# Chapter 7

# ENERGY

# In this lecture you will learn about:

- Work
- Power
- Mechanical Energy : Potential and Kinetic
- Work-Energy Theorem
- Conservation of Energy
- Machines
- Efficiency

# Work

- An object's motion depends both on force and on how long the force acts.

- When 'how long' = time;

  Impulse = force x time

- When 'how long' = distance

  **Work = force x distance**

# Work

Work

- involves force and distance.
- is force $\times$ distance.
- in equation form: $W = Fd$.

Two things occur whenever work is done:

- application of <u>force</u>
- <u>movement</u> of something by that force

If you push against a stationary brick wall for several minutes, you do no work

A. on the wall.
B. at all.
C. Both of the above.
D. None of the above.

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*Explanation*:

You may do work on your muscles, but not on the wall.

# Work

Examples:

- Twice as much work is done in lifting 2 loads 1 story high versus lifting 1 load the same vertical distance.

  Reason: force needed to lift twice the load is twice as much.

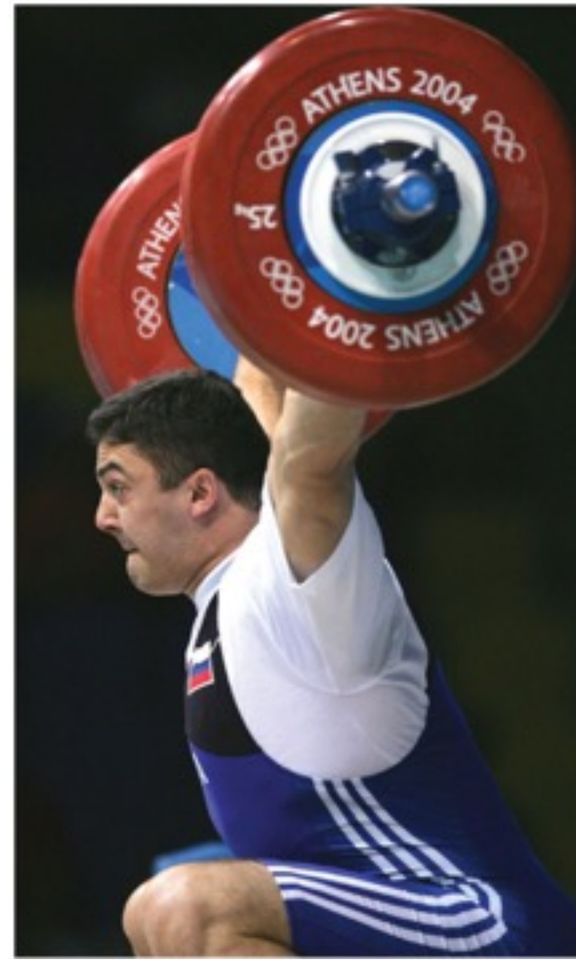
- Twice as much work is done in lifting a load 2 stories instead of 1 story.

  Reason: distance is twice as great.

# Work

Example:

- a weightlifter raising a barbell from the floor does work on the barbell.




Unit of work:

newton-meter (Nm)
or joule (J)

You do work on something when you force it to move against the influence of an opposing force.

Work is done in lifting a barbell. How much work is done in lifting a barbell that is twice as heavy the same distance?

A. Twice as much
B. Half as much
C. The same
D. Depends on the speed of the lift

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*Explanation*:

This is in accord with work = force × distance. Twice the force for the same distance means twice the work done on the barbell.

You do work when pushing a cart with a constant force. If you push the cart twice as far, then the work you do is

A. less than twice as much.
B. twice as much.
C. more than twice as much.
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# Power

Power:

- **Measure of how fast work is done**
- In equation form:

$$Power = \frac{work\ done}{time\ interval}$$

# Power

Example:

- A worker uses more power running up the stairs than climbing the same stairs slowly.
- A high power engine does work rapidly. A more powerful engine can get a car up to a given speed in less time than a less powerful engine can.

# Power

Unit of power

- joule per second, called the watt, after James Watt, developer of the steam engine
  - 1 joule/second = 1 watt
  - 1 kilowatt = 1000 watts

A job can be done slowly or quickly. Both may require the same amount of work, but different amounts of

A. energy.

B. momentum.

C. power.

D. impulse.

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A. energy.
B. momentum.
C. **power.**
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*Comment*:
Power is the rate at which work is done.

