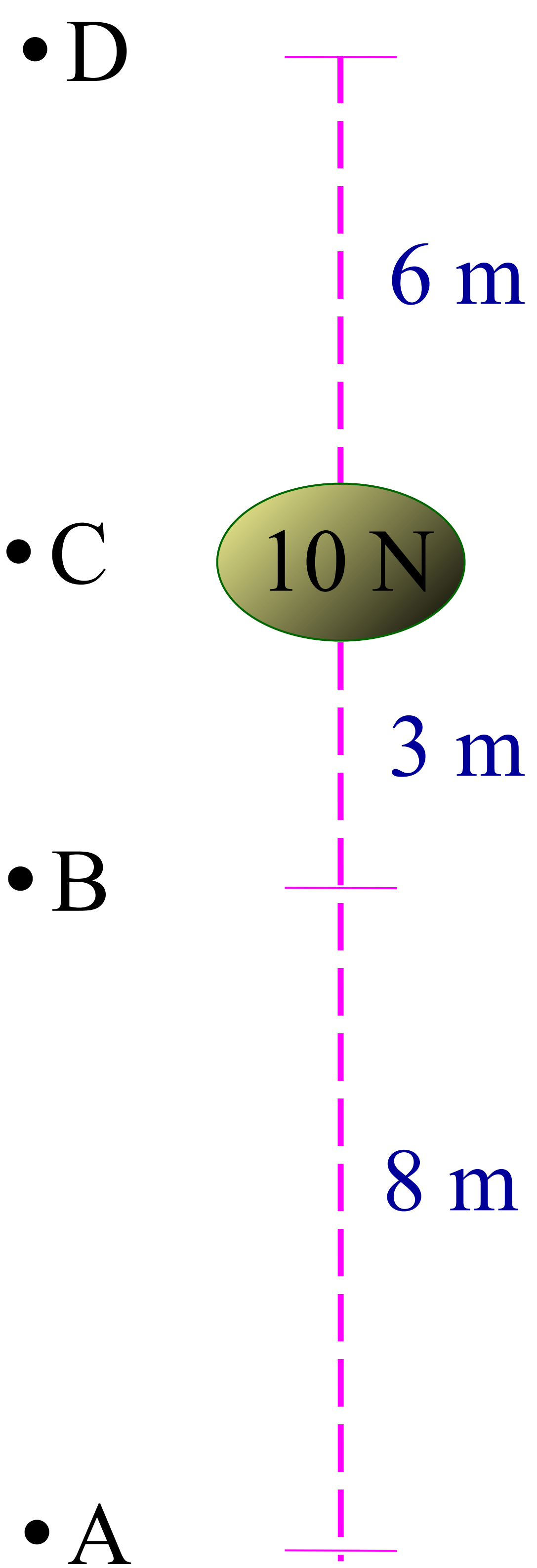
Reference point for U (cont.)



The amount of gravitation potential energy the mini-watermelon has depends on our reference point. It can be positive, negative, or zero.

Note: the weight of the object is given here, not the mass.

Reference Point	Potential Energy
A	110 J
B	30 J
C	0
D	−60 J

Question

A 20 Newton weight is lifted 4 meters. The change in potential energy of the weight in Joules is

(a) 20
(b) 24
(c) 16
(d) 80
(e) 5

Question

A 3.0 kg cart is loaded with a brick and pulled at constant speed along an inclined plane to the height of a seat-top at 0.45 meters. What is the potential energy of the loaded cart at the height of the seat-top?

A) 13.2 Joules

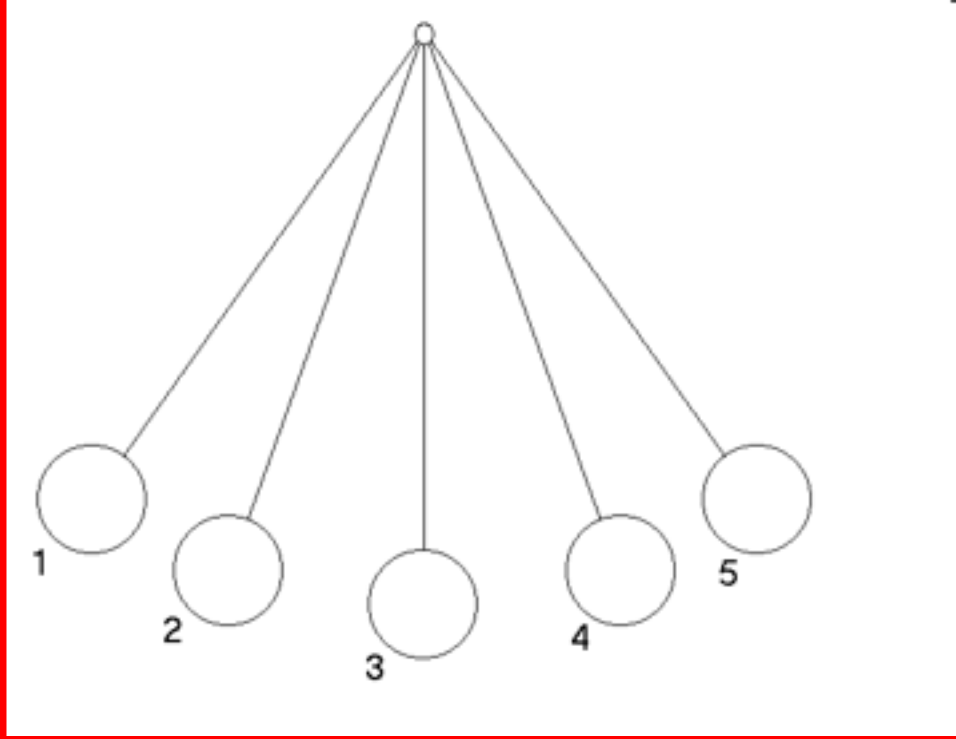
B) 1.35 Joules

C) 3.45 Joules

D) 18.2 Joules

Question

A pendulum is swinging back and forth. At what point is the kinetic energy the highest?



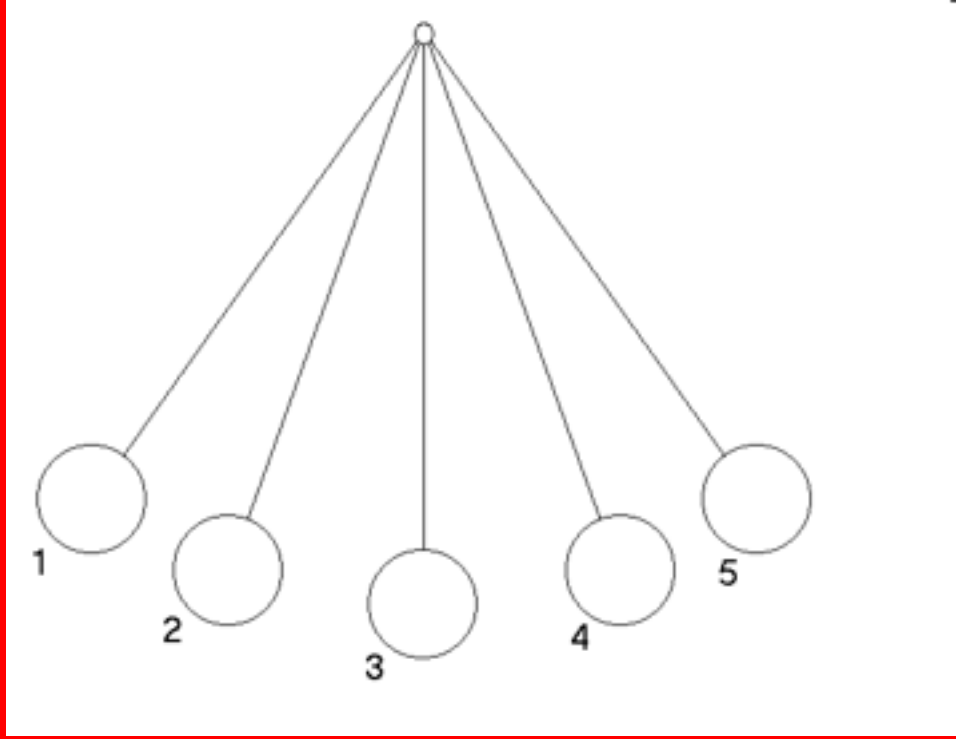
A) Kinetic energy is unrelated to height

B) At the top of its path

C) At the bottom of its path

D) At the middle of its path

Question



At what point is the potential energy the highest for a pendulum?

A) Potential energy is unrelated to height

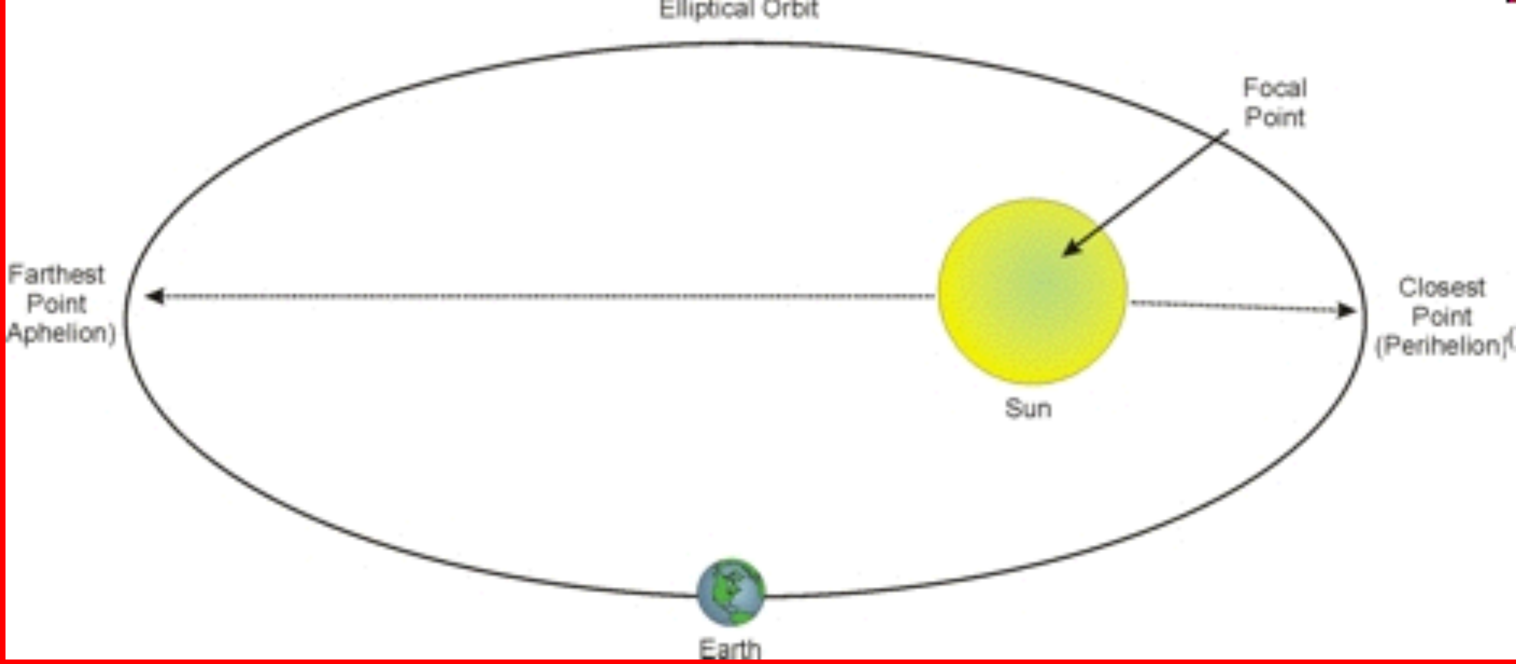
B) At the end of its path (1 & 5)

C) At the middle of its path (2 & 4)

D) At the bottom of its path (3)

E) Potential energy is constant

Question



At what point is the potential energy the highest for a satellite motion?

A) Potential energy is unrelated to satellite motion

B) At the closest point of its path (Penthelion)

C) At the middle of its path

D) At the Farthest point of its path (Aphelion)

E) Potential energy is constant

Do PE Problems

Kinetic Energy

Kinetic energy is the energy of motion. By definition, kinetic energy is given by:

$$K = \tfrac{1}{2} m v^2$$

The equation shows that . . .

- the more mass a body has
- or the faster it's moving

. . . the more kinetic energy it's got.

K is proportional to v^2, so doubling the speed quadruples kinetic energy, and tripling the speed makes it nine times greater.

Kinetic Energy

Mass (kg)

Kinetic Energy (joules) → $$E_k = \frac{1}{2} mv^2$$ ← Speed (m/sec)

Energy Units

The formula for kinetic energy, $K = \frac{1}{2} m v^2$, shows that its units are:

$$\text{kg} \cdot (\text{m/s})^2 = \text{kg} \cdot \text{m}^2/\text{s}^2 = (\text{kg} \cdot \text{m}/\text{s}^2)\text{m} = \text{N} \cdot \text{m} = \text{J}$$

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So the SI unit for kinetic energy is the Joule, just as it is for work. The Joule is the SI unit for all types of energy.

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So the SI unit for kinetic energy is the Joule, just as it is for work. The Joule is the SI unit for all types of energy.

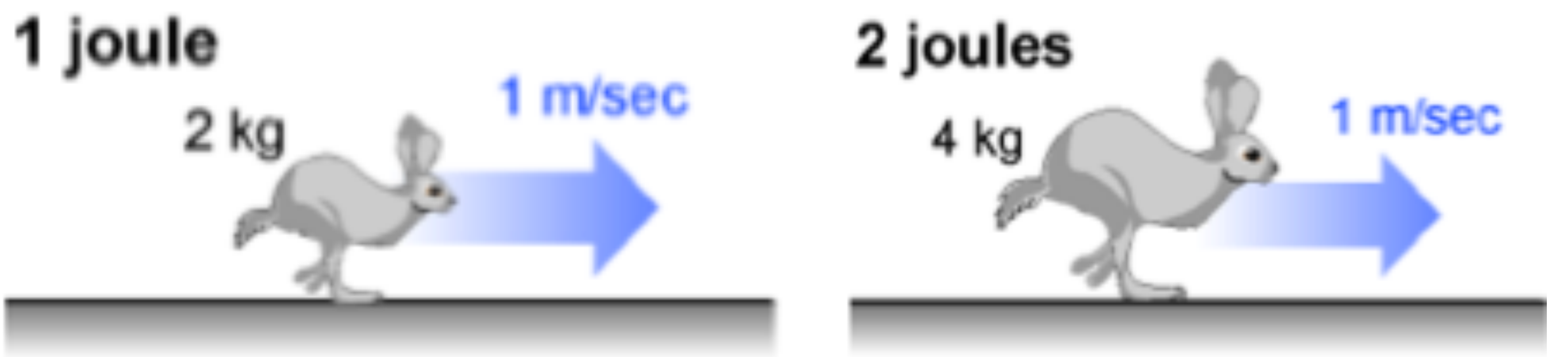
One common non-SI unit for energy is the calorie. 1 cal = 4.186 J. A calorie is the amount of energy needed to raise the temperature of 1 gram of water 1 °C.

A food calorie is really a kilocalorie. 1 Cal = 1000 cal = 4186 J.

Another common energy unit is the British thermal unit, BTU, which the energy needed to raise a pound of water 1 °F. 1 BTU = 1055 J.

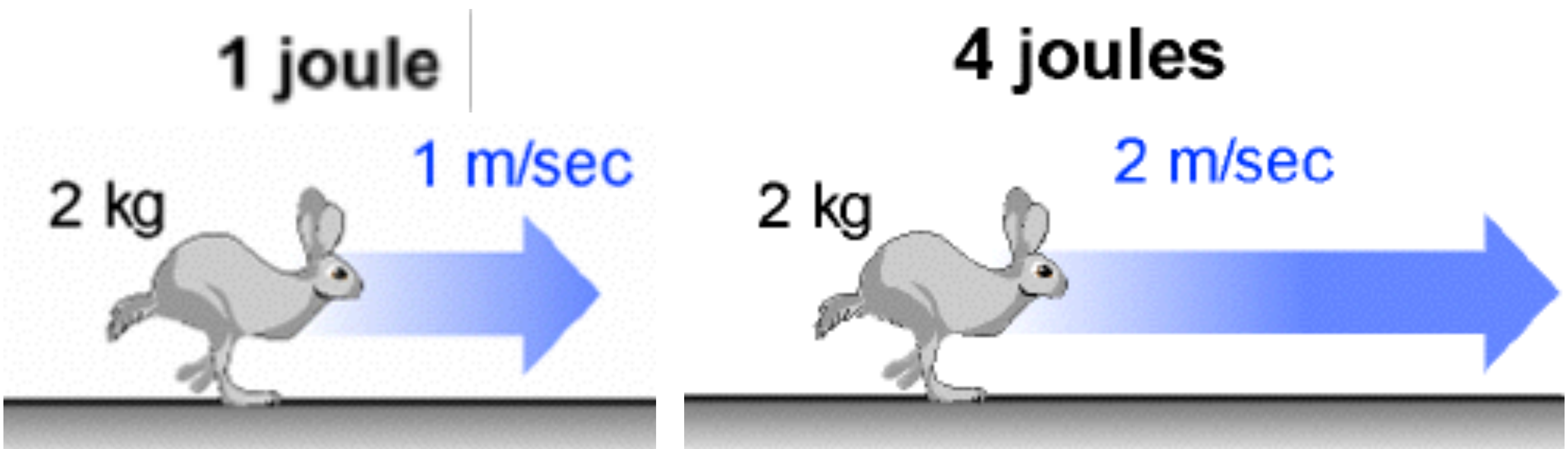
Kinetic Energy

- Energy of motion is called kinetic energy.
- The kinetic energy of a moving object depends on two things: mass and speed.
- Kinetic energy is proportional to mass.



Kinetic Energy

- **Mathematically, kinetic energy increases as the <u>square</u> of speed.**
- **If the speed of an object doubles, its kinetic energy increases four times. (mass is constant)**



Calculate Kinetic Energy

Calculating the kinetic energy of a moving car

- A car with a mass of 1,300 kg is going straight ahead at a speed of 30 m/sec (67 mph).
- The brakes can supply a force of 9,500 N.
- Calculate:
  - a) The kinetic energy of the car.

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- The brakes can supply a force of 9,500 N.
- Calculate:
  - a) The kinetic energy of the car.
  - b) The distance it takes to stop.

