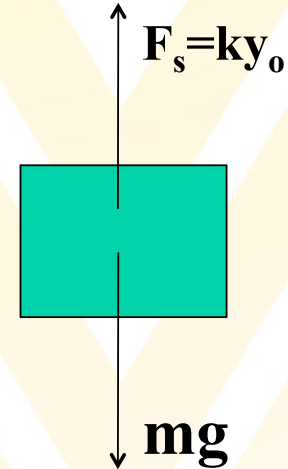
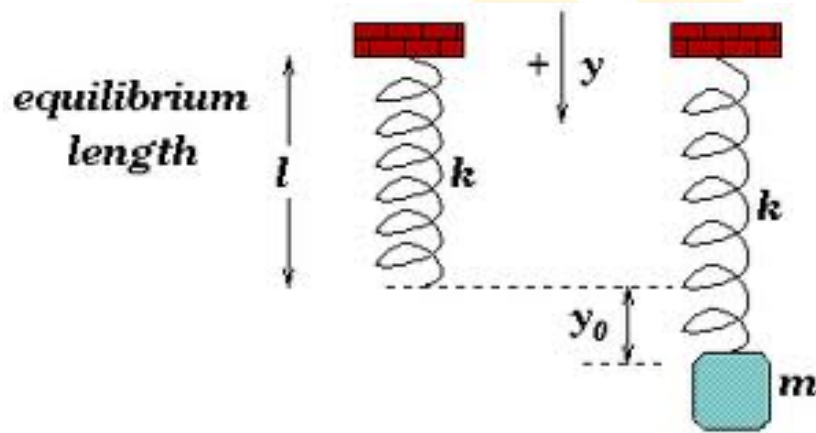


Example problem: Vertical Springs



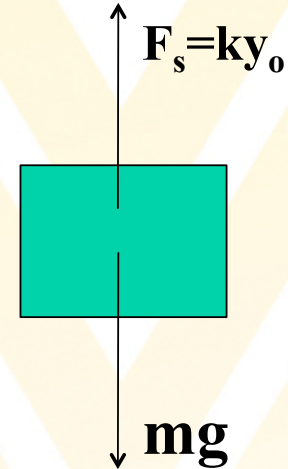
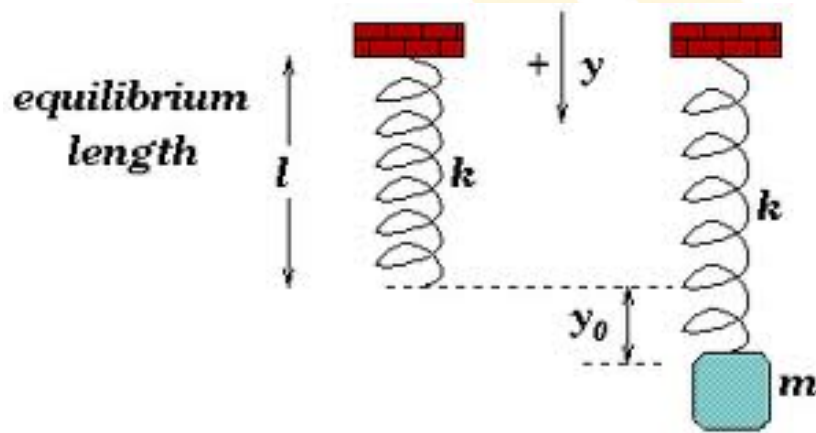
**Free Body
Diagram**

When a 2.5 kg object is hung vertically on a certain light spring, the spring stretches to a distance y_0 . What **force** does the spring apply to the object?

If the string stretches 2.76 cm, what is the force constant of the spring?

What is the force if you stretch it 8 cm?

