Spring 2013

PHYS-2010

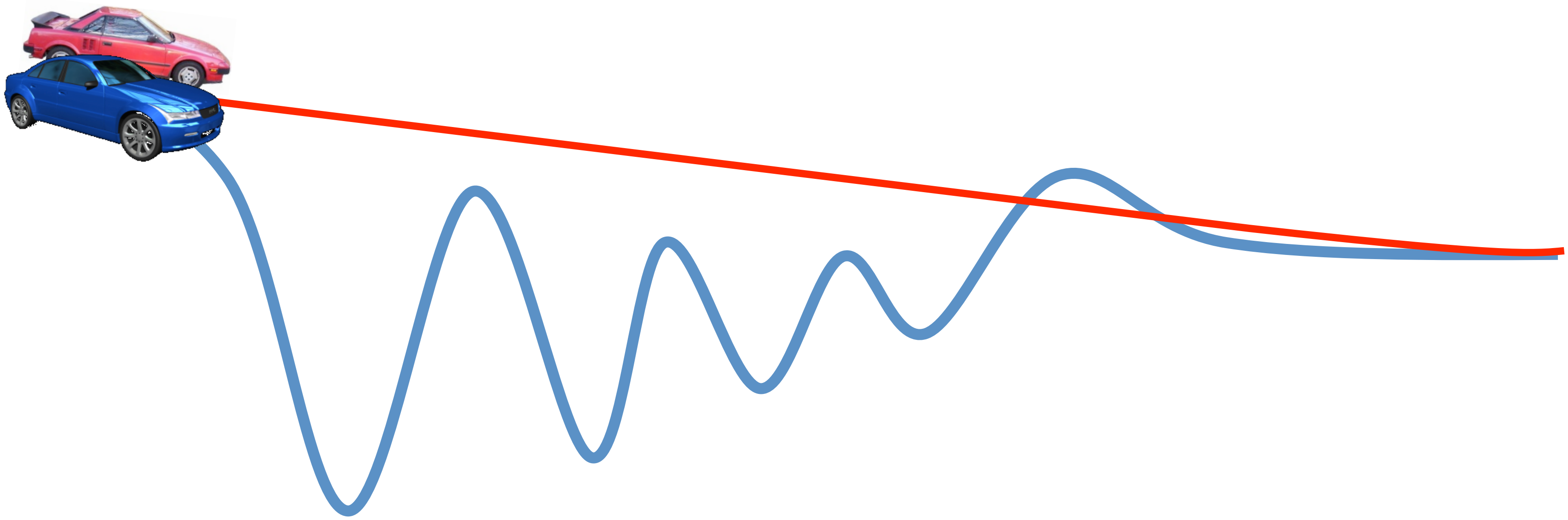
Lecture 24

ANNOUNCEMENTS

- **CAPA Set # 9** due Friday, March 15, at 11:59 pm
- This week in Section: **Lab 3 “Momentum”**
- Start reading **Giancoli Chapter 7**.
- **Midterm Exam #2**:
  - Solutions and scores are posted on D2L;
  - Scores are curved up by adding 10 points.

Clicker Question

Room Frequency BA



A blue car coasts in neutral (no stepping on the gas or brakes) down the blue path.

A red car coasts in neutral (no stepping on the gas or brakes) down the red path.

If only gravity is acting (no friction!), then:

A) The red car ends up with a larger velocity;

B) The blue car ends up with a larger velocity;

C) The two velocities are equal at the end.

Conservative Forces

The effect of some forces is expressed as a Potential Energy:
e.g., gravity, elastic forces produced by springs (later).

These forces are said to be **Conservative**.

For conservative forces, the work done depends only on the starting and ending points, not the path taken while the force is being applied.

The work done by some other forces depends on the path taken:
e.g., friction. Under the action of these forces, mechanical energy is not conserved.