Kinetic Energy Example

A 55 kg toy sailboat is cruising at 3 m/s. What is its kinetic energy?

This is a simple plug and chug problem:

Note: Kinetic energy (along with every other type of energy) is a scalar, not a vector!

Kinetic Energy Example

A 55 kg toy sailboat is cruising at 3 m/s. What is its kinetic energy?

This is a simple plug and chug problem:

$K = 0.5\ (55)\ (3)^2 = 247.5\ \text{J}$

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Kinetic Energy Calculation

- A 1000 kg car is traveling at 20 m/s. What is its kinetic energy?

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- 200,000 J
- The same car is traveling at 40 m/s. What is its kinetic energy?

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- 800,000 J
- The same car is traveling at 60 m/s. What is its kinetic energy?

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- The same car is traveling at 60 m/s. What is its kinetic energy?
- 1,800,000

Kinetic Energy Calculation

- **If the brakes supply 7000-N of stopping force, calculate how far it takes to stop the car when it is going 15 m/s (KE = 200,000 J).**

Kinetic Energy Calculation

- If the brakes supply 7000-N of stopping force, calculate how far it takes to stop the car when it is going 15 m/s (KE = 200,000 J).
- 28 m
- Calculate how far it takes to stop the car when it is going 40 m/s (KE = 800,000 J).

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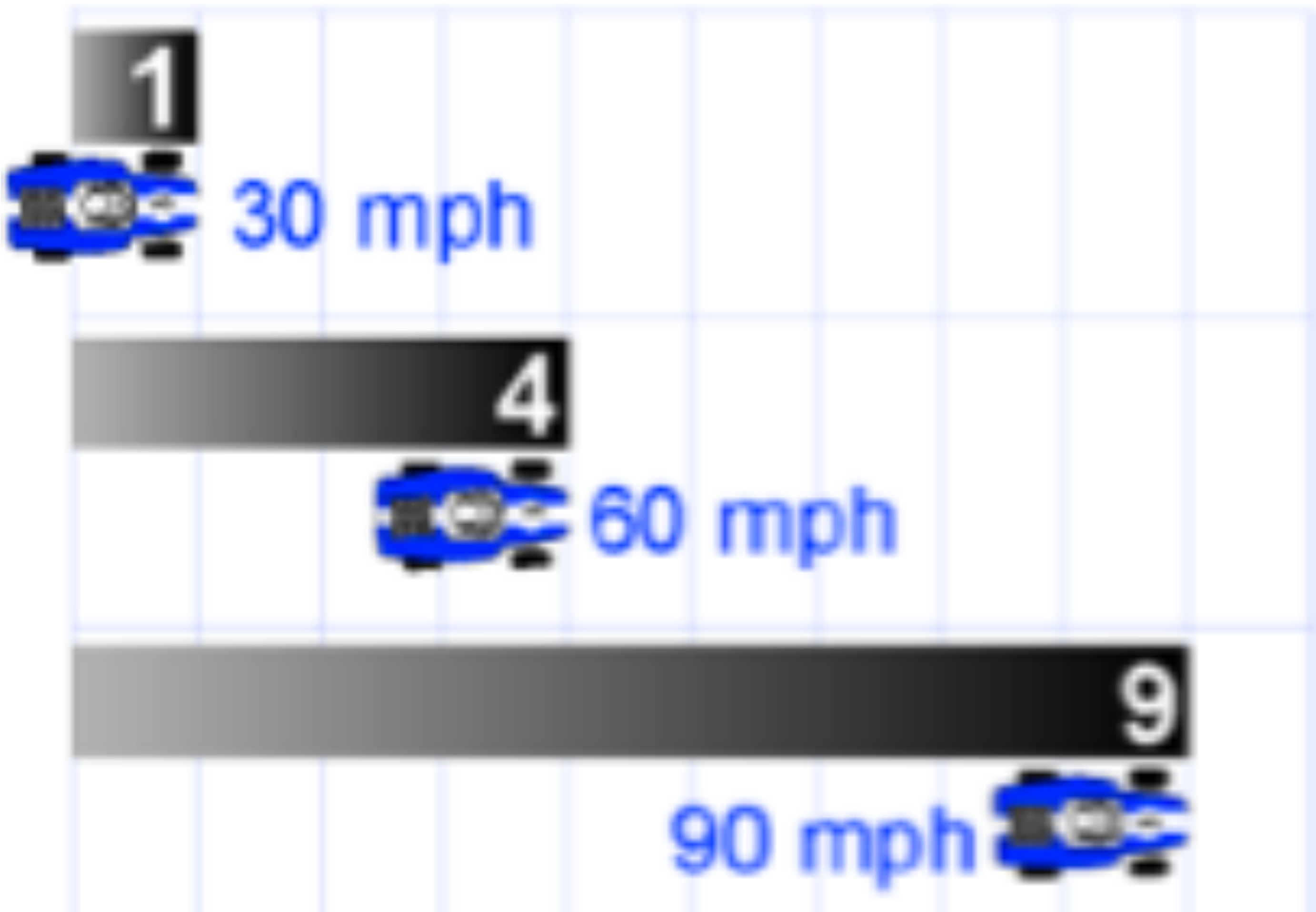
- If the brakes supply 7000-N of stopping force, calculate how far it takes to stop the car when it is going 15 m/s (KE = 200,000 J).
- 28 m
- Calculate how far it takes to stop the car when it is going 40 m/s (KE = 800,000 J).
- 114 m
- Calculate how far it takes to stop the car when it is going 60 m/s (KE = 1,800,000 J).

Kinetic Energy Calculation

- If the brakes supply 7000-N of stopping force, calculate how far it takes to stop the car when it is going 15 m/s (KE = 200,000 J).
- 28 m
- Calculate how far it takes to stop the car when it is going 40 m/s (KE = 800,000 J).
- 114 m
- Calculate how far it takes to stop the car when it is going 60 m/s (KE = 1,800,000 J).
- 257 m

- **Kinetic energy becomes important in calculating braking distance**



Question

Determine the kinetic energy of a 204-kg roller coaster car that is moving with a speed of 18.3 m/s.

A) 1,496 Joules

B) 23,451 Joules

C) 34,159 Joules

D) 4,978 Joules

Question

Determine the kinetic energy of a 100-kg car that is moving with a speed of 5 m/s.

A) 20 Joules

B) 480 Joules

C) 1250 Joules

D) 500 Joules

Question

Determine the kinetic energy of a 90-kg person that is running with a speed of 10 m/s.

A) 900 Joules

B) 100 Joules

C) 9 Joules

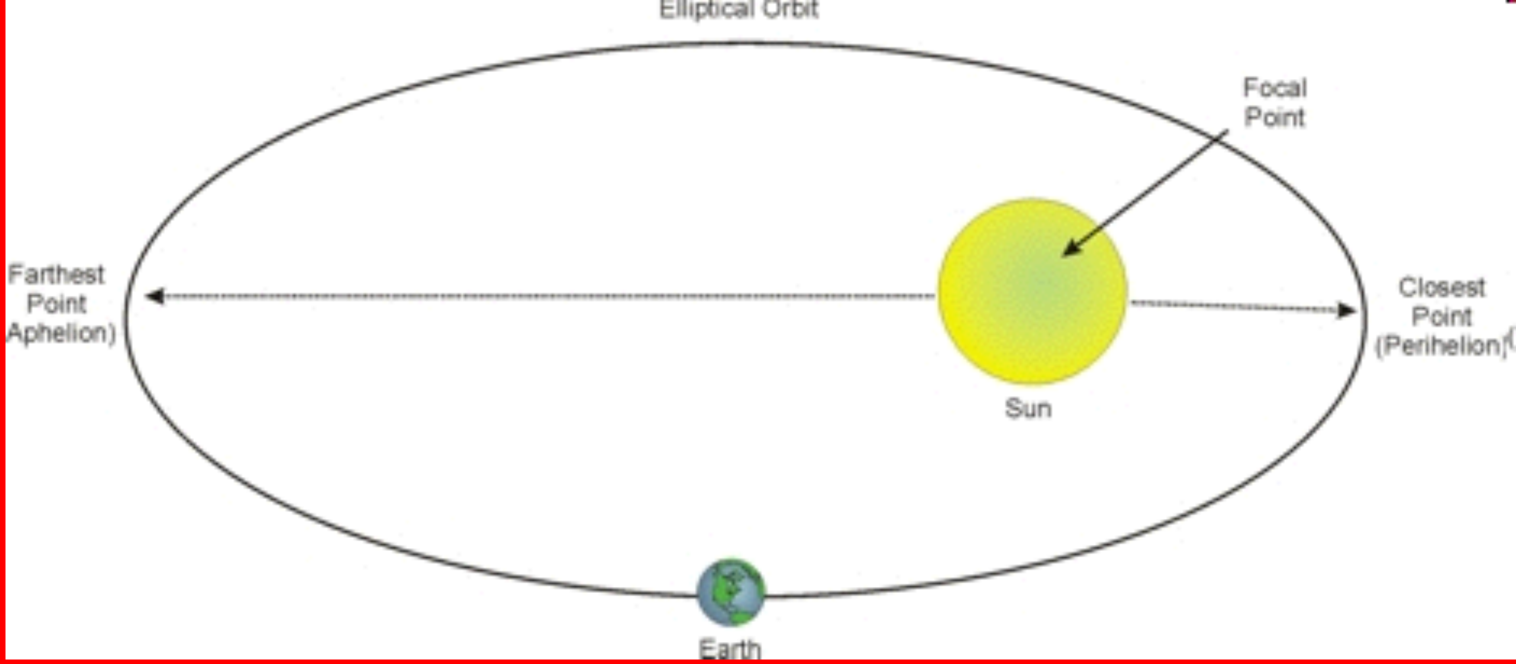
D) 4500 Joules

Question

An object of mass 6 kg is traveling at a velocity of 30 m/s. How much total work was required to obtain this velocity starting from a position of rest?

(a) 180 Joules
(b) 2700 Joules
(c) 36 Joules
(d) 5 Joules
(e) 180 N

Question



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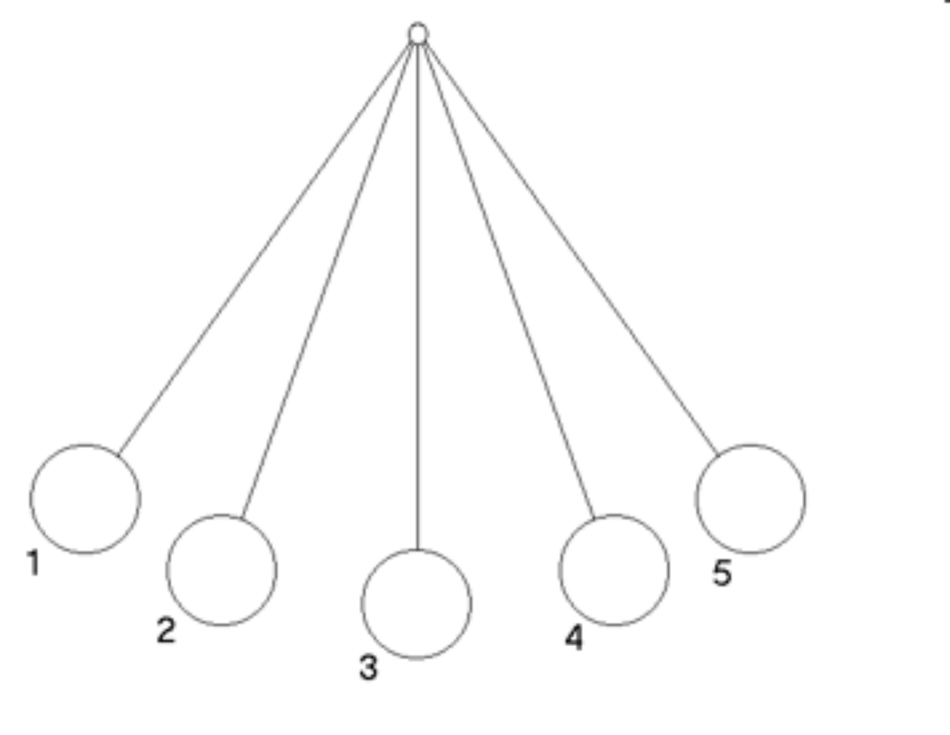
Question



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Do KE Problems

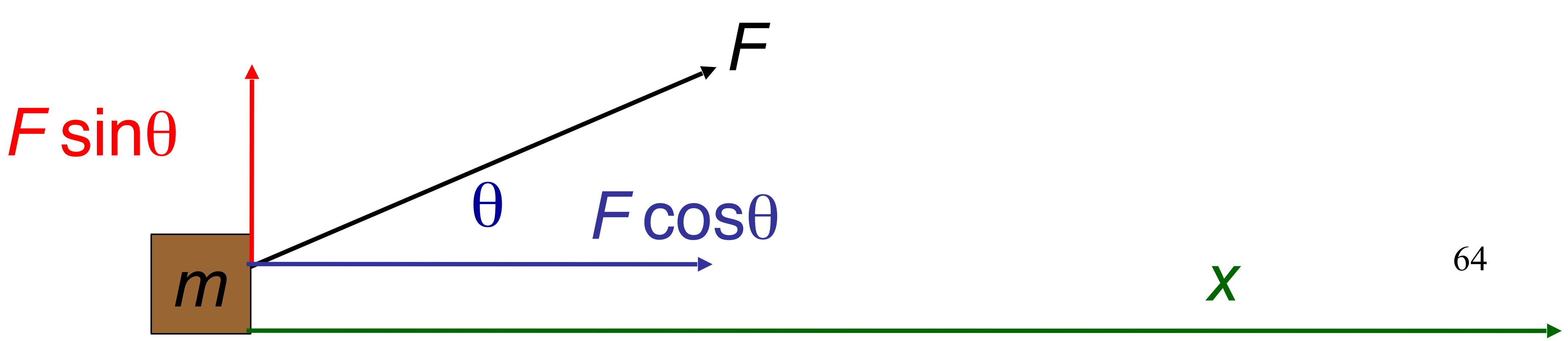
Power

Power is defined as the rate at which work is done. It can also refer to the rate at which energy is expended or absorbed. Mathematically, power is given by:

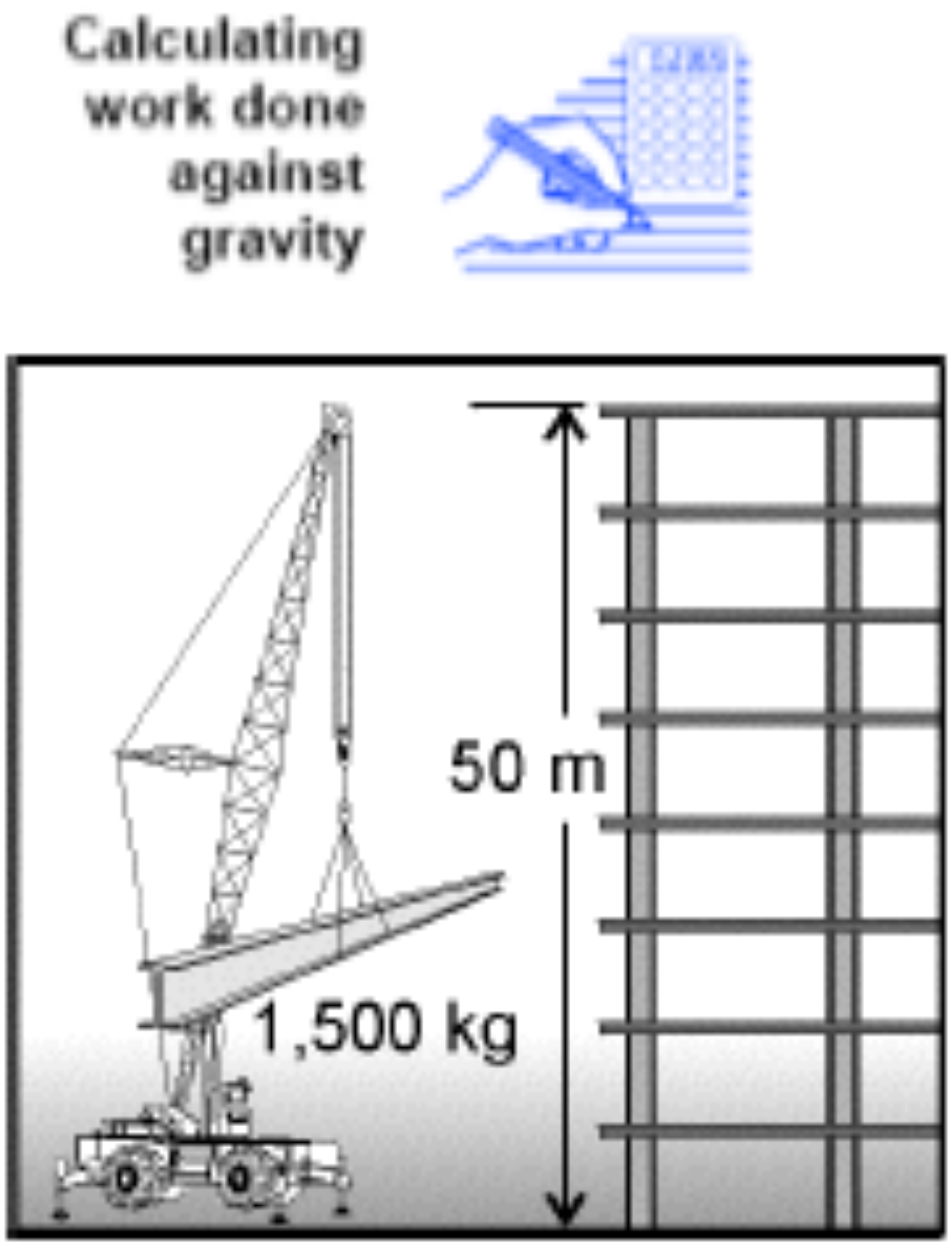
$$P = \frac{W}{t}$$

Since work is force in the direction of motion times distance, we can write power as:

$$P = (Fx\cos\theta)/t = (F\cos\theta)(x/t) = Fv\cos\theta.$$

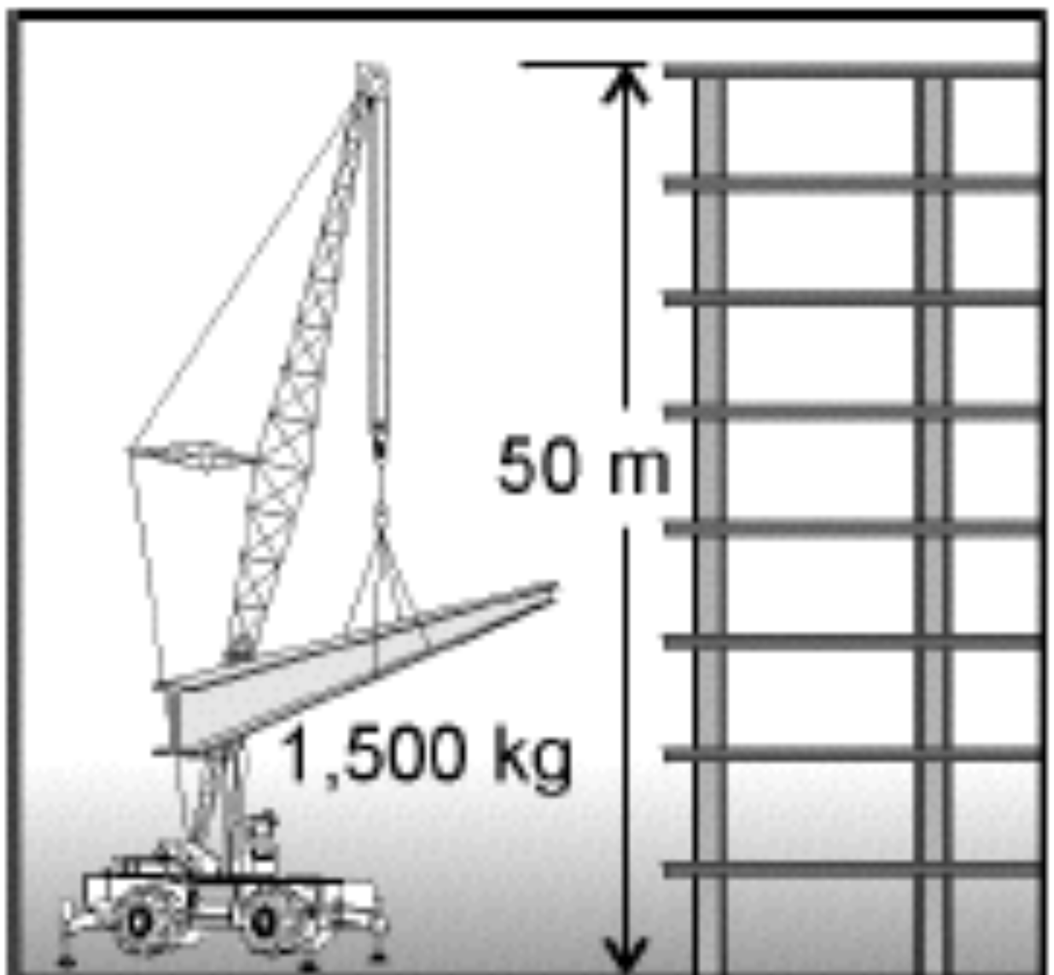


Calculate work



- A crane lifts a steel beam with a mass of 1,500 kg.
- Calculate how much work is done against gravity if the beam is lifted 50 meters in the air.

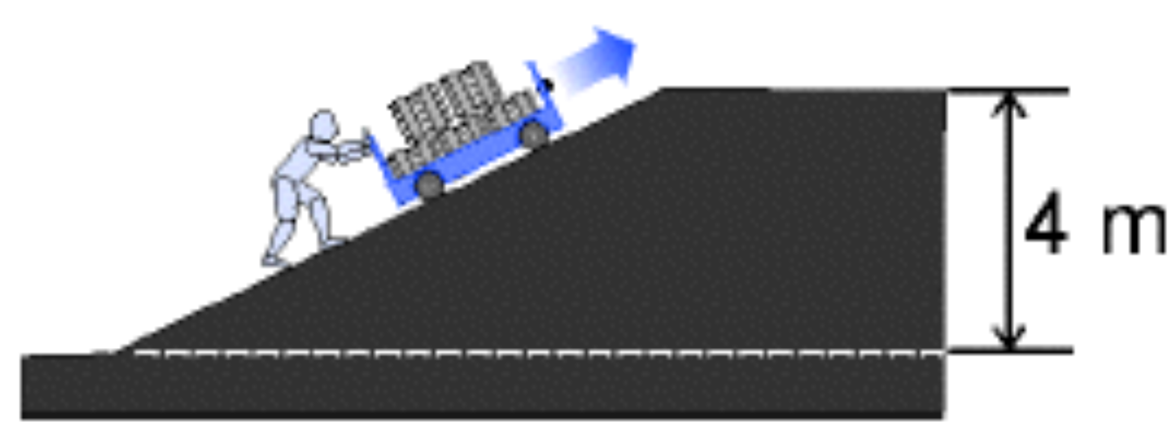
Calculate work



- A crane lifts a steel beam with a mass of 1,500 kg.
- Calculate how much work is done against gravity if the beam is lifted 50 meters in the air.
- How much time does it take to lift the beam if the motor of the crane can do 10,000 joules of work per second?

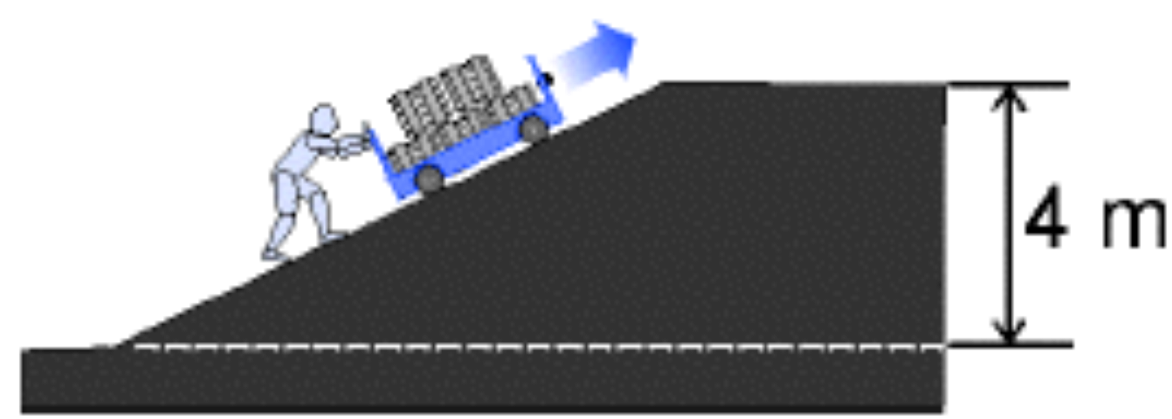
Gravitational Potential Energy

- A cart with a mass of 102 kg is pushed up a ramp.
- The top of the ramp is 4 meters higher than the bottom.
- How much potential energy is gained by the cart?



Gravitational Potential Energy

- A cart with a mass of 102 kg is pushed up a ramp.
- The top of the ramp is 4 meters higher than the bottom.
- How much potential energy is gained by the cart?
- If an average student can do 50 joules of work each second, how much time does it take to get up the ramp?



Power

- Power is simply energy exchanged per unit time, or how fast you get work done (Watts = Joules/sec)
- One horsepower = 745 W
- Perform 100 J of work in 1 s, and call it 100 W
- Run upstairs, raising your 70 kg (700 N) mass 3 m (2,100 J) in 3 seconds = 700 W output!
- Shuttle puts out a few GW (gigawatts, or 10^9 W) of power!

A small electric motor is used to lift a 0.50-kilogram mass at constant speed. If the mass is lifted a vertical distance of 1.5 meters in 5.0 seconds, the average power developed by the motor is

A. 0.15 W

B. 1.5 W

C. 3.8 W

D. 7.5 W

What is the maximum amount of work that a 6000.-watt motor can do in 10. seconds?

A. 6.0×10^1 J

B. 6.0×10^2 J

C. 6.0×10^3 J

D. 6.0×10^4 J

If a motor lifts a 400.-kilogram mass a vertical distance of 10. meters in 8.0 seconds, the *minimum* power generated by the motor is

A. 3.2×10^2 W

B. 5.0×10^2 W

C. 4.9×10^3 W

D. 3.2×10^4 W

What is the maximum height to which a motor having a power rating of 20.4 watts can lift a 5.00-kilogram stone vertically in 10.0 seconds?

A. 0.0416 m

B. 0.408 m

C. 4.16 m

D. 40.8 m

A 70.-kilogram cyclist develops 210 watts of power while pedaling at a constant velocity of 7.0 meters per second east.

What average force is exerted eastward on the bicycle to maintain this constant speed?

A. 490 N

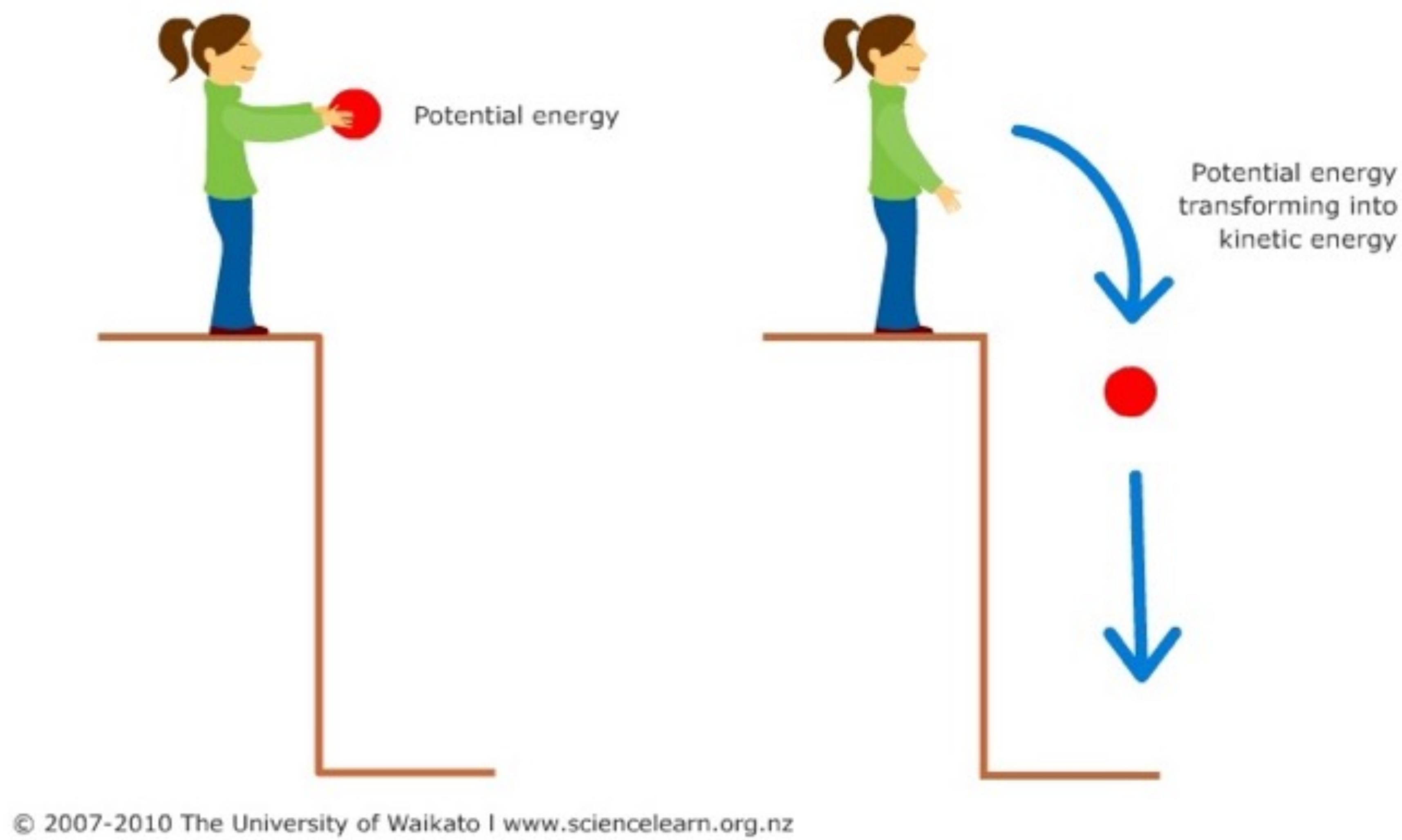
B. 30. N

C. 3.0 N

D. 0 N

Do Power Problems

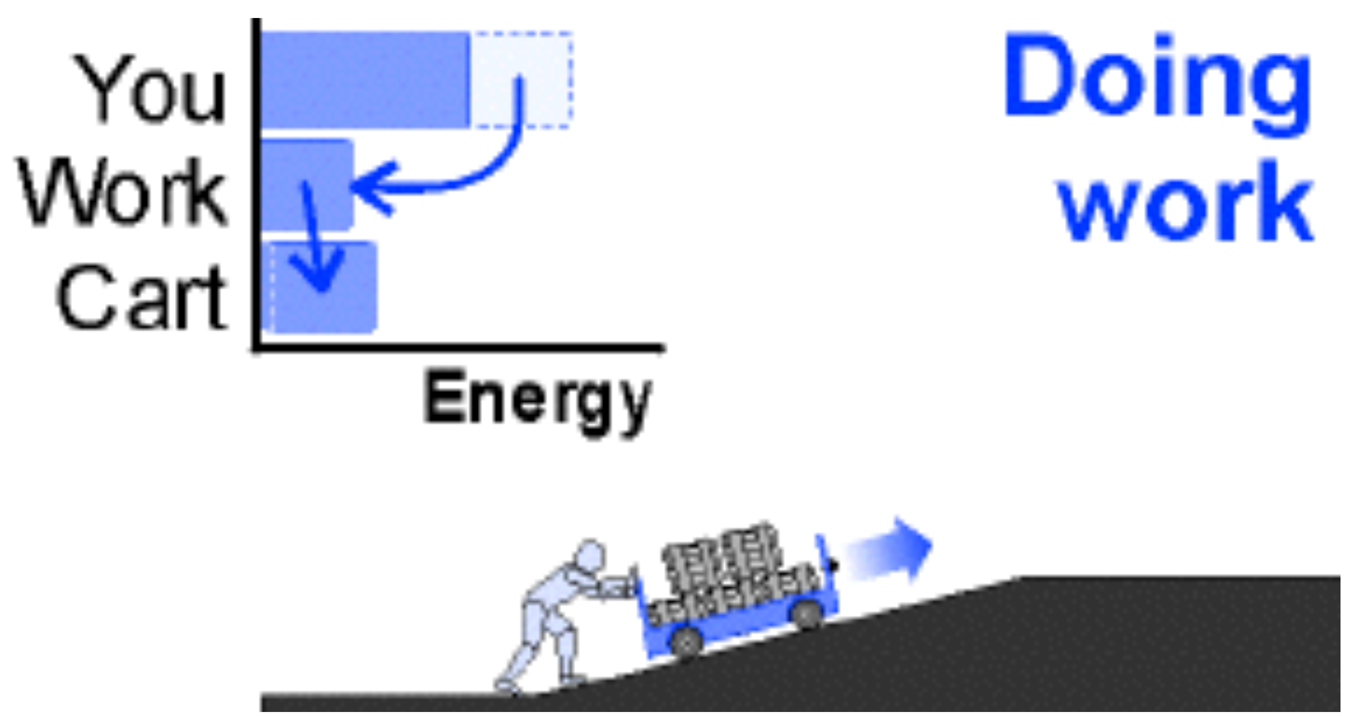
Potential Energy Converted to Kinetic Energy



Potential energy converts to kinetic energy when stored energy begins to move.

Conservation of Energy

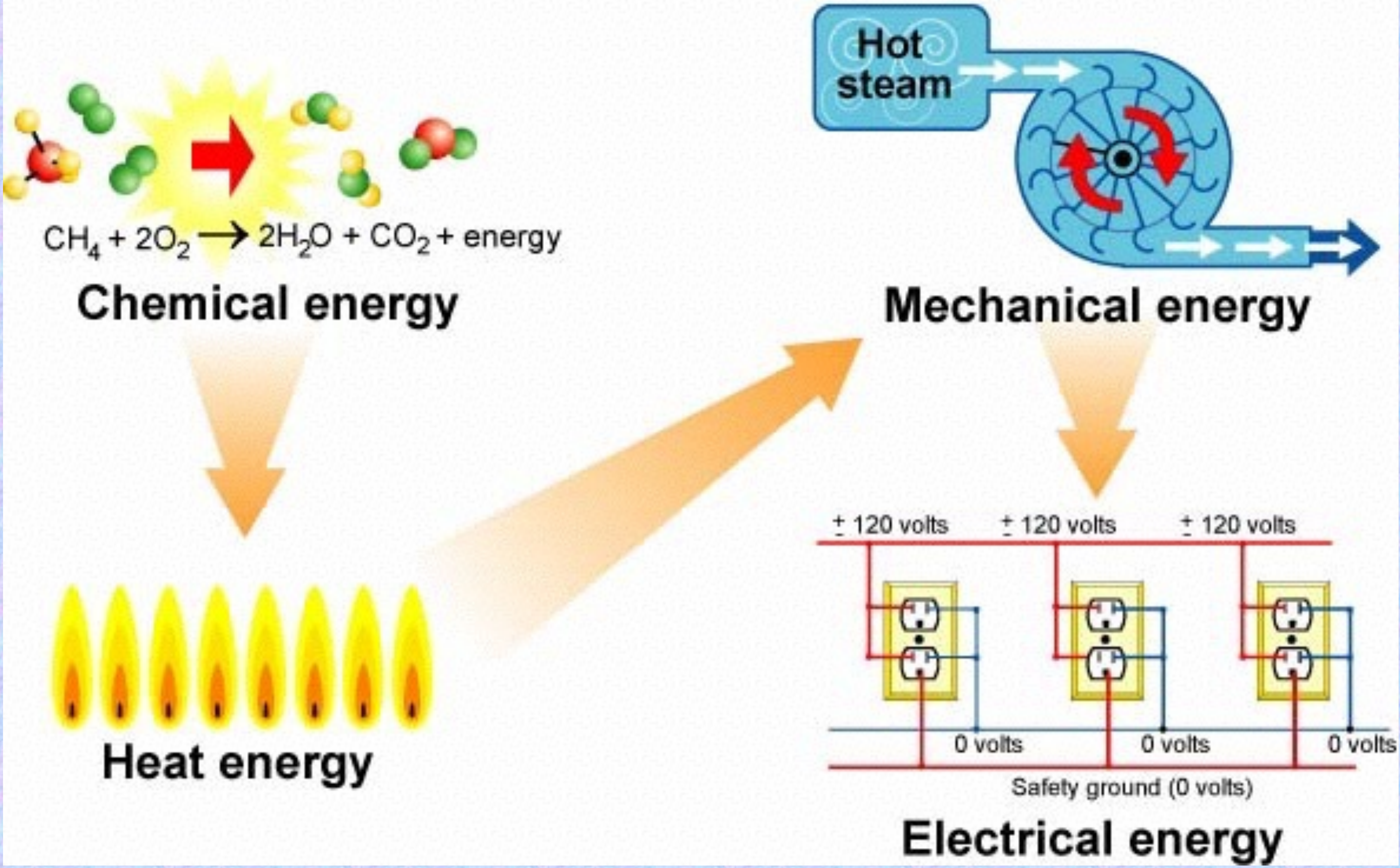
- Energy is the ability to make things change.
- A system that has energy has the ability to do work.
- Energy is measured in the same units as work because energy is transferred during the action of work.