# Energy

- Property of a system that enables it to do work.
- Examples: mechanical energy, thermal energy, chemical energy, electrical energy.

# Mechanical Energy

Mechanical energy is due to position or to motion, or both.

There are two forms of mechanical energy:

- Potential energy
- Kinetic energy

# Potential Energy

Stored energy held in readiness with a potential for doing work.

Example:

- A stretched bow has stored energy that can do work on an arrow.
- A stretched rubber band of a slingshot has stored energy and is capable of doing work.

# Potential Energy—Gravitational

Potential energy due to elevated position

Example:

- water in an elevated reservoir
- raised ram of a pile driver

http://li-jack.com/pile_driver

# Potential Energy—Gravitational

- Equal to the work done (force required to move it upward × the vertical distance moved against gravity) in lifting it.

- In equation form:

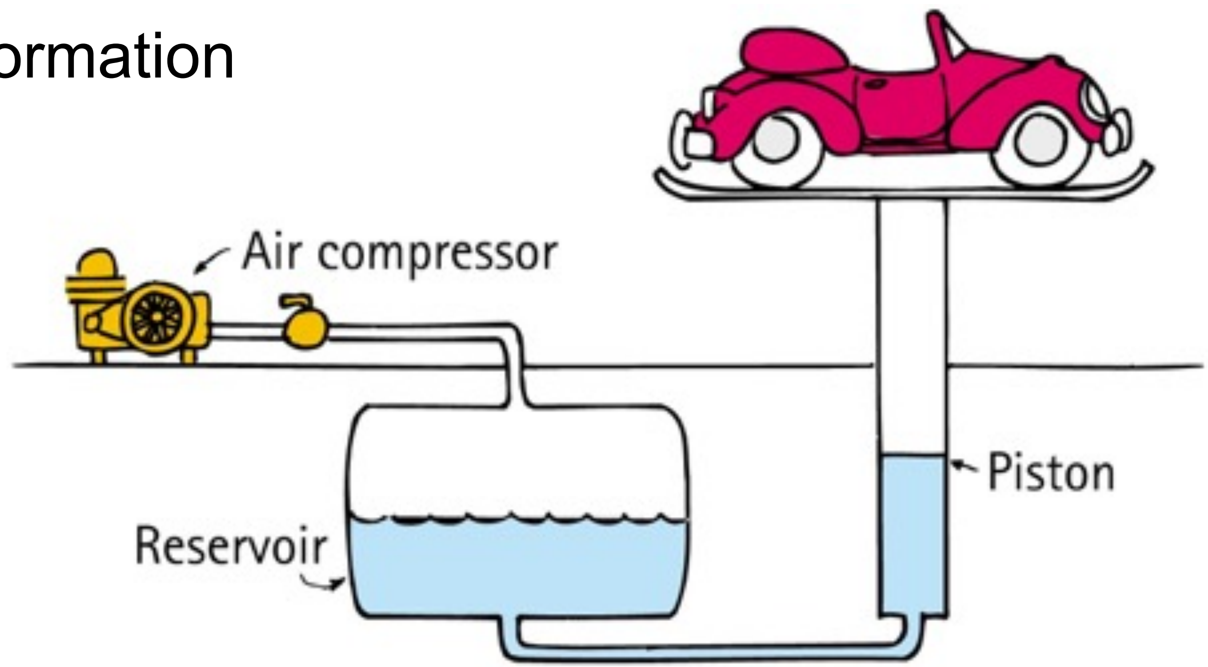
  Potential energy

  = mass × acceleration due to gravity × height

  = *mgh*

Does a car hoisted for repairs in a service station have increased potential energy relative to the floor?

A. Yes
B. No
C. Sometimes
D. Not enough information



Does a car hoisted for repairs in a service station have increased potential energy relative to the floor?