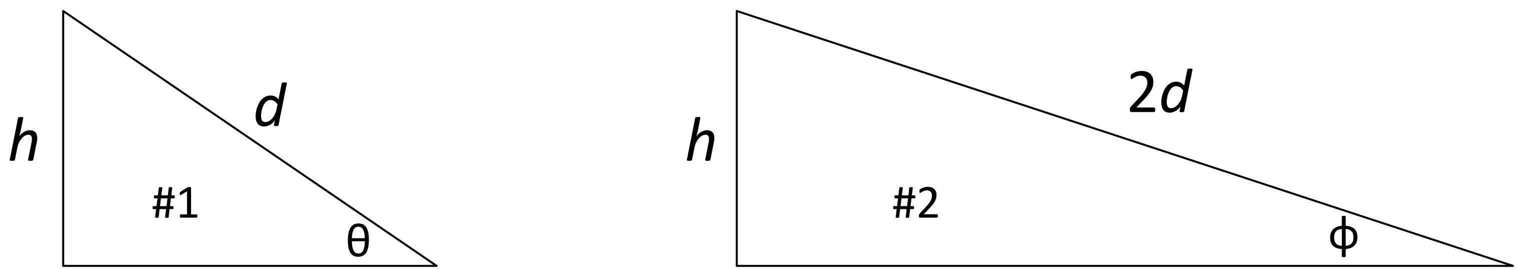
The friction force is **Non-Conservative**.

Its effect cannot be expressed as a Potential Energy.

Two paths lead to the top of a big hill.
Path #1 is steep and direct and Path #2 is twice as long but less steep.
Both are ***rough*** paths and you push a box up each.

How much more gravitational potential energy is gained if you take the longer path?

- $\boxed{\text{A) none}}$
- B) twice as much
- C) four times as much
- D) half as much



$\sqrt{d^2 - h^2}$ $\sqrt{4d^2 - h^2}$

$\Delta PE = mgh$ in both cases.

Clicker Question

Room Frequency BA

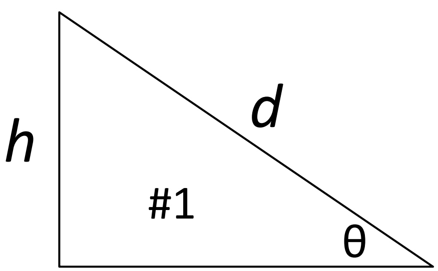
Consider the same two paths as in the previous problem. Is the amount of work done the same along each path?

A) Yes

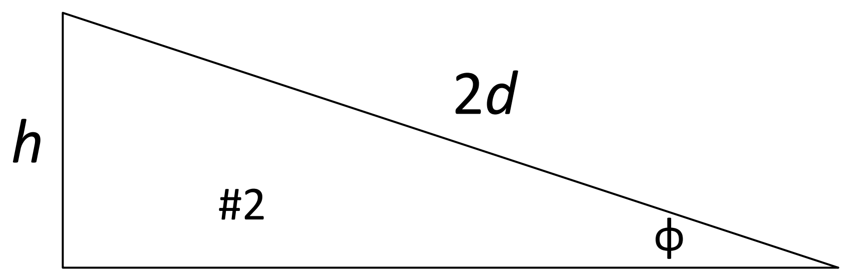
B) No, more work is done on the steeper path.

C) No, more work is done on the longer path.

D) Probably not, but the details are needed to know which is larger.



$$\sqrt{d^2 - h^2}$$



$$\sqrt{4d^2 - h^2}$$

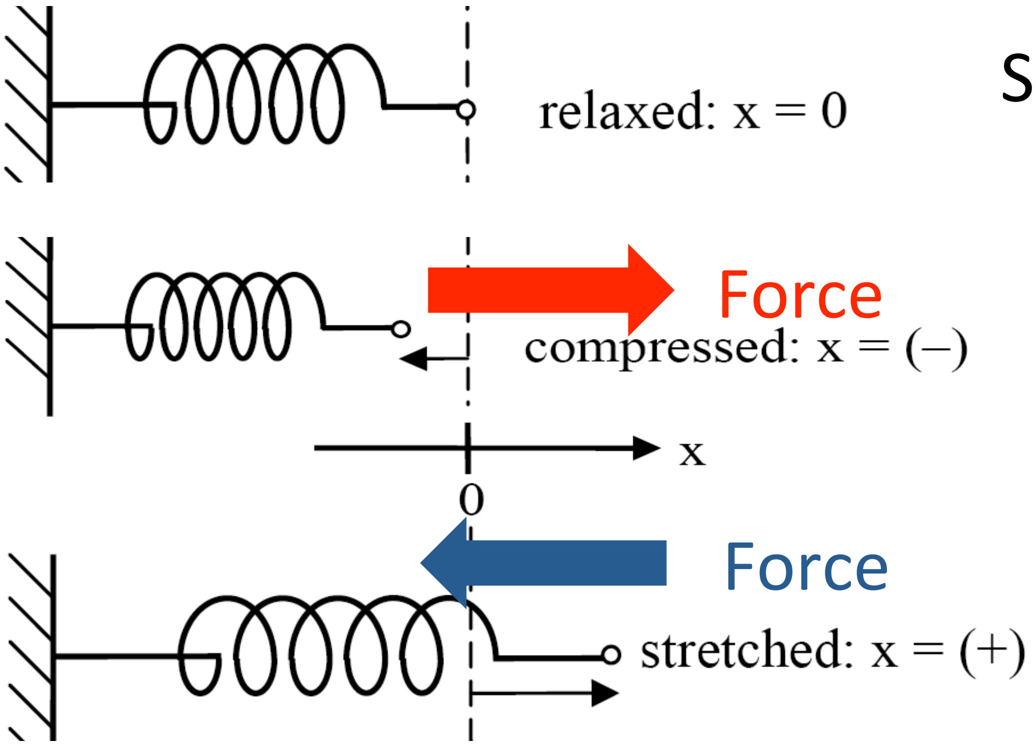
$$|W_f| = F_f d = \mu N d = \mu(mg\cos\theta)d$$