Forms of Energy

- Mechanical energy is the energy possessed by an object due to its motion or its position.
- Radiant energy includes light, microwaves, radio waves, x-rays, and other forms of electromagnetic waves.
- Nuclear energy is released when heavy atoms in matter are split up or light atoms are put together.
- The Electrical energy we use is derived from other sources of energy such as chemical reactions

Forms of Energy



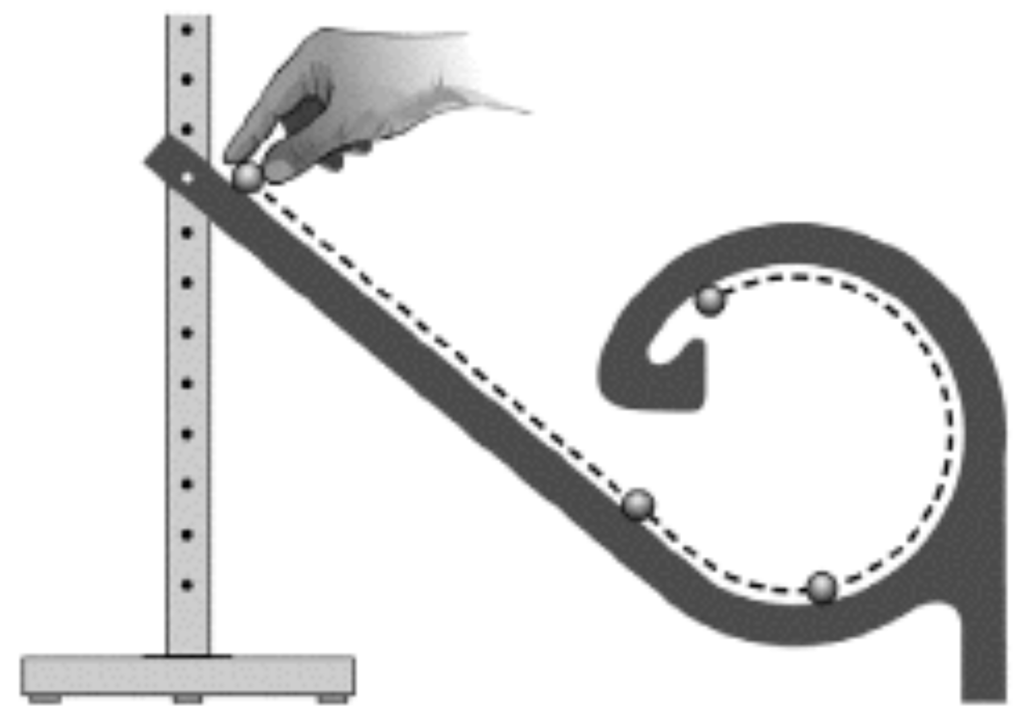
Law of Conservation of Energy

- As energy takes different forms and changes things by doing work, nature keeps perfect track of the total.
- No new energy is created and no existing energy is destroyed.

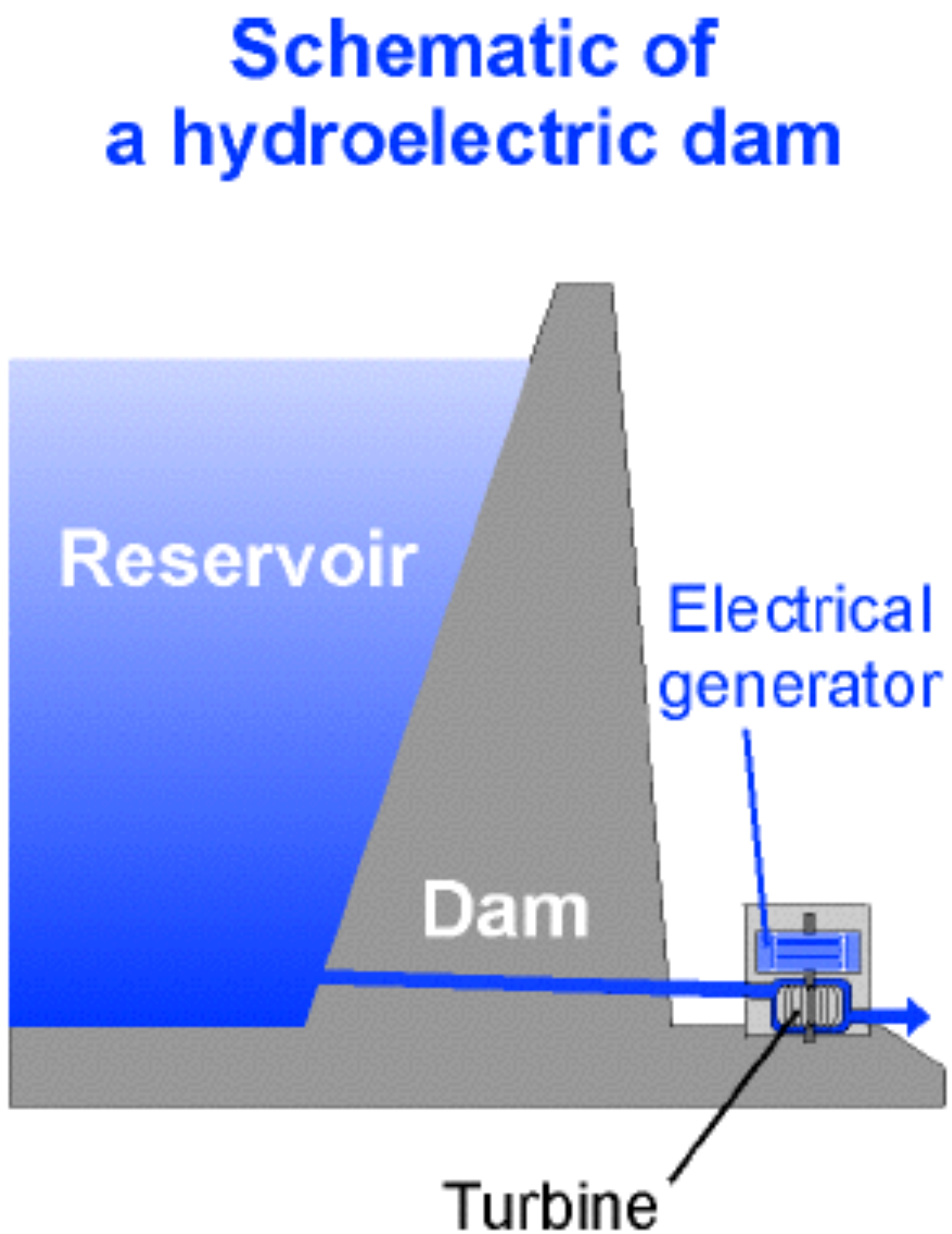
- How many energy **transformations** have you been involved with so far today?

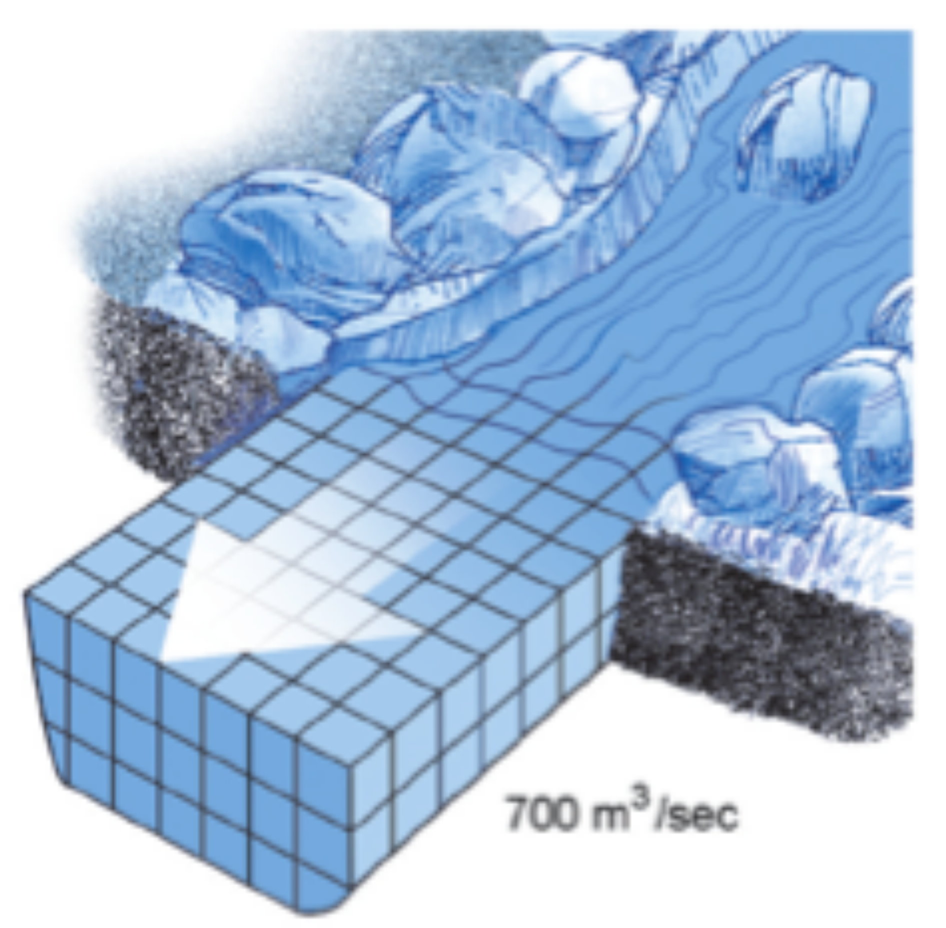
Conservation of Energy

- Key Question:
- **How is motion on a track related to energy?**



Hydroelectric Power





Conversion of PE → KE

PE + KE = PE + KE

Conversion of PE → KE

$$PE + KE = PE + KE$$

or

$$mgh + \tfrac{1}{2}mv^2 = mgh + \tfrac{1}{2}mv^2$$

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All masses are the same…

Conversion of PE → KE

$$PE + KE = PE + KE$$

or

$$mgh + \tfrac{1}{2}mv^2 = mgh + \tfrac{1}{2}mv^2$$

All masses are the same…

$$\frac{\boldsymbol{m}gh}{\boldsymbol{m}} + \frac{\tfrac{1}{2}\boldsymbol{m}v^2}{\boldsymbol{m}} = \frac{\boldsymbol{m}gh}{\boldsymbol{m}} + \frac{\tfrac{1}{2}\boldsymbol{m}v^2}{\boldsymbol{m}}$$

Conversion of PE → KE

$$PE + KE = PE + KE$$

or

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

All masses are the same…

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

Therefore

$$gh + \frac{1}{2}v^2 = gh + \frac{1}{2}v^2$$

Acceleration due to gravity is independent of mass

Conservation of Energy vs. Kinematics

Many problems that we've been solving with kinematics can be solved using energy methods. For many problems energy methods are easier, and for some it is the only possible way to solve them. Let's do one both ways:

A 185 kg orangutan drops from a 7 m high branch in a rainforest in Indonesia. How fast is he moving when he hits the ground?

Kinematics:

Conservation of energy:

Conservation of Energy vs. Kinematics

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Kinematics:

$$v_f^2 - v_0^2 = 2\,a\,\Delta x$$

$$v_f^2 = 2\,(-9.8)\,(-7)$$

$$v_f = 11.71 \text{ m/s}$$

Conservation of energy:

Conservation of Energy vs. Kinematics

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$$v_f = 11.71 \text{ m/s}$$

Conservation of energy:

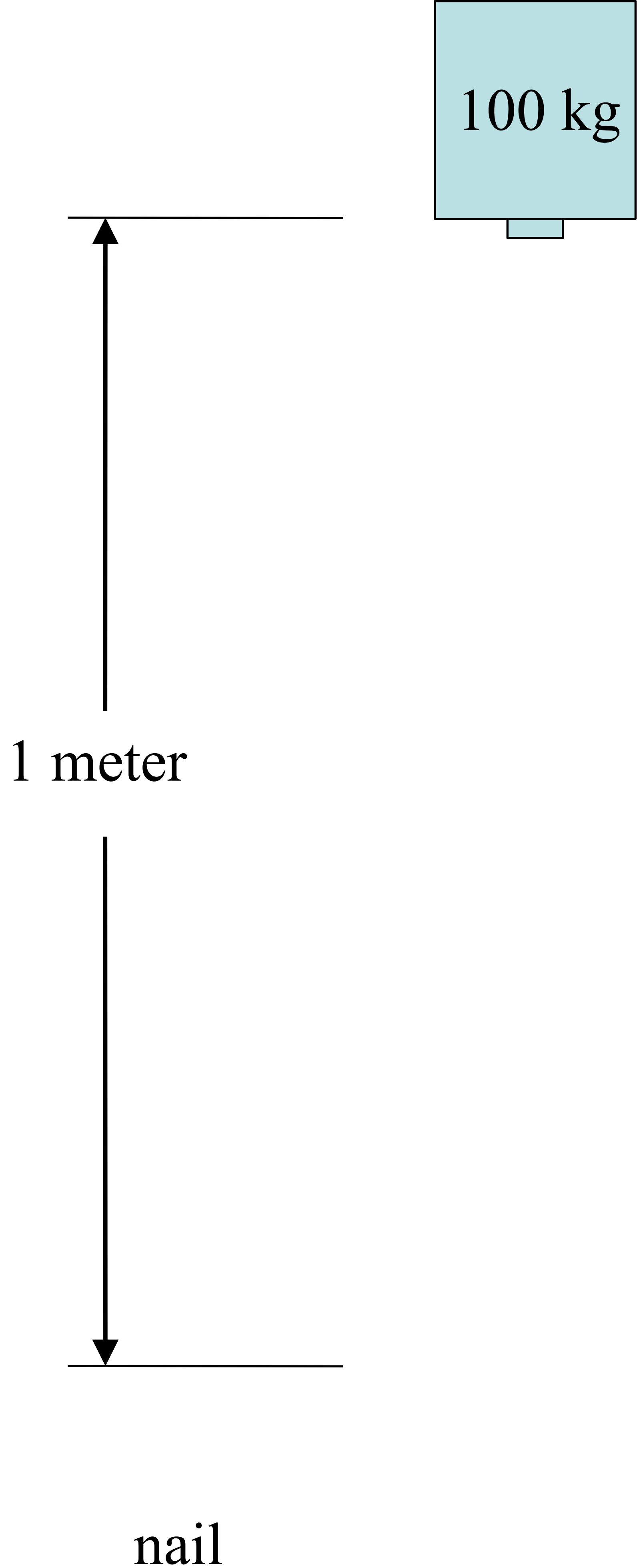
$$E_0 = E_f$$

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

$$2gh = v^2$$

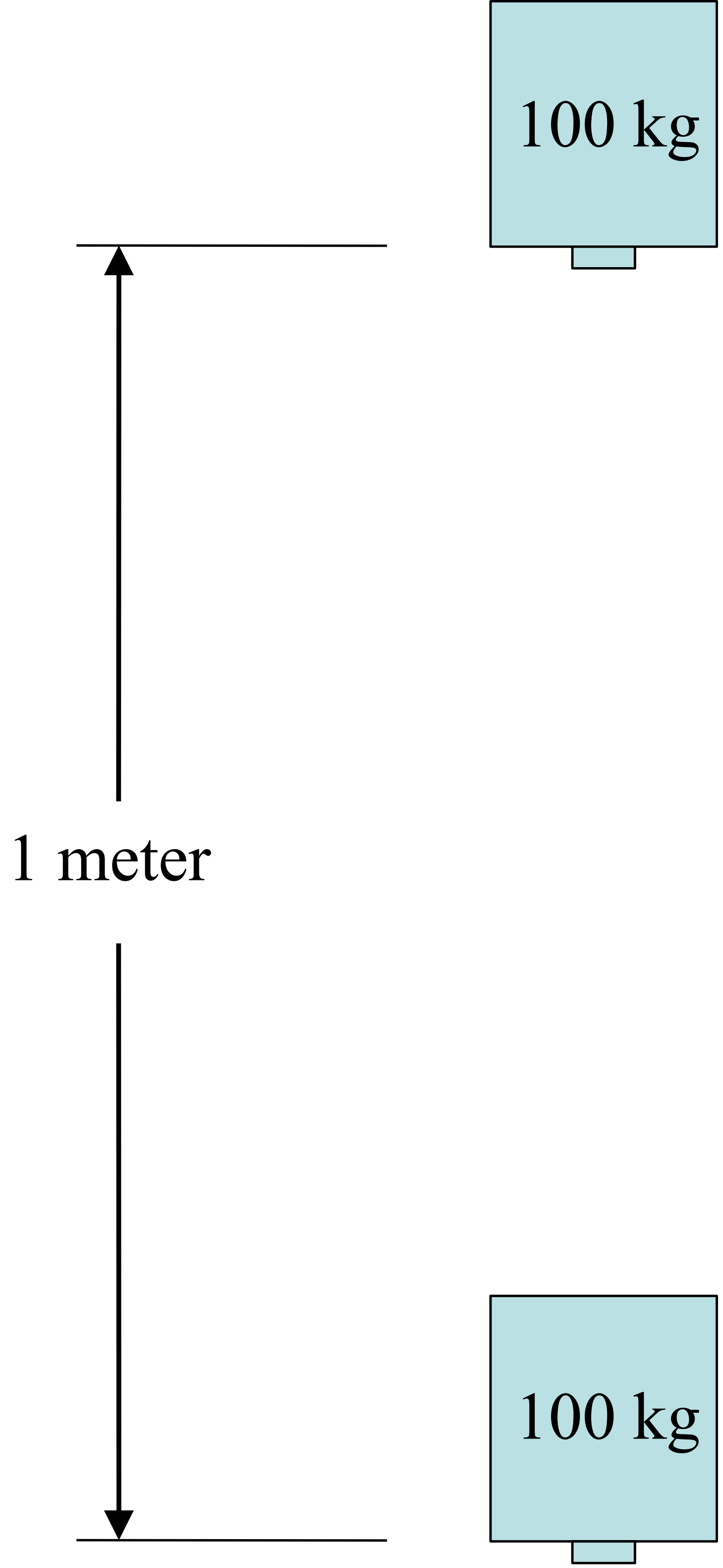
$$v = [2(9.8)(7)]^{1/2} = 11.71 \text{ m/s}$$