**A. Yes**

B. No

C. Sometimes

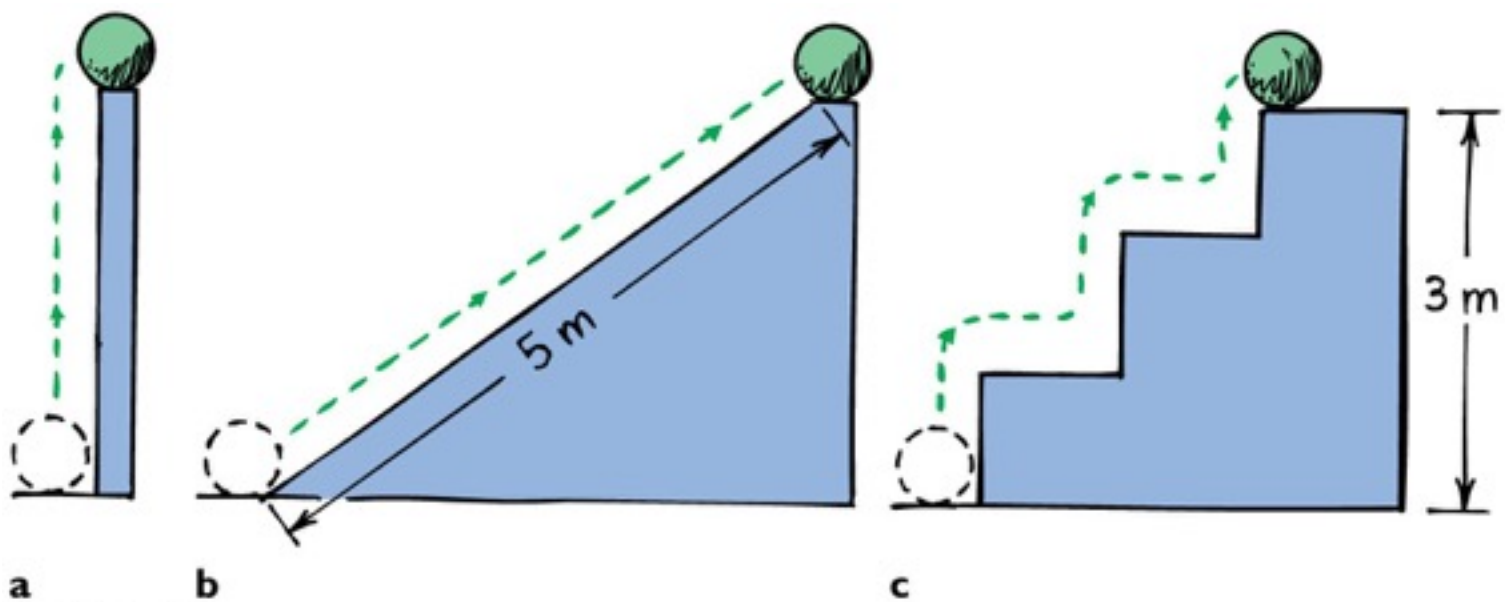
D. Not enough information

*Comment*:

If the car were twice as heavy, its increase in potential energy would be twice as great.

# Potential Energy

Example: Potential energy of 10-N ball is the same in all 3 cases because work done in elevating it is the same.



# Kinetic Energy

- **Energy of motion**
- Depends on the mass of the object and square of its speed
- Include the proportional constant 1/2 and

  kinetic energy = 1/2 × mass × speed × speed
- If object speed is doubled ⇒ kinetic energy is quadrupled.

Must a car with momentum have kinetic energy?

A. Yes, due to motion alone
B. Yes, when motion is nonaccelerated
C. Yes, because speed is a scalar and velocity is a vector quantity
D. No

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*Explanation*:

Acceleration, speed being a scalar, and velocity being a vector quantity are irrelevant. **Any moving object has both momentum and kinetic energy.**

# Kinetic Energy

If an object is moving, then it is capable of doing work. It has energy of motion (K.E.)

When you throw a ball, you do work on it to give it speed as it leaves your hand.

The moving ball can then hit something and push it, doing work on the second object.

- Kinetic Energy → Work

# Kinetic Energy

- Kinetic energy of a moving object is equal to the work required to bring it from rest to that speed, or

  the work the object can do while being brought to rest.

