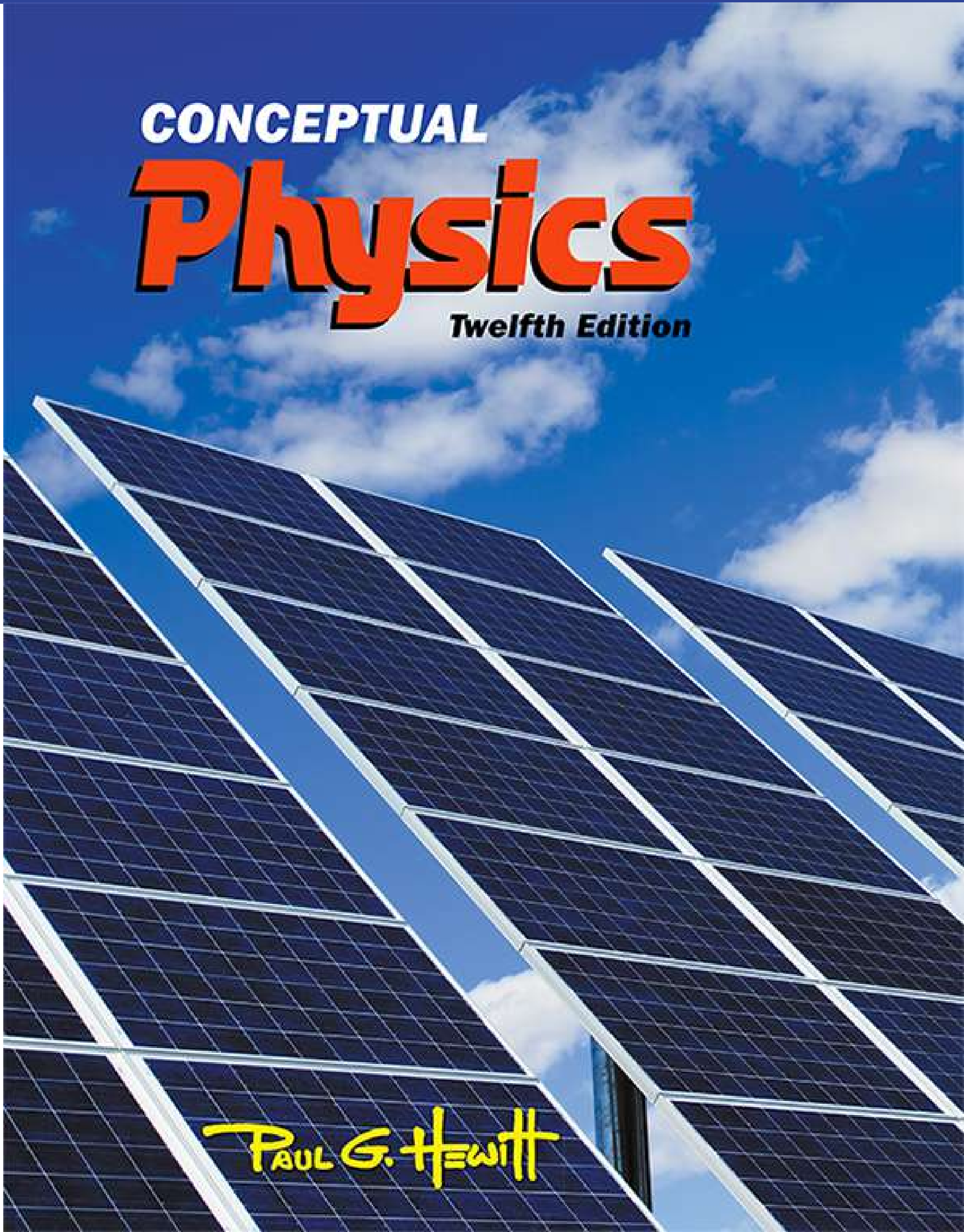
Lecture Outline

Chapter 7: Energy



This lecture will help you understand:

- Mechanical Energy:
- Kinetic
- Work-Energy Theorem

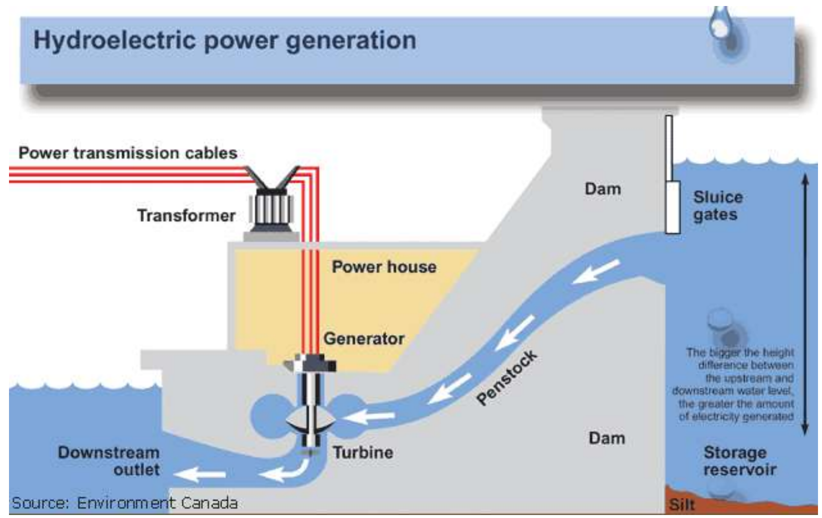
Review:

- What are the units for energy and work? joules J
- What is the equation for work? $W = F \cdot d$
- What is the equation for change in PE….
- …that has weight w in it? $PE = w \cdot h$
- …that has mass m in it? $PE = mgh$
- What are the 2 types of mechanical energy?

PE and…. kinetic energy KE

When all object falls, what happens to its PE?

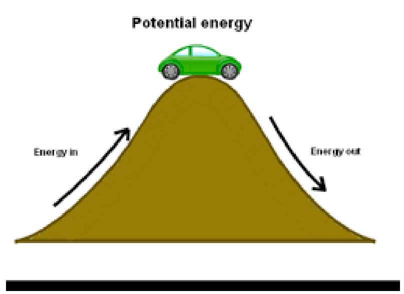
It is transformed into kinetic energy KE.



PE

KE

PE



KE

PE

KE

Kinetic Energy KE

- Energy of motion
- Depends on the mass of the object and square of its speed
- Include the proportional constant ½:

$$KE = (1/2) \times \text{mass} \times \text{speed} \times \text{speed}$$

$$= \left(\frac{1}{2}\right) m\, v^2$$

Ex. Calculate KE

- Calculate the kinetic energy of a 4-kg bicycle moving at 2 m/s.

$$KE = \left(\frac{1}{2}\right) m\, v^2$$

$$= \left(\frac{1}{2}\right) (4\ \text{kg})\ (2\ \text{m/s})^2$$

$$= 8\ \text{kg}\cdot\text{m}^2/\text{s}^2$$

$$= 8\ \text{J}$$

Notice that the units are same as for PE!

Ex. Calculate KE

- Calculate the kinetic energy of a 4-kg bicycle moving at 4 m/s.

$$KE = \left(\frac{1}{2}\right) m\, v^2$$

$$= \left(\frac{1}{2}\right) (4\ \text{kg})\ (4\ \text{m/s})^2$$

$$= 32\ \text{kg}\cdot\text{m}^2/\text{s}^2$$

$$= 32\ \text{J}$$

Ex. Calculate KE

- Calculate the kinetic energy of a 4-kg bicycle moving at 6 m/s.

$$KE = \left(\frac{1}{2}\right) m\, v^2$$

$$= \left(\frac{1}{2}\right) (4\ \text{kg})\ (6\ \text{m/s})^2$$

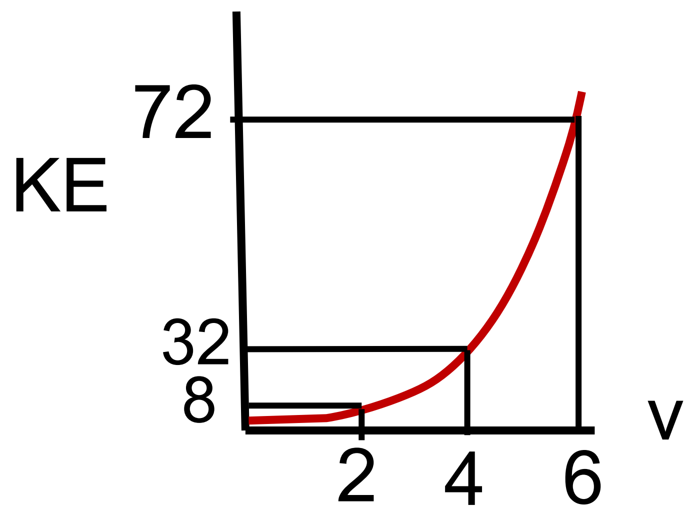
$$= 72\ \text{kg}\cdot\text{m}^2/\text{s}^2$$

$$= 72\ \text{J}$$

Compare the last 3 examples

Speed (m/s)	KE (J)	How many times greater?
2 m/s	8 J	
4 m/s	32 J	32/8 = 4x
6 m/s	72	72/8 = 9x

There is a "squared" or quadratic relationship between the speed v and the KE.