Note: the mass didn't matter in either method. Also, we ignored air resistance in each, meaning *a* is a constant in the kinematics method and no heat is generated in the energy method.



$$KE = \tfrac{1}{2}mv^2 = 0$$

$$PE = mgh = (100kg)(9.8m/s^2)(1m) = 980J$$



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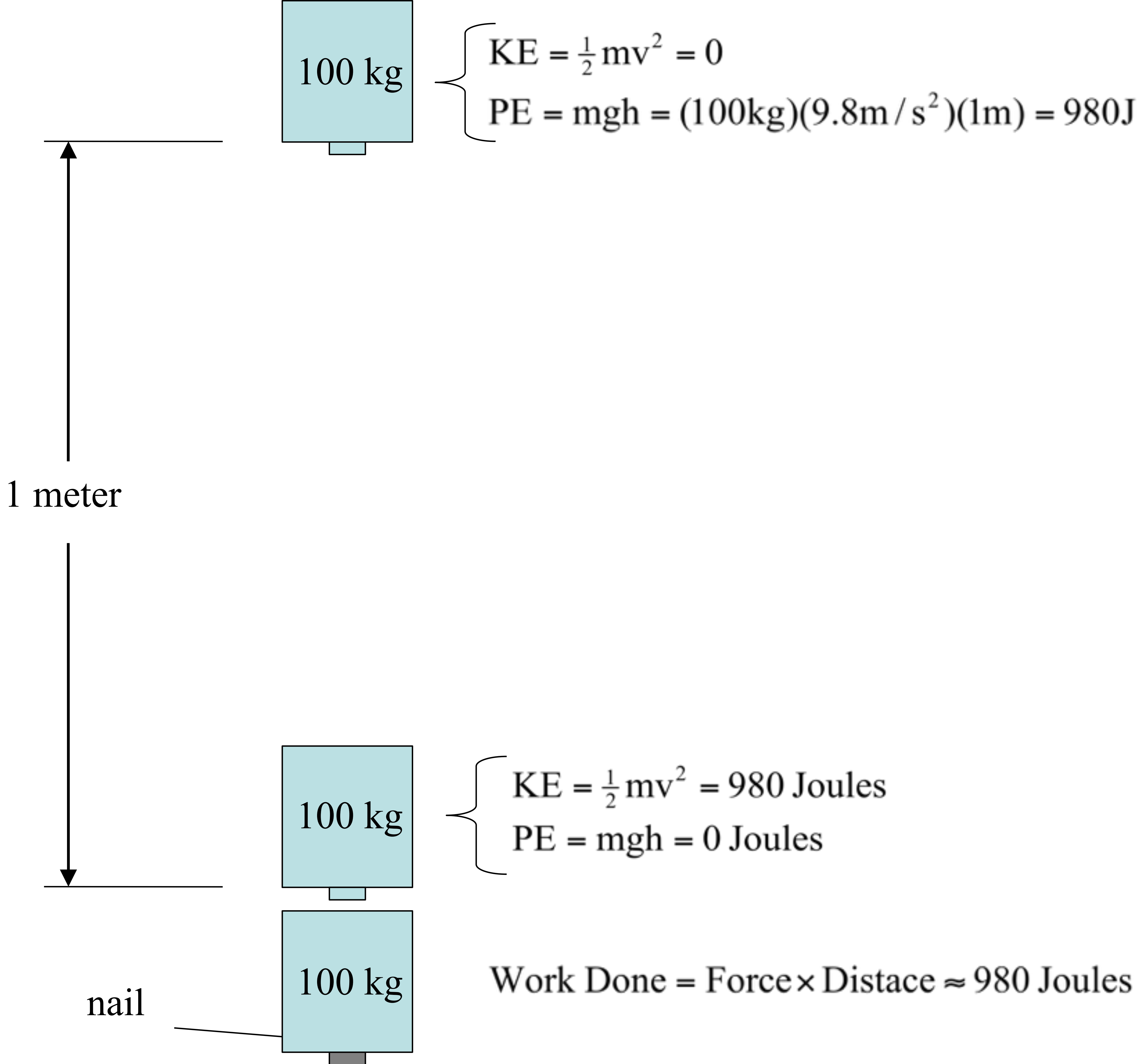
$$PE = mgh = 0 \text{ Joules}$$


100 kg
$KE = \frac{1}{2}mv^2 = 0$
$PE = mgh = (100kg)(9.8m/s^2)(1m) = 980J$
1 meter
100 kg
$KE = \frac{1}{2}mv^2 = 980$ Joules
$PE = mgh = 0$ Joules
100 kg
Work Done = Force $\times$ Distace $\approx$ 980 Joules
nail

Example Problem

- A 100 kg mass is dropped from rest from a height of 1 meter.
- How much potential energy does it have when it is released?

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- A 100 kg mass is dropped from rest from a height of 1 meter.
- How much potential energy does it have when it is released?
- How much kinetic energy does it have just before it hits the ground?
- What is its speed just before impact?

Example Problem

- A 100 kg mass is dropped from rest from a height of 1 meter.
- How much potential energy does it have when it is released?
- How much kinetic energy does it have just before it hits the ground?
- What is its speed just before impact?
- How much work could it do if it were to strike a nail before hitting the ground?

Goliath Question

- Goliath the ride at Six Flags Magic Mountain takes 5.2 seconds to go down the first incline.

- What is the height of the first incline?

Goliath Question

- Goliath the ride at Six Flags Magic Mountain takes 5.2 seconds to go down the first incline (135.2 m)

- If each cart that holds four people and weighs a total of 2000-kg. What is the potential energy for that cart at the top of the first hill?

Goliath Question

- Goliath the ride at Six Flags Magic Mountain takes 5.2 seconds to go down the first incline (135.2 m) and each cart has a PE = 2.7×10^6 at the top of the hill.

- What is the PE half way down the first hill?

Goliath Question

- Goliath the ride at Six Flags Magic Mountain takes 5.2 seconds to go down the first incline (132.5 m) and each cart has a PE = 2.7 x 10^6 at the top of the hill.

- What is the KE half way down the first hill?

Goliath Question

- Goliath the ride at Six Flags Magic Mountain takes 5.2 seconds to go down the first incline (132.5 m) and each cart has a PE = 2.7×10^6 at the top of the hill.

- What is the speed of the cart (2000-kg) half way down the first hill?

Goliath Question

- Goliath the ride at Six Flags Magic Mountain takes 5.2 seconds to go down the first incline (132.5 m) and each cart has a PE = 2.7×10^6 at the top of the hill.

- What is the PE at the bottom of the first hill?

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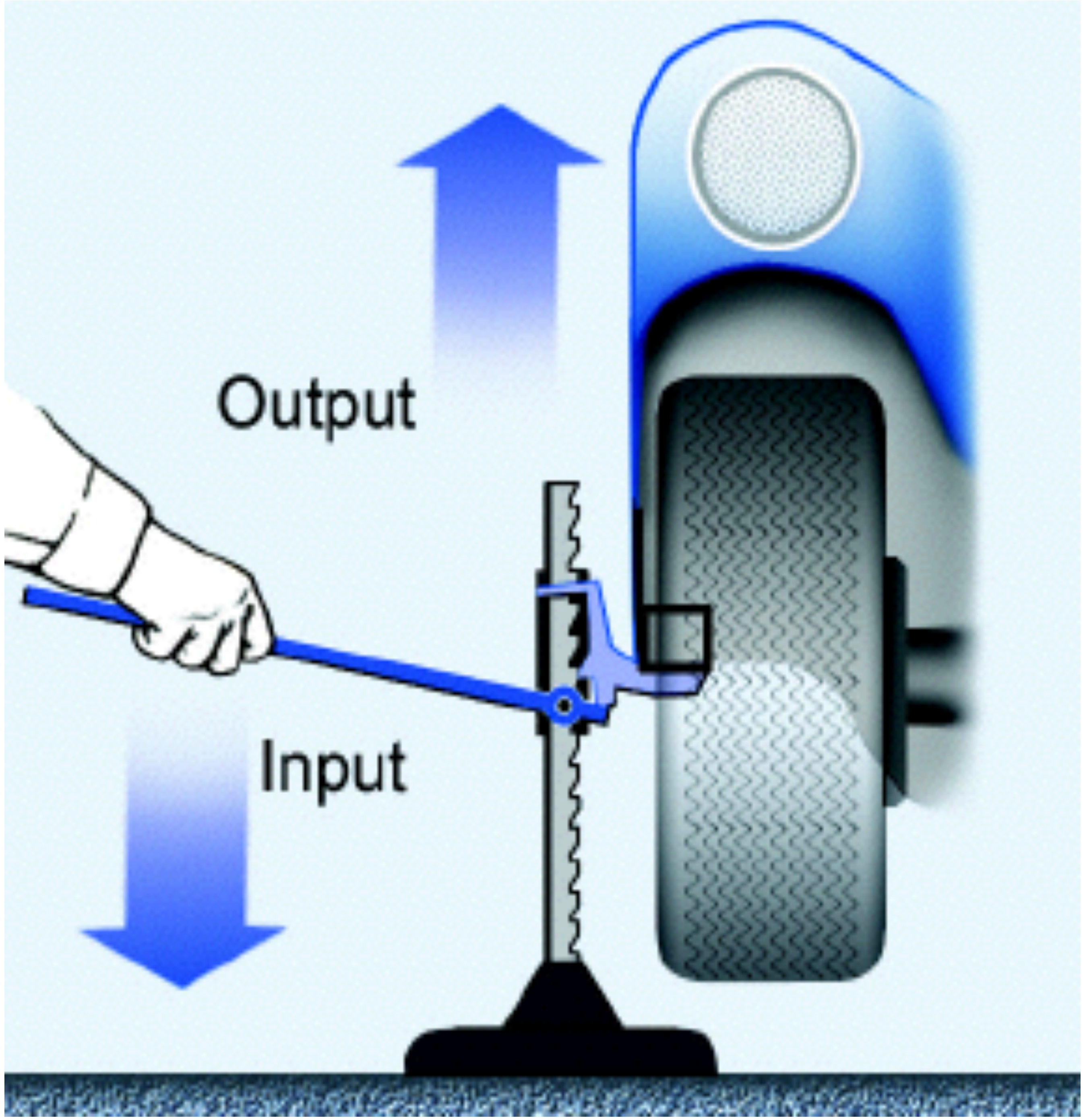
- What is the speed of the cart (2000-kg) at the bottom of the first hill?

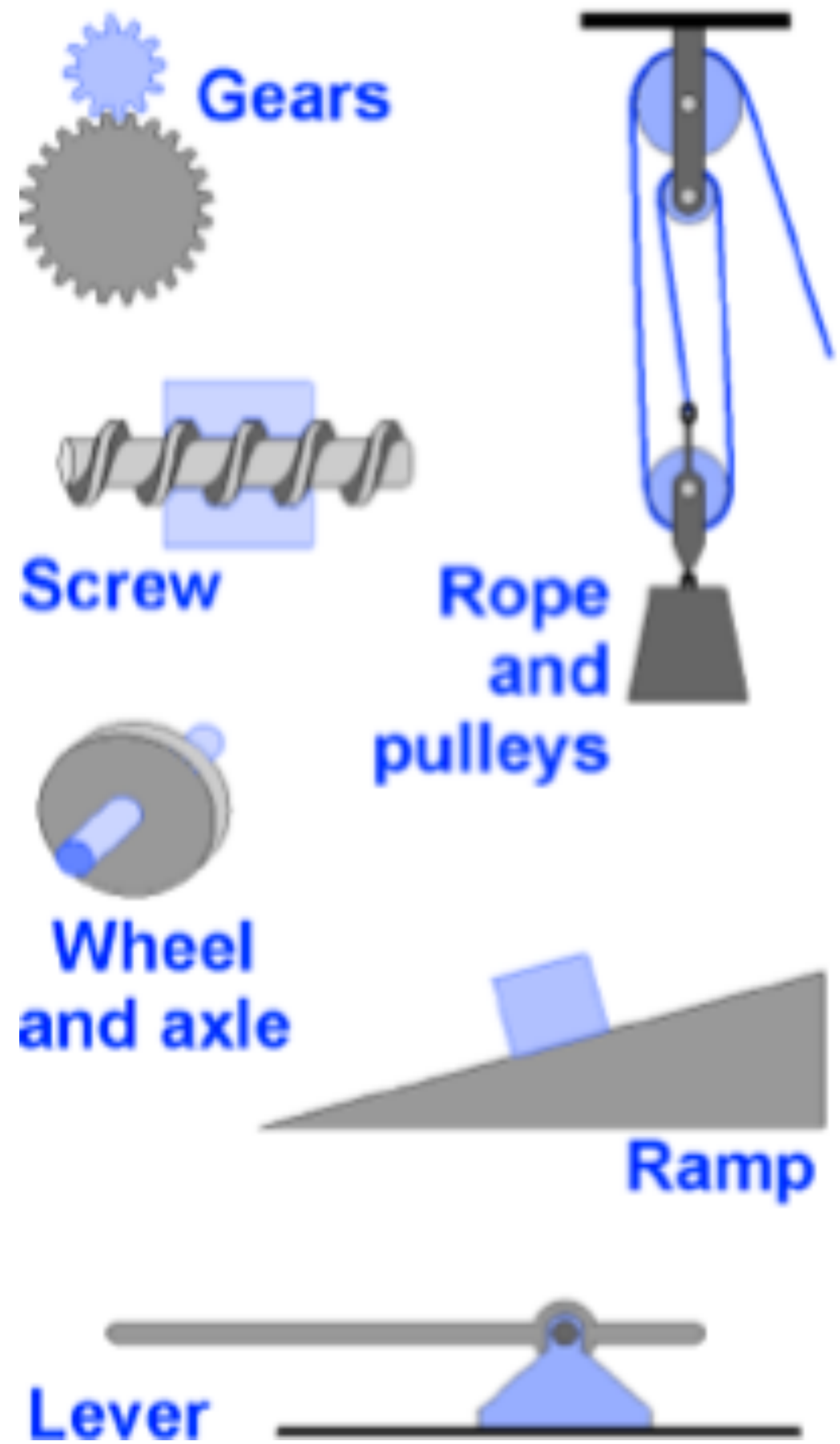
Do Conservation of Energy Problems

•How do simple machines work?



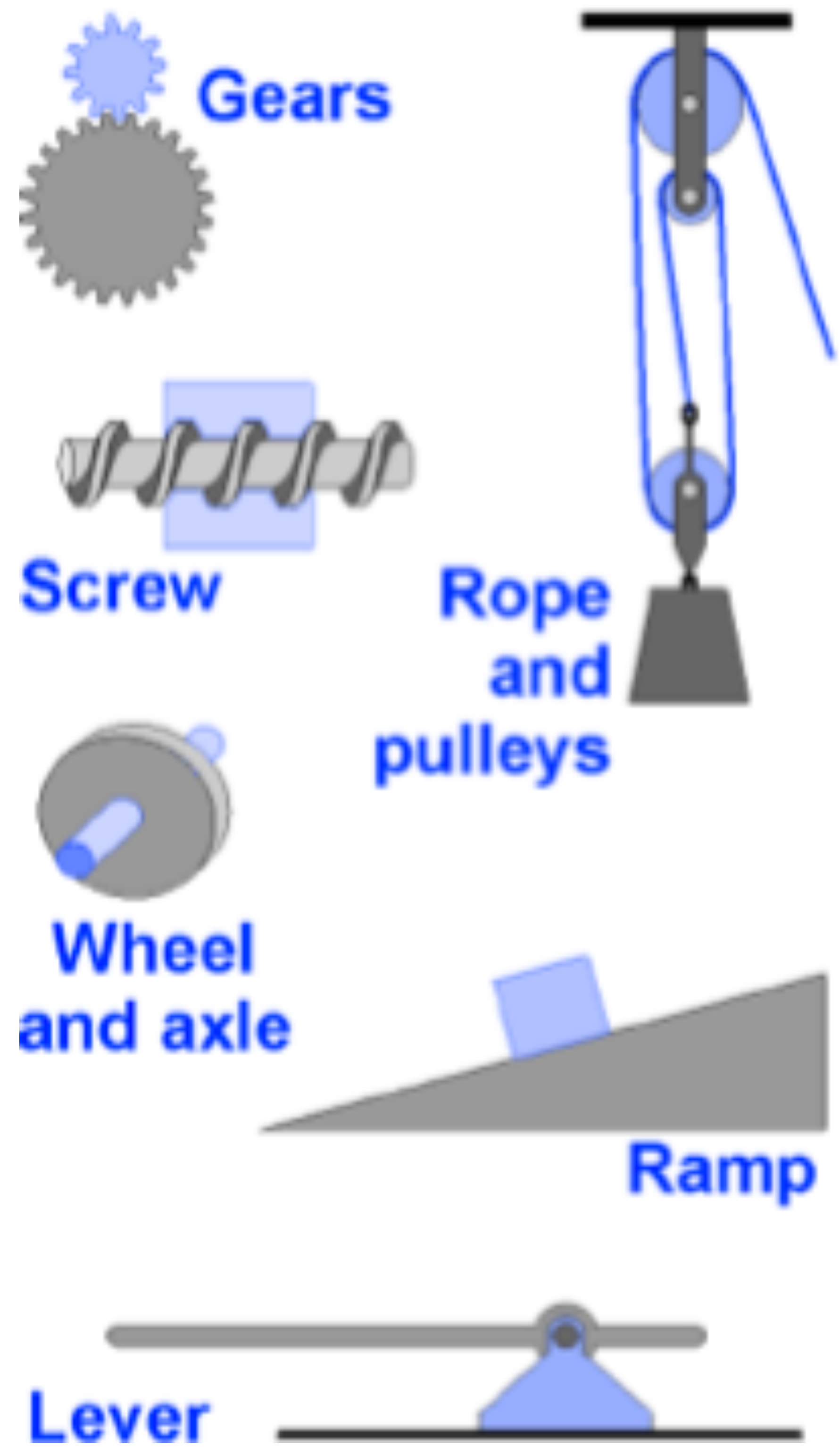
Machines

- The ability of humans to build buildings and move mountains began with our invention of machines.
- .