Kinetic Energy = Work = Net Force x Distance

$$F\,d = \tfrac{1}{2} mv^2$$

# Work-Energy Theorem

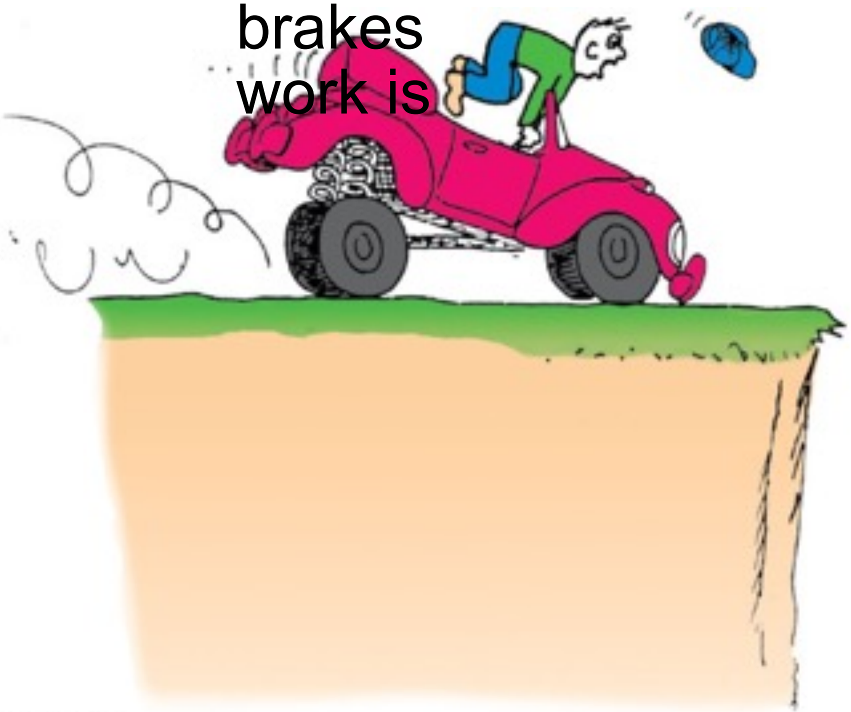
- Gain or reduction of energy is the result of work.
  In other words, **work** = **change in kinetic energy** (here, the work is <u>net</u> work, the work based on the <u>net</u> force.
- In equation form: $W = \Delta KE$
- Doubling speed of an object requires 4 times the work.

# Work-Energy Theorem

- Applies to decreasing speed:
  - reducing the speed of an object or bringing it to a halt.

Example: Applying the brakes to slow a moving car, work is done on it.

(the friction force supplied by the brakes × distance).



Consider a problem that asks for the distance of a fast-moving crate sliding across a factory floor and then coming to a stop. The most useful equation for solving this problem is

A. $F = ma$.

B. $Ft = \Delta mv$.

C. $\mathrm{KE} = {}^1/_2 mv^2$.

D. $Fd = \Delta {}^1/_2 mv^2$.

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The work done in bringing a moving car to a stop is the force of tire friction × stopping distance. If the initial speed of the car is doubled, the stopping distance is

A. actually less.
B. about the same.
C. twice.
D. None of the above.

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*Explanation*:

**Twice the speed means** four times the kinetic energy and **four times the stopping distance**.

$$Fd = \Delta \, {}^{1}/_{2} m v^{2}$$

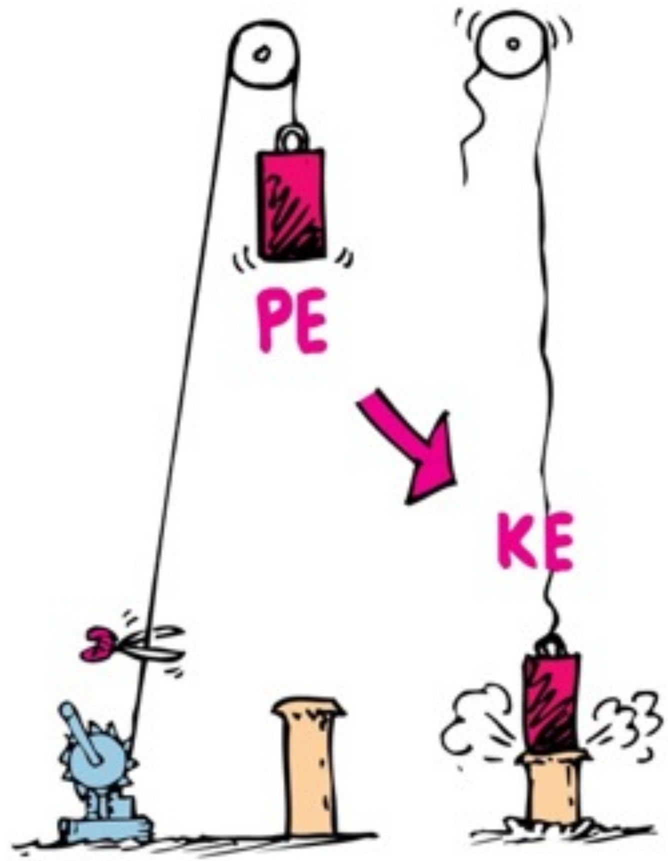
# Conservation of Energy

Law of conservation of energy

- Energy cannot be created or destroyed; it may be transformed from one form into another, but the total amount of energy never changes.

# Conservation of Energy

Example: Energy transforms without net loss or net gain in the operation of a pile driver.



# Conservation of Energy

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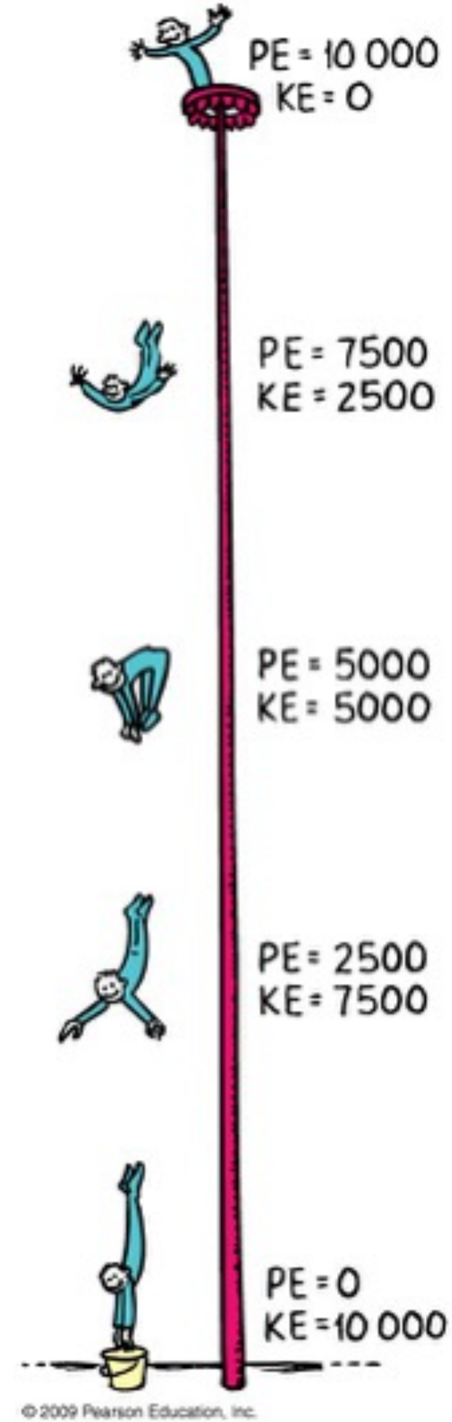

# Conservation of Energy

## A situation to ponder…

Consider the system of a bow and arrow. In drawing the bow, we do work on the system and give it potential energy. When the bowstring is released, most of the potential energy is transferred to the arrow as kinetic energy and some as heat to the bow.

# A situation to ponder…

Suppose the potential energy of a drawn bow is 50 joules and the kinetic energy of the shot arrow is 40 joules. Then

A. energy is not conserved.
B. 10 joules go to warming the bow.
C. 10 joules go to warming the target.
D. 10 joules are mysteriously missing.

# A situation to ponder…

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D. 10 joules are mysteriously missing.

*Explanation*:

The total energy of the drawn bow, which includes the poised arrow, is 50 joules. The arrow gets 40 joules and the remaining 10 joules warms the bow—still in the initial system.

# Kinetic Energy and Momentum Compared

Similarities between momentum and kinetic energy:

- Both are properties of moving things.