Kinetic Energy
CHECK YOUR NEIGHBOR

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

Kinetic Energy
CHECK YOUR ANSWER

Must a car with momentum have kinetic energy?

A. Yes, due to motion alone

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 and Momentum Compared

- **Similarities** between momentum (mv) and kinetic energy $(1/2)mv^2$:
  - Both are properties of moving things (v).
  - Both depend on the mass m.

- **Differences** 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 mv depends on velocity v.
  - Kinetic energy (1/2) mv^2 depends on the *square* of velocity v^2.

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

Work-Energy Theorem

- Work-energy theorem
  - Gain or reduction of energy is the result of work.
  - In equation form:
  - work = change in kinetic energy
  - $W = \Delta KE$

Substitute in this the equation for W = Fd

..and for KE = $(1/2)\ mv^2$

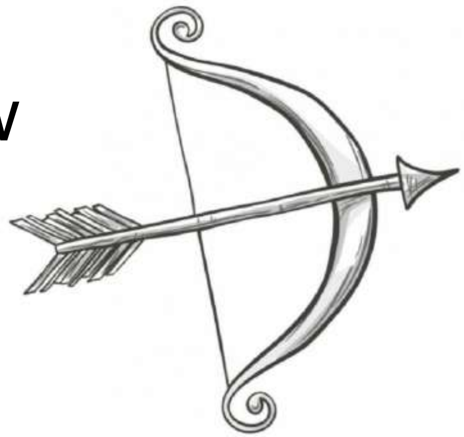
This gives:

$$Fd = (1/2)\ mv^2$$

Work increases KE: $Fd = 1/2\ mv^2$

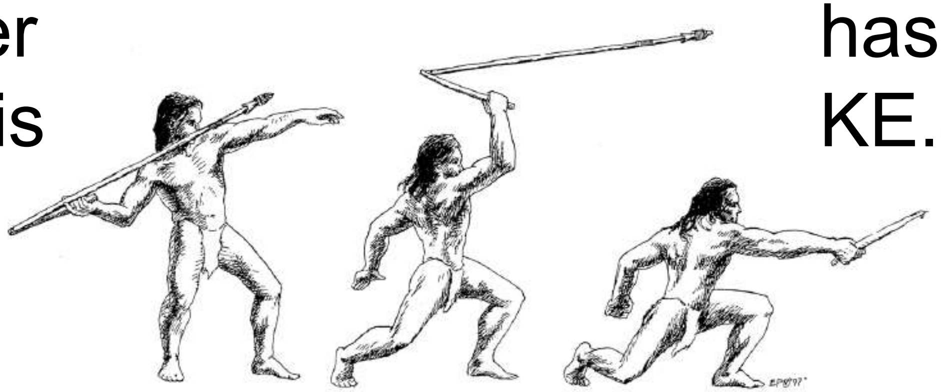
- Bow and arrow:
- Pulling back the bow is the

  Force x distance



- When released, the arrow has KE.

- Atlatl: Increases the distance over which the force is applied.



- As a result, the spear has more KE.

Work-Energy Theorem, Continued

- 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 x distance).

Braking distances, part 1:

- Your car brakes use friction to do work to stop a car. This work changes the car's KE:

$$Fd = 1/2\ mv^2$$

A) If the speed of the car is doubled, how much more KE does it have? 4 x

B) How much more Fd will it need? 4 x

C) The friction force does not depend on speed. Force F is constant. So how much more distance d will the car need to stop? 4 x

Braking distances, part 2:

- Your car brakes use friction to do work to stop a car. This work changes the car's KE:

$$Fd = 1/2\ mv^2$$

A) If the speed of the car is *tripled*, how much more KE does it have?

9 x

B) How much more Fd will it need?

9 x

C) Friction force is constant. How much more distance d will it need to stop?

9 x

Work-Energy Theorem
CHECK YOUR NEIGHBOR, Continued

The work done in bringing a moving car to a stop is the force of tire friction x 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.

D. None of the above.

Explanation:

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

Work-Energy Theorem
CHECK YOUR NEIGHBOR, Continued

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

A. one third as much
B. the same.
C. tripled.
D. nine times greater

D. nine times greater

Explanation:

3x the speed means 9x the kinetic energy and 9x the stopping distance.

Work-Energy Theorem
CHECK YOUR NEIGHBOR

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

Work-Energy Theorem
CHECK YOUR ANSWER

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

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

Comment:

The work-energy theorem is the physicist's favorite starting point for solving many motion-related problems.

Homework: due Monday @ 7pm

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- page 127: #36-38