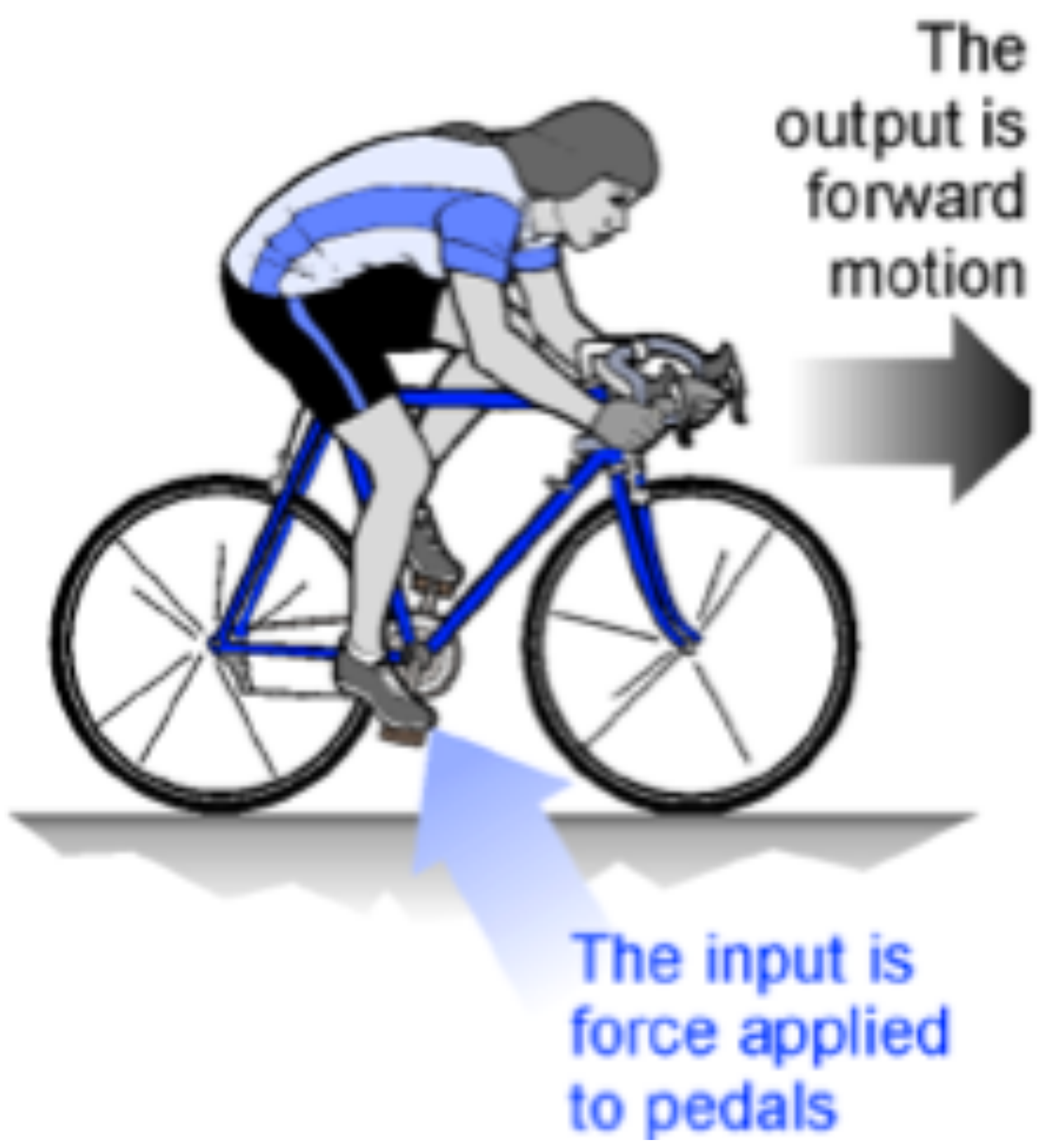
Machines

- The ability of humans to build buildings and move mountains began with our invention of machines.
- In physics the term "simple machine" means a machine that uses only the forces directly applied and accomplishes its task with a single motion.



Machines

- **The best way to analyze what a machine does is to think about the machine in terms of input and output**



Machines - An Application of Energy Conservation

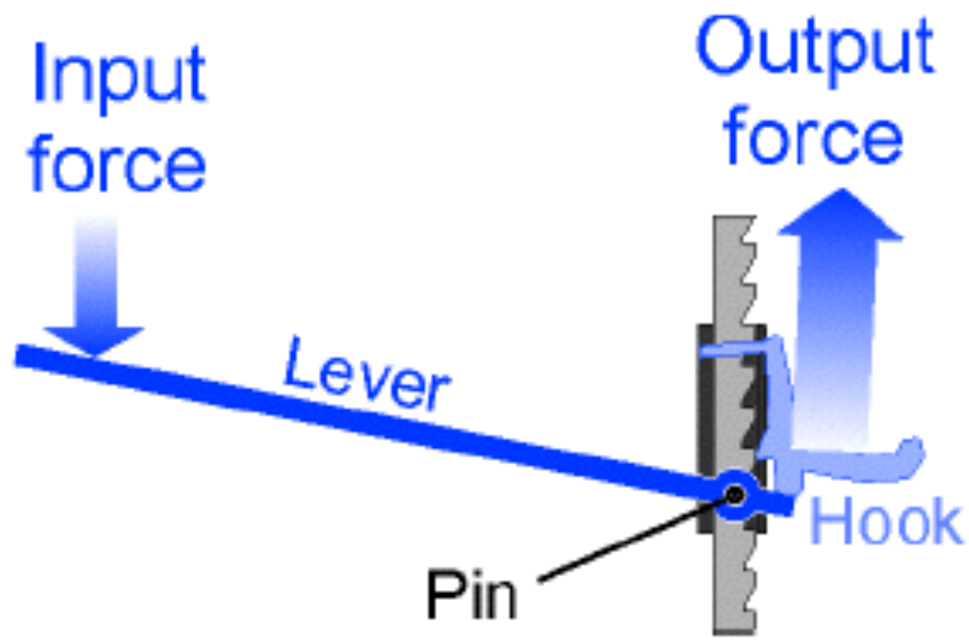
- If there is no mechanical energy losses then for a simple machine...

- work input = work output
- $(F\ \mathrm{d})_{input} = (\mathrm{F}\ d)_{output}$

- Examples - levers and tire jacks

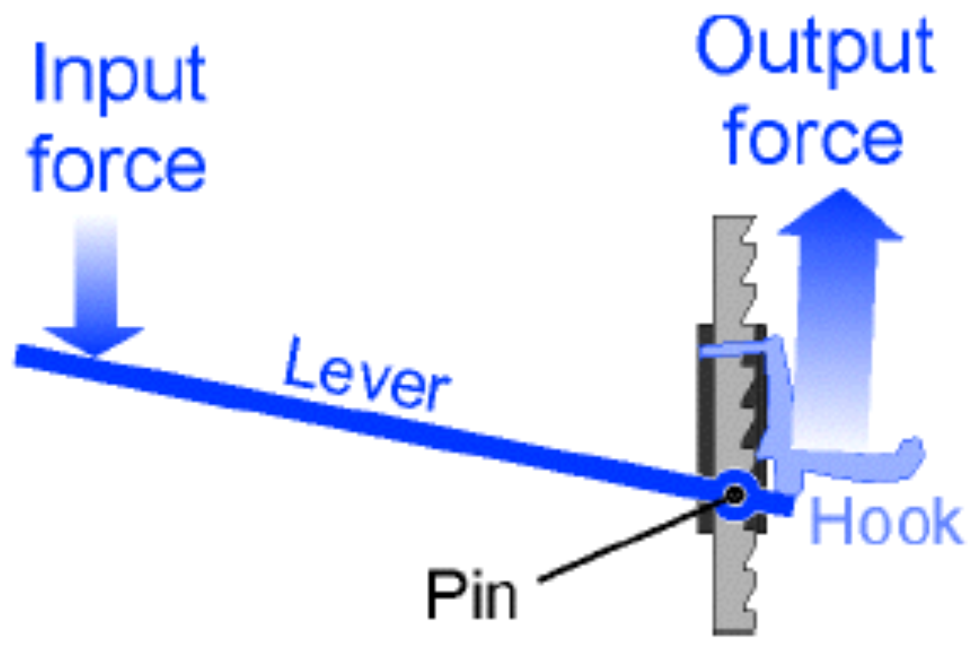
Mechanical Advantage

- Mechanical advantage is the ratio of output force to input force.



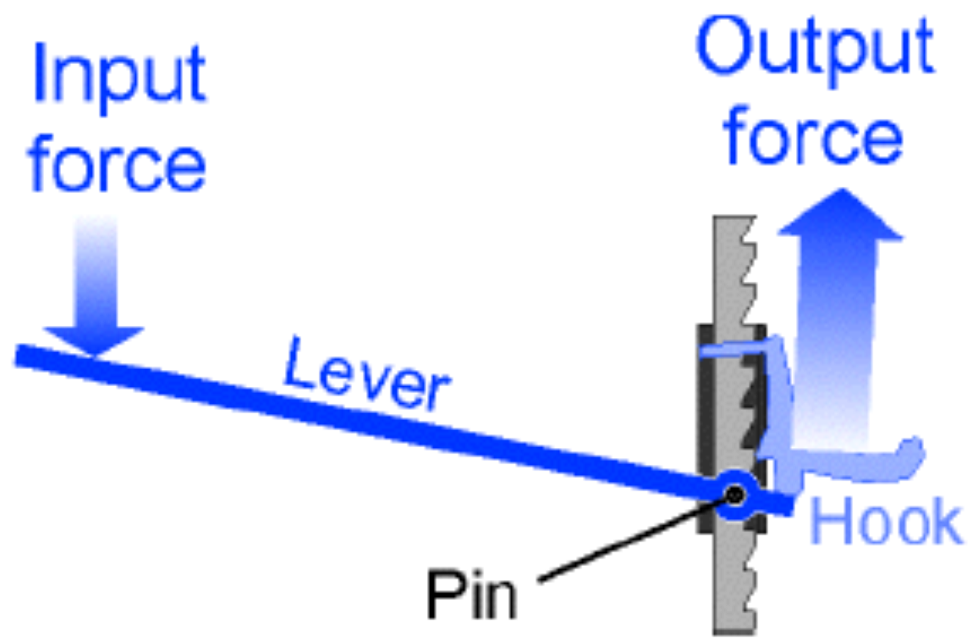
Mechanical Advantage

- Mechanical advantage is the ratio of output force to input force.
- For a typical automotive jack the mechanical advantage is 30 or more.



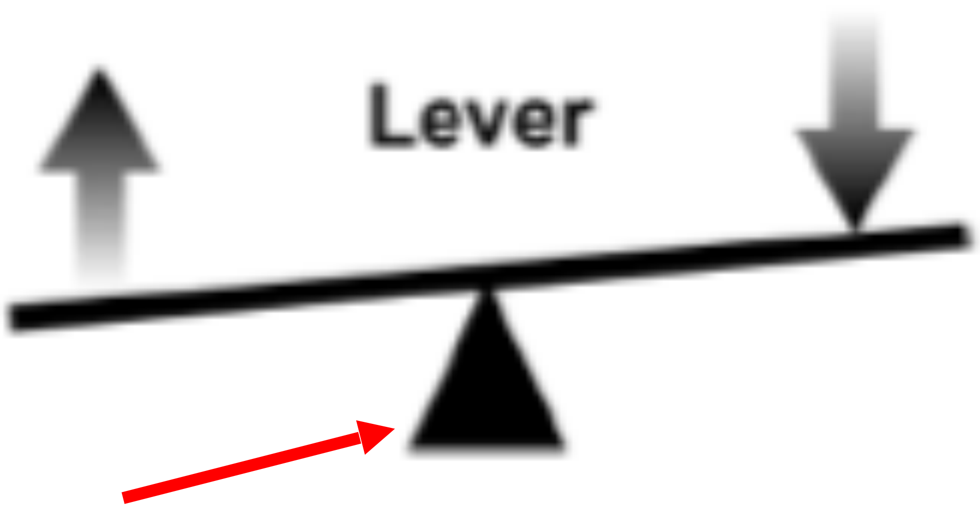
Mechanical Advantage

- Mechanical advantage is the ratio of output force to input force.
- For a typical automotive jack the mechanical advantage is 30 or more.
- A force of 100 Newtons (22.5 pounds) applied to the input arm of the jack produces an output force of 3,000 Newtons (675 pounds)—enough to lift one corner of an automobile.



Introducing… The Lever

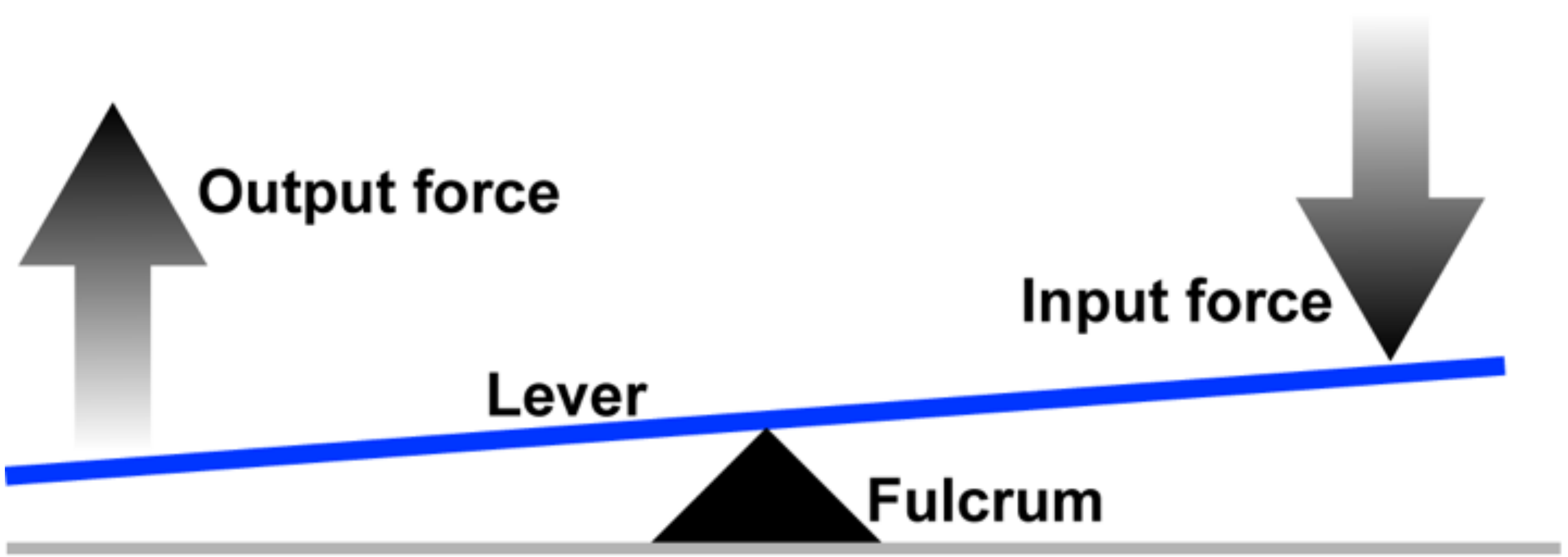
- A **lever** includes a stiff structure (the lever) that rotates around a fixed point called the **fulcrum**.