Difference between momentum and kinetic energy:

- Momentum is a vector quantity and therefore is directional and can be canceled.
- Kinetic energy is a scalar quantity and can never be canceled.

# Kinetic Energy and Momentum Compared

- Velocity dependence
  - Momentum depends on velocity.
  - Kinetic energy depends on the square of velocity.

    Example: An object moving with twice the velocity of another with the same mass, has twice the momentum but 4 times the kinetic energy.

# Machines

## Principle of a machine

- Conservation of energy concept:

  Work input = work output

- Input force × input distance =

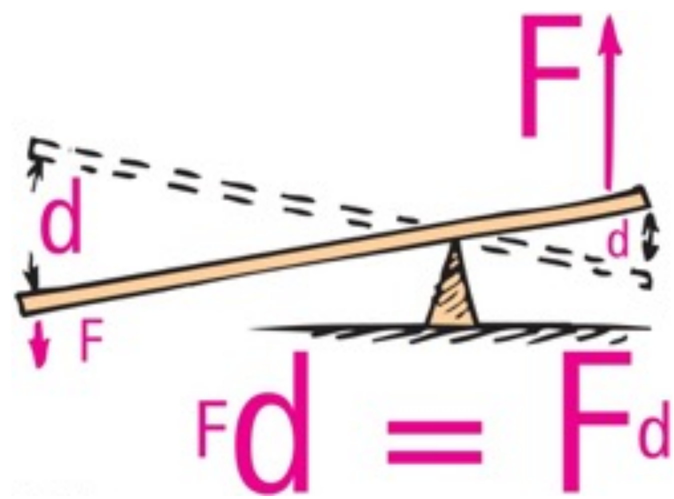
  Output force × output distance

- $(\text{Force} \times \text{distance})_{\text{input}} = (\text{force} \times \text{distance})_{\text{output}}$

# Machines

Simplest machine

- Lever
  - rotates on a point of support called the fulcrum
  - allows small force over a large distance and large force over a short distance



# Efficiency

Efficiency

- Percentage of work put into a machine that is converted into useful work output
- In equation form:

$$\mathit{Efficiency} = \frac{\mathit{useful\ energy\ output}}{\mathit{total\ energy\ input}}$$

A certain machine is 30% efficient. This means the machine will convert

A. 30% of the energy input to useful work—70% of the energy input will be wasted.
B. 70% of the energy input to useful work—30% of the energy input will be wasted.
C. Both of the above.
D. None of the above.

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C. Both of the above.

D. None of the above.

# Chapter 7 Problems

## Problem 1

1. The second floor of a house is 6 m above the street level. How much work is required to lift a 300 kg refrigerator to the second-story level

$W = F \cdot d = m \cdot g \cdot h = 300\text{kg}\ 10\ \text{m/s}^2\ 6\ \text{m} =$ **18000 Joules.**

# Chapter 7 Problems

## Problem 2

(a) How much work is done when you push a crate horizontally with 100 N across a 10 m factory floor?
$W = F \cdot d = 100\ N \cdot 10\ m = \mathbf{1000\ J.}$

(b) If the force of friction on the crate is a steady 70 N, show that the KE gained by the crate is 300 J.
$\Delta KE = W - F_{friction} \cdot d = 1000J – 70\ N \cdot 10\ m = \mathbf{300\ J}.$

(c) Show that 700 J is turned into heat.
Heat = Energy loss to Friction = $70\ N \cdot 10\ m = \mathbf{700\ J.}$

# Chapter 7 Problems

6. Consider an ideal pulley system. If you pull one end of the rope 1 m downward with a 50 N force, show that you can lift a 200 N load one-quarter of a meter high.

   Work input = Work output
   
   or $F_{in}\ d_{in} = F_{out}\ d_{out}$
   
   then,
   
   $50\text{ N}\ 1\text{ m} = 200\text{ N}\ d_{out}$
   
   and
   
   $d_{out} = 50\text{N}\ 1\text{m} / 200\text{N} =$ **¼ m**

# Homework

- Read Chapter 7 in Detail.
- Do Ranking 1
- Do Exercises 2, 6, 15, 24
- Do Problems 3, 4, 8

Homework due: will be announced in class