$$= \mu mg \frac{\sqrt{d^2 - h^2}}{d} d = \mu mg\sqrt{d^2 - h^2}$$

$$|W_f| = F_f d = \mu N(2d) = \mu(mg\cos\varphi)(2d)$$

$$= \mu mg \frac{\sqrt{(2d)^2 - h^2}}{2d} 2d = \mu mg\sqrt{4d^2 - h^2}$$

SPRINGS



Spring in "relaxed" position exerts no force

Compressed spring pushes back

Stretched spring pulls back

Hooke's "Law"

$$\boxed{\textbf{Force} = -\,\mathbf{kx}}$$

k = "spring constant"
units = N/m
x = displacement of spring

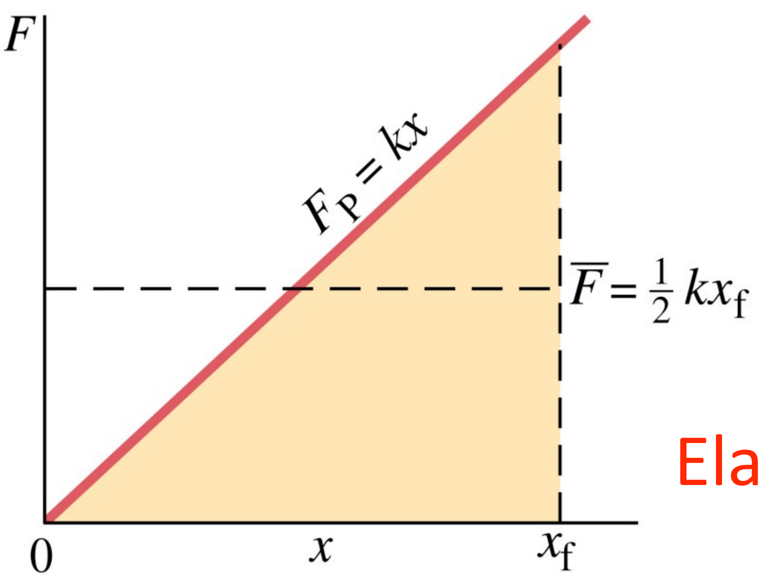
Robert Hooke (1635-1703)

Stored Energy in Springs

Compressed spring has elastic potential energy

Stretched spring also has elastic potential energy

If no change in any other energy, then $\Delta PE = W_{ext} = - F_{spring} \times d$



However $\mathbf{F_{spring} = - kx}$ changes as we stretch the spring

Use average $F_{spring} = - \frac{1}{2} kx$

Elastic potential energy: $\mathbf{PE = \frac{1}{2} kx^2}$

Elastic Potential Energy

In contrast with the gravitational potential energy (PE_{grav} = mgy), which can be positive and negative, the **elastic potential energy** of a spring is always **positive**:

$$PE_{elastic} = \frac{1}{2}kx^2 \geq 0$$

Clicker Question

Room Frequency BA

A force of magnitude $\mathbf{F}_{ext}$ stretches a spring through a displacement **x**. The force is then increased so that displacement is doubled.

$F = -kx, \quad PE = \frac{1}{2}kx^2$

What is the magnitude of force needed to double the displacement and what will be the effect on the potential energy of doubling displacement?