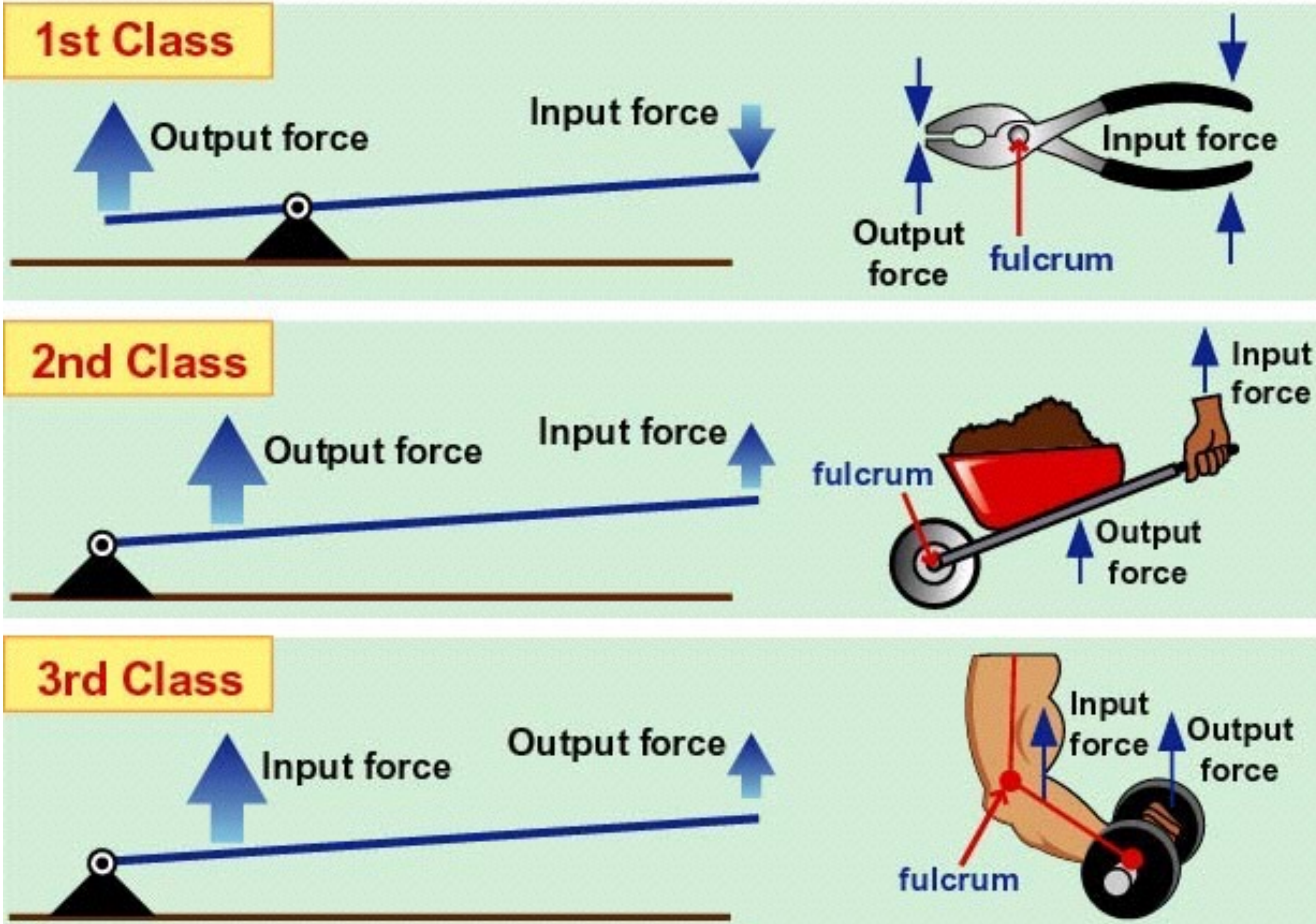
fulcrum

Anatomy of the Lever

- **Fulcrum** – point around which the lever rotates
- **Input Force** – Force exerted ON the lever
- **Output Force** – Force exerted BY the lever



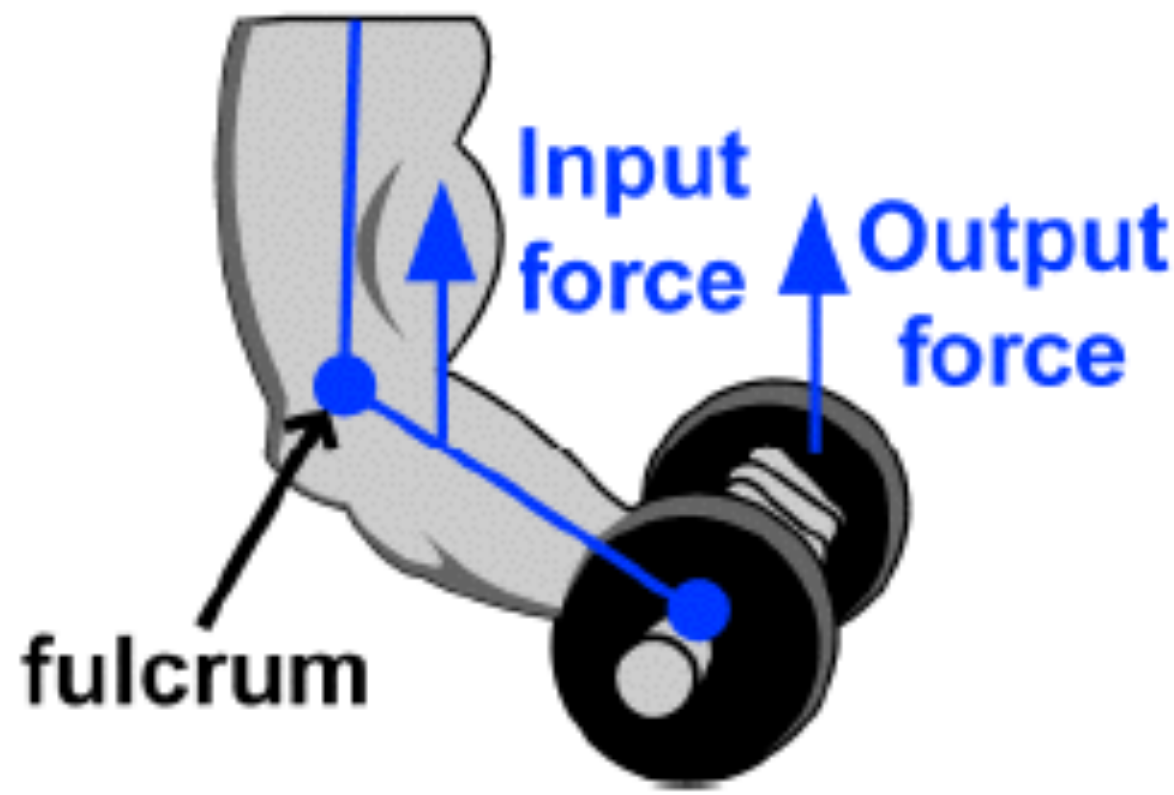
The 3 Classes of Levers



Levers and the Human Body

- **Your body contains muscles attached to bones in ways that act as levers.**

- **Here the biceps muscle attached in front of the elbow opposes the muscles in the forearm.**



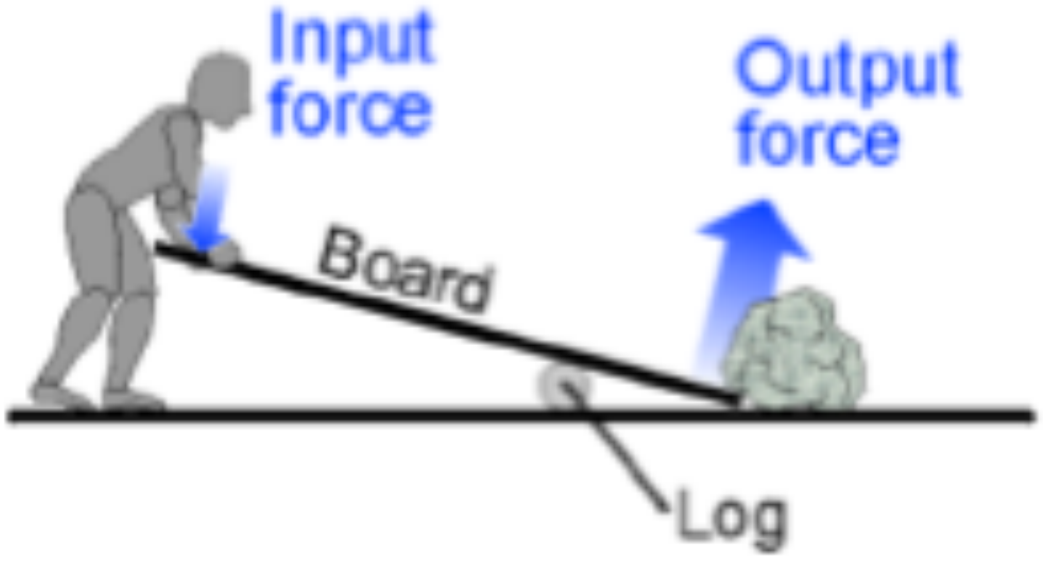
Can you think of other muscle levers in your body?

Mechanical Advantage

Output force (N)

Mechanical advantage → $$MA = \frac{F_o}{F_i}$$

Input force (N)

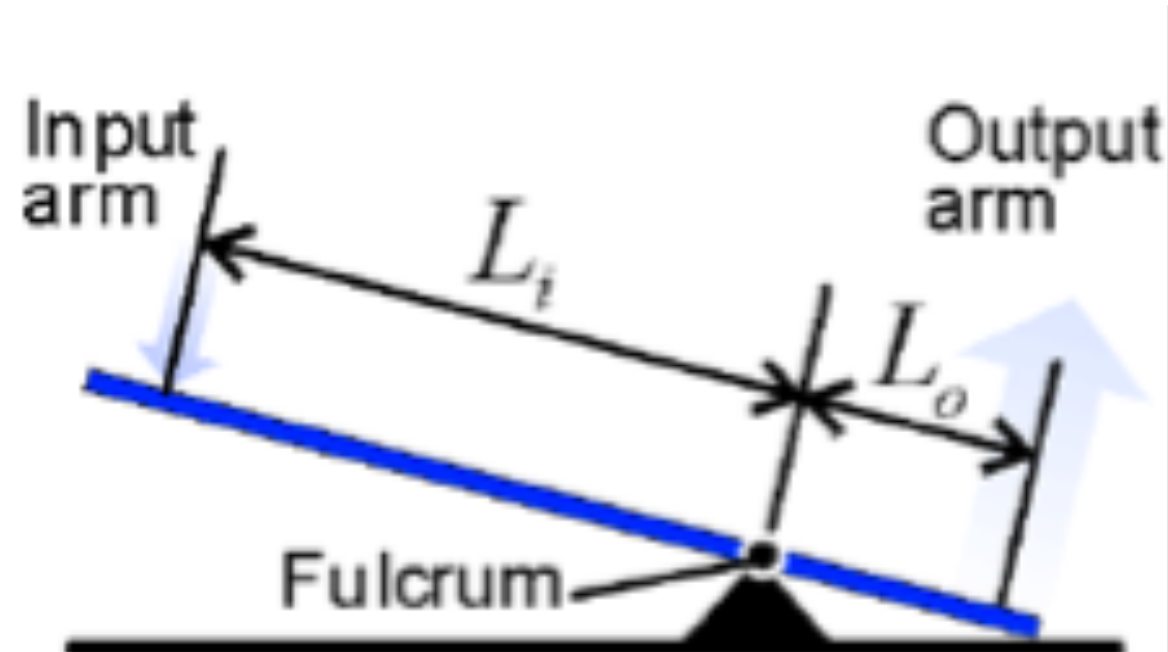


Mechanical Advantage of a Lever

Mechanical advantage → $$MA_{lever} = \frac{L_i}{L_o}$$

Length of input arm (m)

Length of output arm (m)

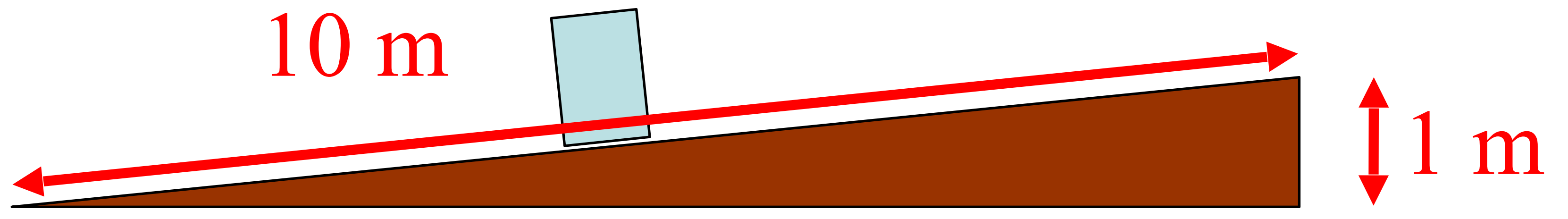


What force must be applied to the end of a 2.0 meter long crowbar in order to lift a 500 Newton rock if the fulcrum of the bar is 0.5 meters from the rock?

Do Lever Problems

Ramp Example

- Ramp 10 m long and 1 m high
- Push 100 kg all the way up ramp
- Would require *mg* = 980 N of force to lift directly (brute strength)
- Work done is (980 N)·(1 m) = 980 N·m in direct lift



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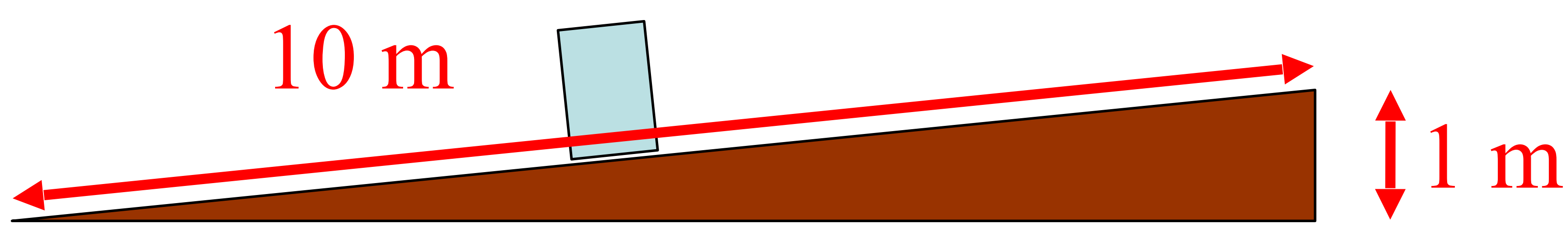
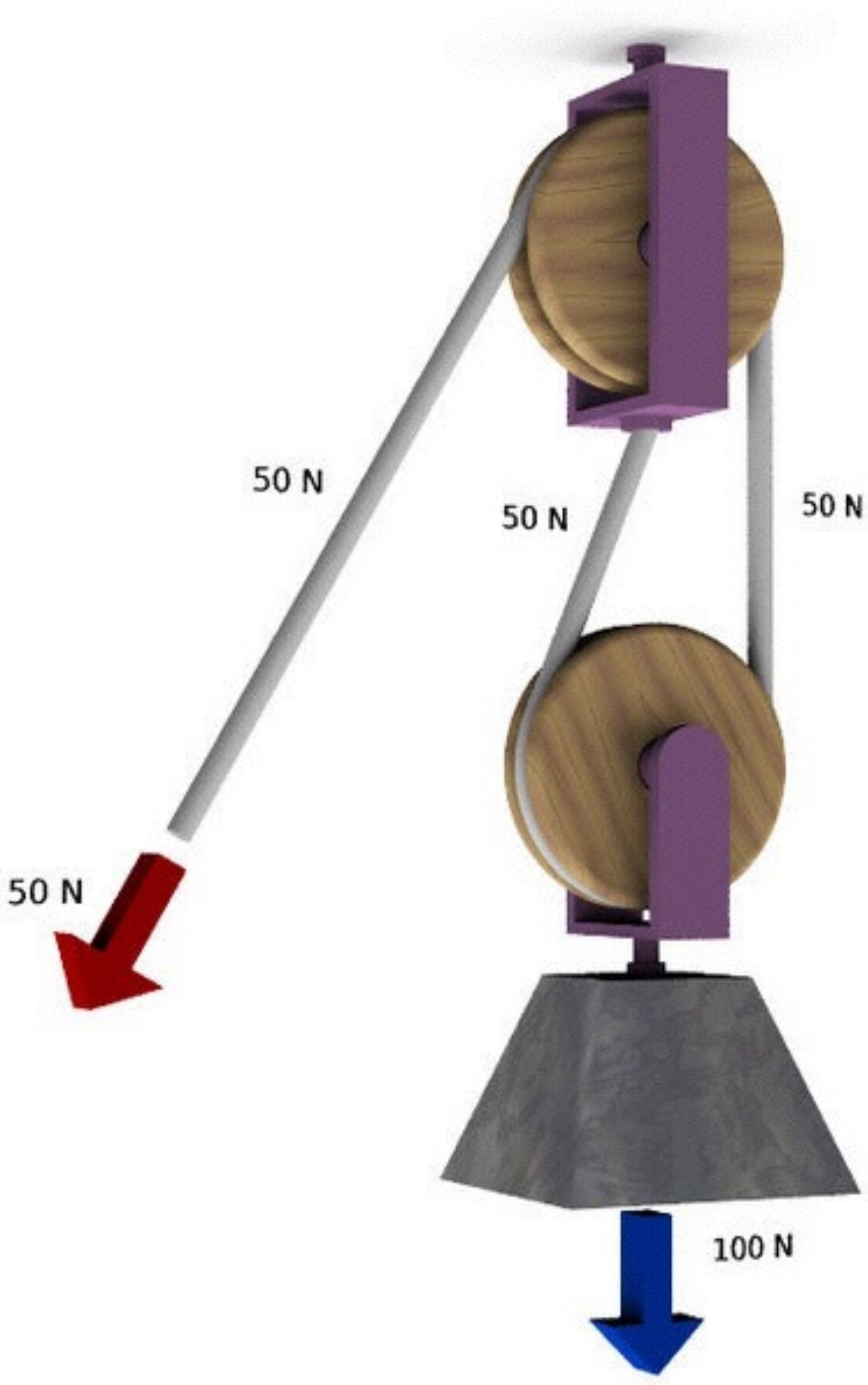


- Extend over 10 m, and only 98 N is needed
  - Something we can actually provide
  - Excludes frictional forces/losses