Example problem: Vertical Springs

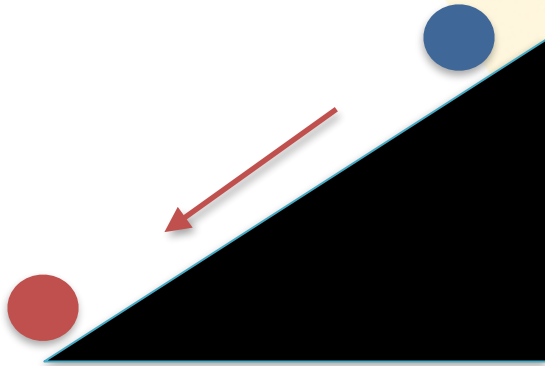


A 2.5 kg object is hung vertically on a certain light spring with spring constant $k=888\text{N/m}$.

How much work must an external agent do to stretch the same spring 8.00 cm from its unstretched position?

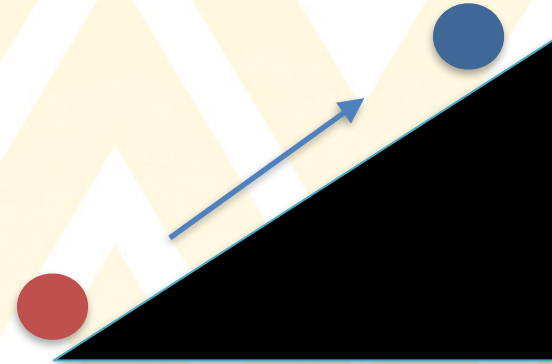
**Free Body
Diagram**

Irreversible processes



A ball easily rolls down a hill and heats up via friction while going downhill.

Its energy is transformed from potential to kinetic energy and finally to heat.



A hot ball at rest at the bottom of a hill does not start moving uphill, while cooling down.

Its energy is not transformed from heat to kinetic energy and finally to potential energy.

No energy is lost. It just cannot be transformed back from heat to potential energy.

Roller coasters



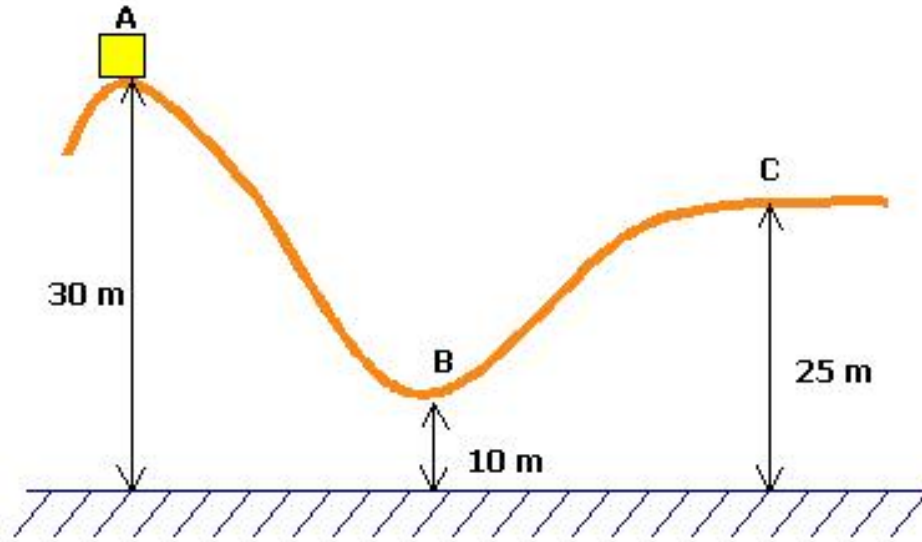
Riding a roller coaster is a typical application of energy conservation (neglecting friction).

Potential energy is transformed into kinetic energy and vice versa.

$$KE_i + PE_{gi} = KE_f + PE_{gf}$$



Example problem: Rollercoaster



A 1000 kg roller coaster car moves from point A to B and to C. Its initial velocity is 0 m/s. Neglect all non-conservative forces, e.g. friction.

- What is its potential energy at points A, B, C?
- What is its speed and kinetic energy at A, B, C?
- What is its total energy at A, B, C?