A) Force doubles, PE doubles.

B) Force doubles, PE quadruples.

C) Force quadruples, PE doubles.

D) Force doubles, PE halves.

E) Force quadruples, PE quarters.

A block of mass **m** is released from rest at height **H** on a frictionless ramp. It strikes a spring with spring constant **k** at the end of the ramp.

How far will the spring compress (i.e. x)?

$$KE_i + PE_i + \cancel{W_{frict}}^{\,0} + \cancel{W_{external}}^{\,0} = KE_f + PE_f$$

$$0 + \mathbf{mgH} + 0 + 0 = 0 + (\mathbf{0} + \tfrac{1}{2} kx^2)$$

gravitational

elastic

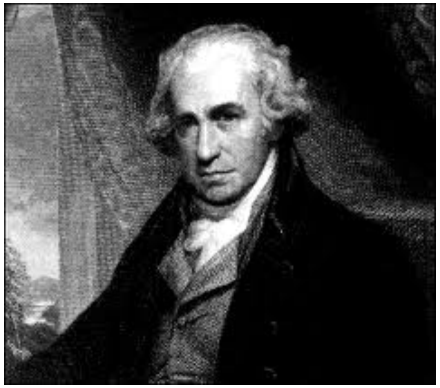
$$\boxed{x = \sqrt{\frac{2mgH}{k}}}$$

Elastic Potential Energy – Does Not Have to Look Like a Spring

POWER

Power is a rate of energy or work per time

$$\overline{P} = \text{average power} = \frac{\text{work}}{\text{time}}$$



James Watt (1736-1819)

SI unit of power: Joule / second = Watt

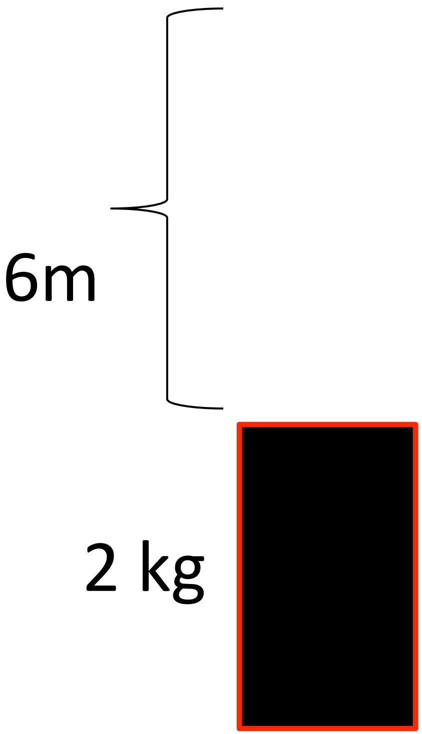
Another common unit of power:

1 horsepower (hp) = 746 watts

The average power can be written in terms of the force and the average velocity:

$$\overline{P} = \frac{W}{t} = \frac{Fd}{t} = F\overline{v}$$

Raise a box of mass 2.0 kg at constant velocity by a height of 6 meters over a time interval of 2 seconds.



How much energy is required to do the work?

$W_{ext} = \Delta PE = mgh$ since $\Delta KE=0$

$W_{ext} = 2\text{ kg} \times 9.8\text{ m/s}^2 \times 6\text{ m} = 117$ Joules

Also $W_{ext} = F_{ext} \times d \rightarrow F_{ext} = m\,g = 19.6$ N

How much power is required to do the work in that amount of time?

Power = W_{ext} / time = 117 J / 2 s = 59 Watts

Also: Power = $F_{ext}\,v = 19.6\text{ N} \times (6\text{m}/2\text{s}) = 59$ Watts

Clicker Question

Room Frequency BA

A kiloWatt-hour (kWh) is a unit of energy (Power x time).
1 kW-hour = 1000 W X 3600 s = 3.6×10^6 Joules = 3.6 MJ.

The average US household uses 2.7 billion Joules of electrical energy each month.

Approximately how many 100 Watt light bulbs would need to be left on all the time to amount to that energy consumption?

A) 1 lightbulb
B) $\boxed{\text{10 lightbulbs}}$
C) 100 lightbulbs
D) 1000 lightbulbs
E) 10,000 lightbulbs

Energy = Power x time = (10 x 100 W) x (30x24x60x60 s) $\approx 2.6 \times 10^9$ J