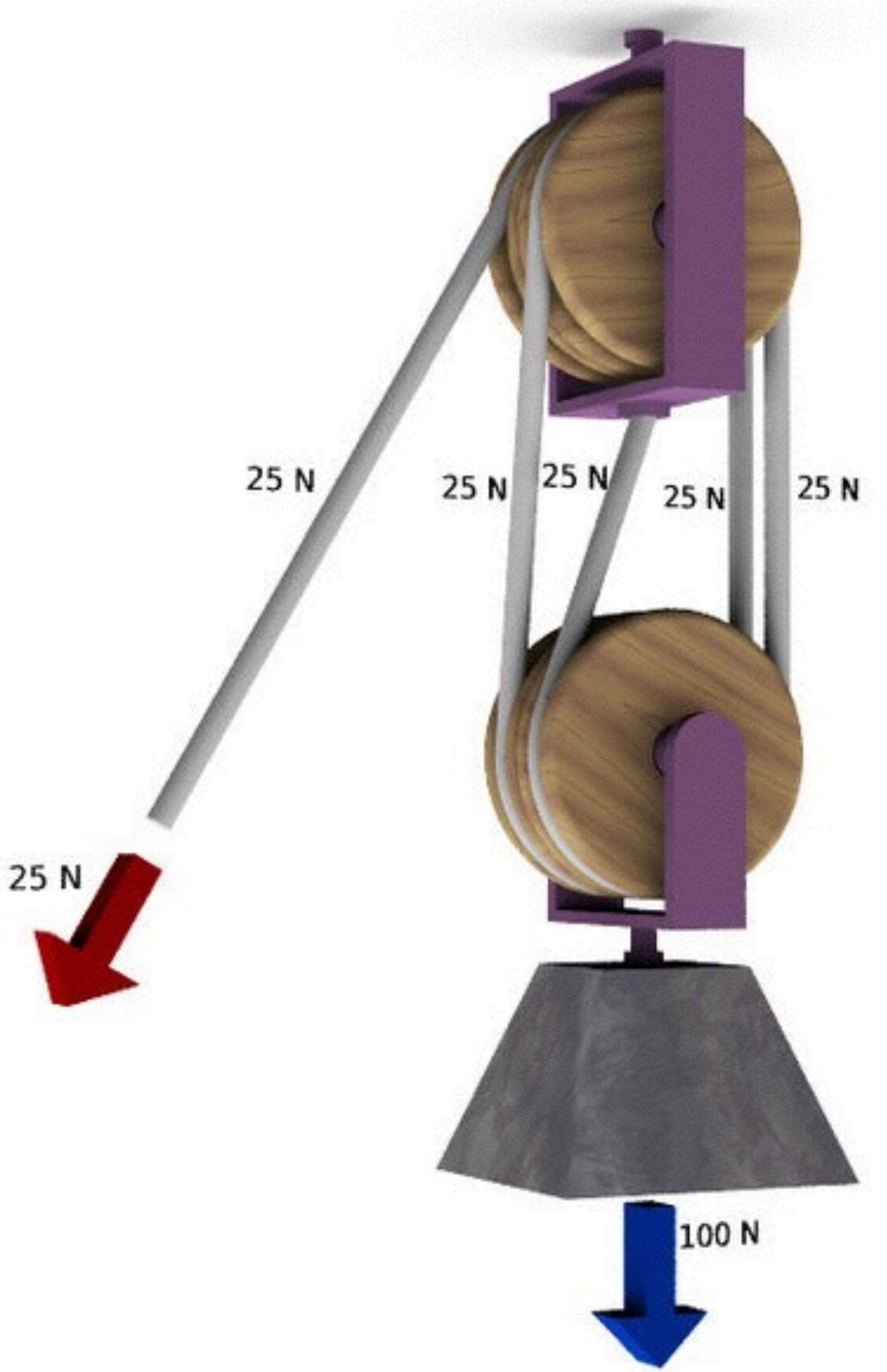
Do Ramp Problems

Pulleys



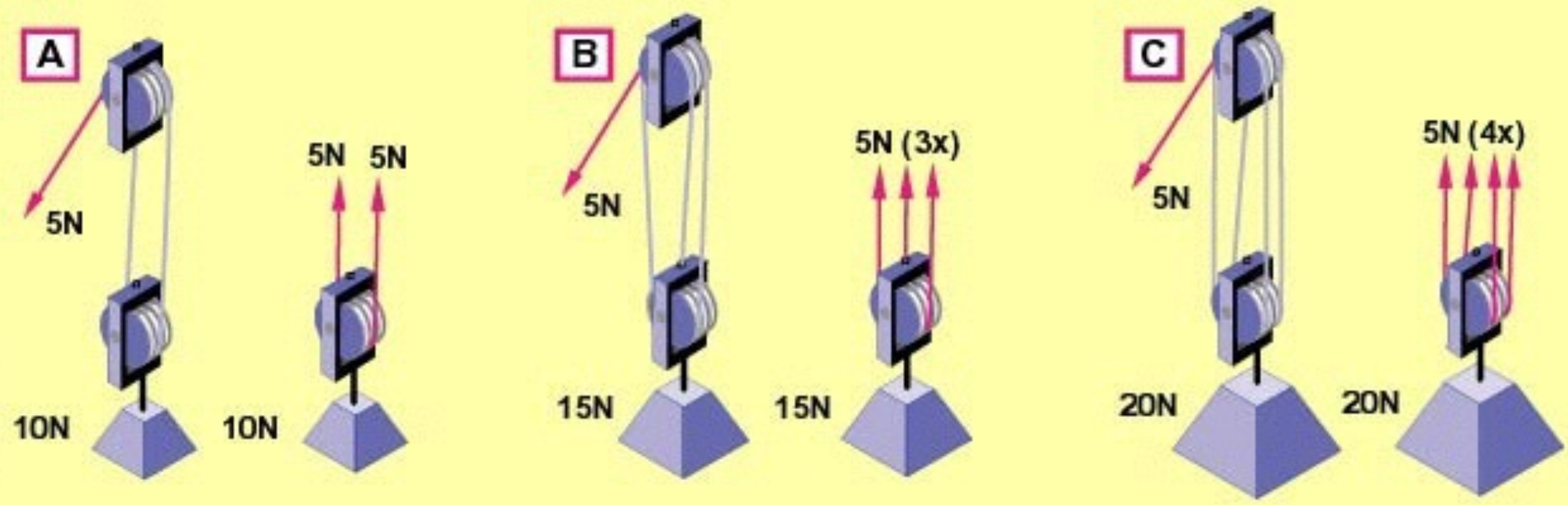
- Like levers, ramps, and screws…. Sacrifices displacement to achieve a greater force
- By pulling a greater displacement you have to apply less force
- MA is shown by how many ropes are supporting the load in this case there are two

Another Pulley



- MA = 4
- 4 ropes supporting load
- Force applied is 4 times less than 100 N
- So rope must be pulled with 25 N of force with a distance 4 times greater than the upward distance the load moves

Mechanical Advantage

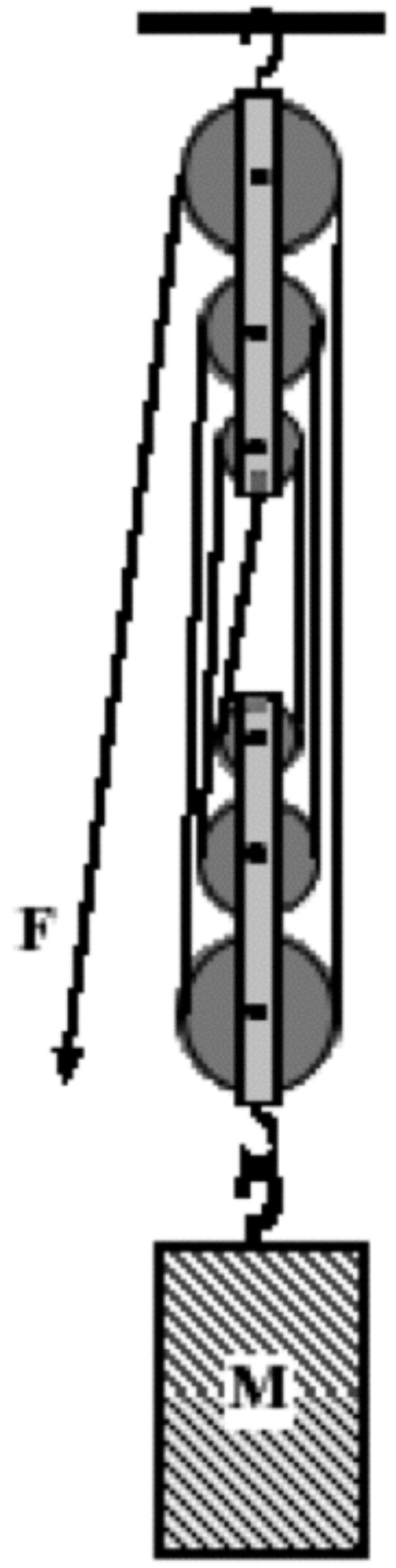


$$\text{Mechanical advantage} = \frac{\text{Output force}}{\text{Input force}}$$

	A	B	C
Input force	5N	5N	5N
Output force	10N	15N	20N
Mechanical advantage	2	3	4

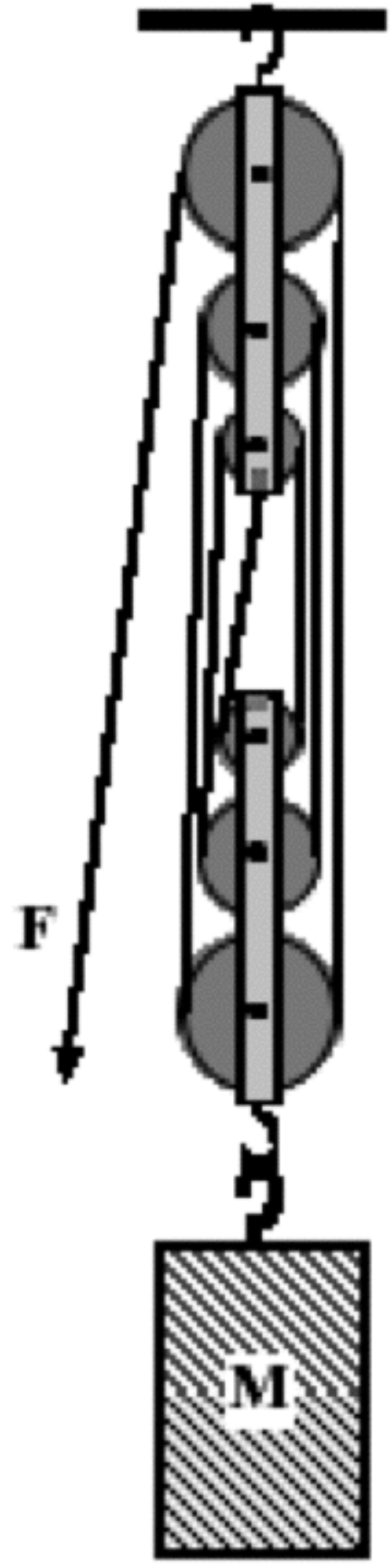
A pulley system consisting of six pulleys as shown to the right has an input force of 220 N applied to it. As a result of this input force the mass M is lifted a distance of 25.0 cm.

What is the ideal mechanical advantage of the system



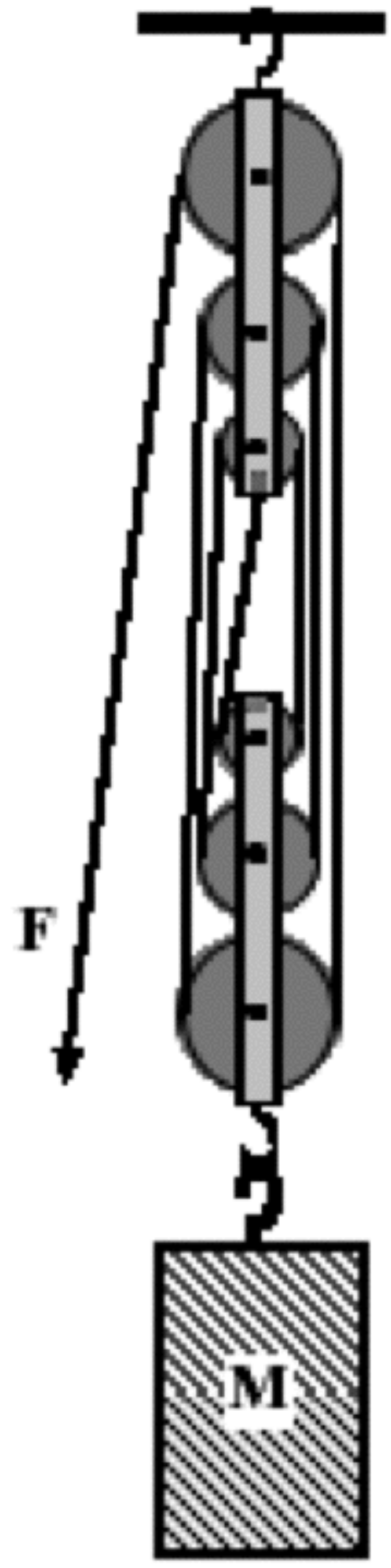
A pulley system consisting of six pulleys as shown to the right has an input force of 220 N applied to it. As a result of this input force the mass M is lifted a distance of 25.0 cm.

How much work was done on the mass M?



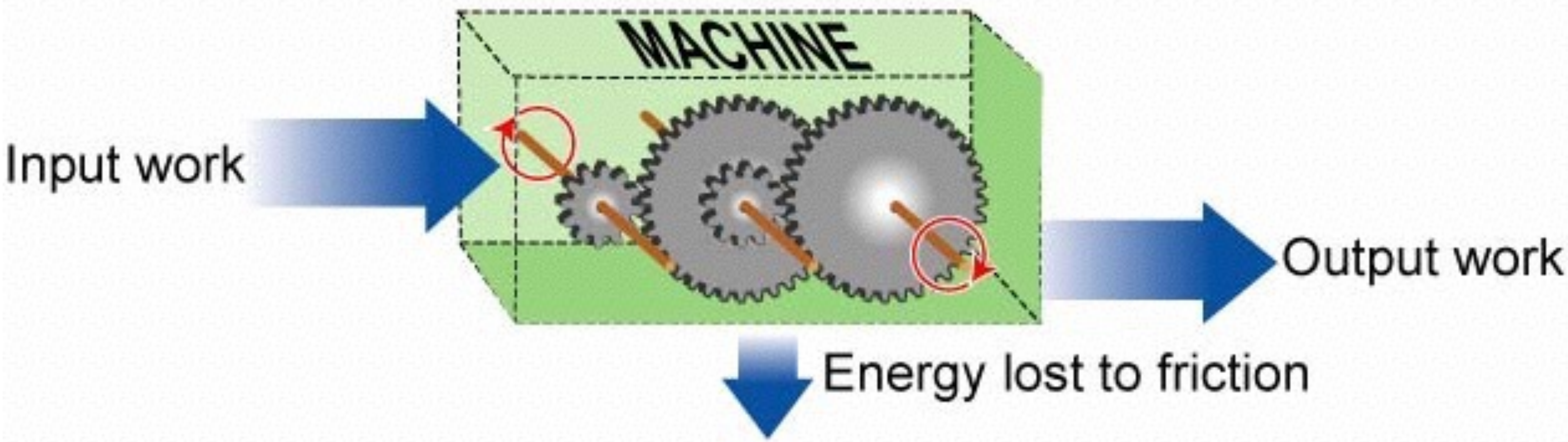
A pulley system consisting of six pulleys as shown to the right has an input force of 220 N applied to it. As a result of this input force the mass M is lifted a distance of 25.0 cm.

Through what distance was the input force applied?



Do Pulley Problems

Efficiency



$$\text{Efficiency} = \frac{\text{Output work}}{\text{Input work}}$$

A power plant burns 75kg of coal every second. Each kg of coal contains 27 MJ (27 million joules) of chemical energy.

What is the power of the power station, in watts?

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What is the power of the power station, in watts?

The Solution

Power in watts = energy transferred in one sec

= (75 kg x 27 million J/kg) per sec

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What is the power of the power station, in watts?

<u>The Solution</u>

Power in watts = energy transferred in one sec

= (75 kg x 27 million J/kg) per sec

= 2025 million J per sec

<u>= 2025 million watts</u>

<u>(2025 megawatts)</u>

The electrical power output of the power plant is 800MW (800 million watts). But the chemical energy output of the station was 2025 MW…..So, **What has happened to the rest of the energy?**

The electrical power output of the power plant is 800MW (800 million watts). But the chemical energy output of the station was 2025 MW…..So, **What has happened to the rest of the energy?**

The Answer

Most of the rest of the energy is wasted as heat - up the chimney of the power station, in the cooling towers, and because of friction in the machinery.

Efficiency of Machines

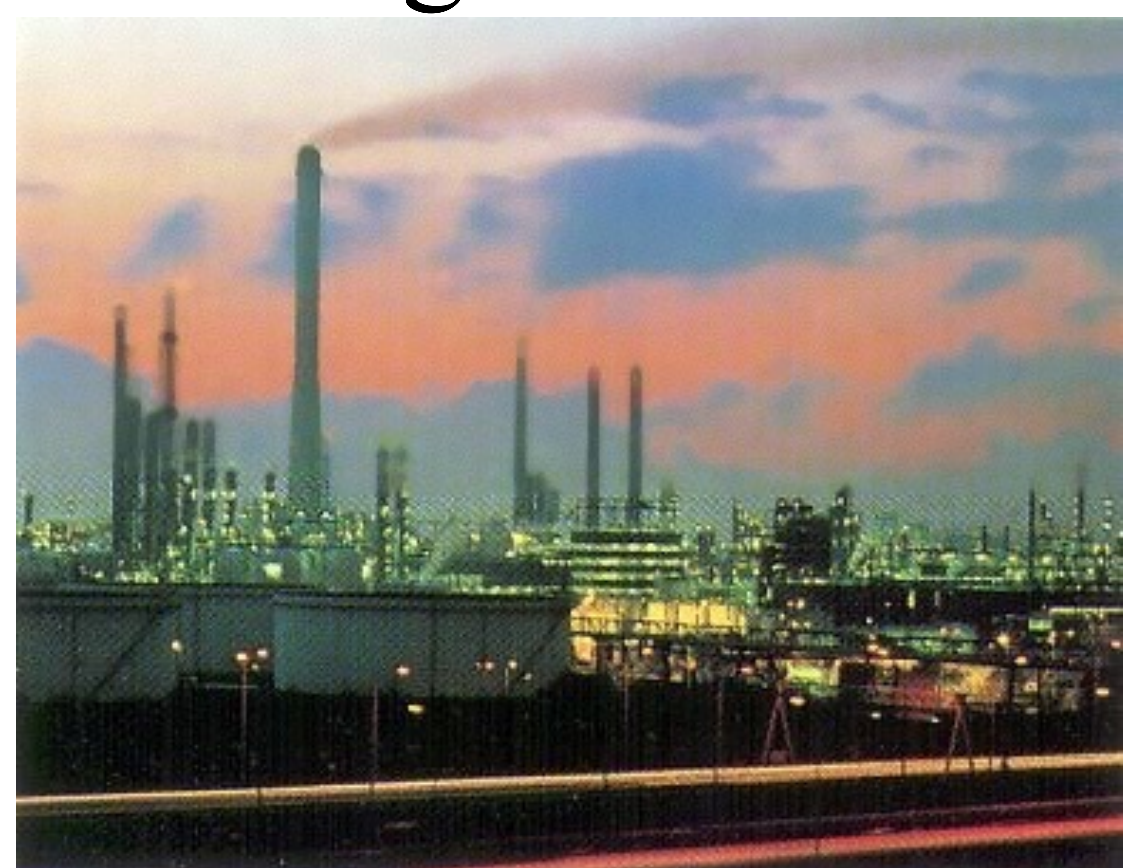
- C of E says that *energy in* must equal *energy out*
  - However, often a lot of energy is lost
    - Heat, friction, sound, etc.
- Efficiency equals

$$\frac{\text{(Useful energy out)}}{\text{(Energy in)}} \quad *100\%$$

- Higher the percentage….the more efficient

- Calculate the efficiency of the power plant as a percentage.

- Calculate the efficiency of the power plant as a percentage.
- **The Solution**
- Efficiency = useful power output/total power input
- = 800,000,000 W/2,025,000,000 W
- = 0.395 x 100% to create a percentage
- = 39.5%



- **A box weighing 100 newtons is pushed up an inclined plane that is 5 meters long. It takes a force of 75 newtons to push it to the top, which has a height of 3 meters. What is the efficiency?**

- **A machine with 75% efficiency uses 3,300 J of energy. Using the machine, how much work did you do?**

- **Suppose the efficiency of a 1.65 m long crowbar is 60%. What force will be needed to remove a tree stump that resists with a force of 15,500 Newtons if the fulcrum of the crowbar is 8.0 cm from the tree stump?**

Do Efficiency Problems