Clicker question

An athlete jumping vertically on a trampoline leaves the surface with a velocity of 8.5 m/s upward.

What maximum height does he reach?

- A. 13 m
- B. 2.3 m
- C. 3.7 m
- D. 0.27 m
- E. The answer cannot be determined because the mass of the athlete is not given.



Power

Power is the rate at which energy is transformed from one type to another:

Average power: $\bar{P} = \frac{W}{\Delta t}$ Power is a scalar quantity.

Unit: $1W = 1J/s = 1kg \cdot m/s^2 \cdot m \cdot s^{-1} = 1kg \cdot m^2/s^3$

Alternative expression for power:

$W = F \cdot \Delta x$ if F is parallel to Δx .

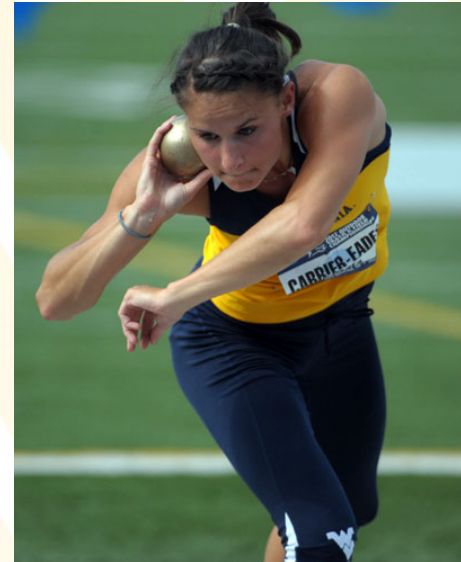
$\rightarrow \bar{P} = F \cdot \frac{\Delta x}{\Delta t} = F\bar{v}$



Example problem: Power

A shot-putter accelerates a 7.3-kg shot from rest to 14 m/s.

If this motion takes 2.0 s, what average power was produced?



Clicker question

Weightlifter A lifts a 100-kg weight to a height of 2.5 m above the ground in 1.0 s.
Weightlifter B lifts a 75-kg weight to a height 2.5 m above the ground in 0.5 s.
Which of the two weightlifters uses more power to lift the weights?

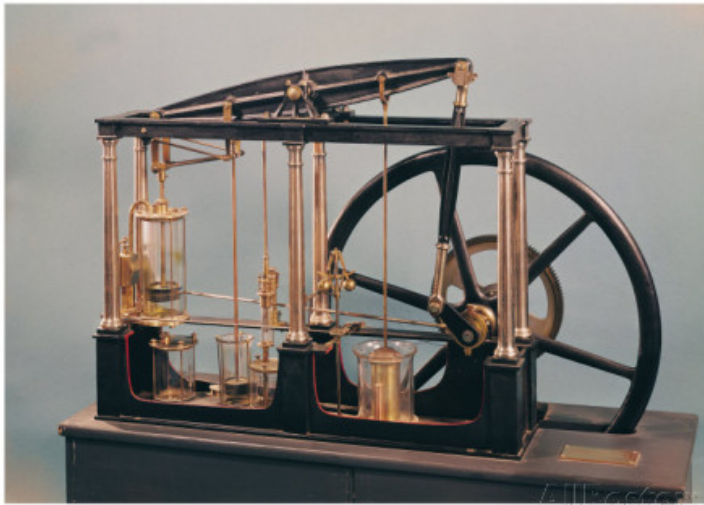
- A. A
- B. B
- C. They both use the same amount of power.
- D. Impossible to determine.



Horsepower - An alternative unit of Power

When James Watt invented the steam engine, he needed a large power unit to rate the output power of his new invention. He chose a standard horse.

$$1 \text{ hp} = 746 \text{ W}$$



Kilowatt-hour: A unit of energy

When you read your electricity bill, it will tell you how many **kilowatt-hours** (KWHRs, kWh) you consumed.

What does that mean?

1 kWh is the energy consumed in 1 hour at the constant rate of 1 W.

$$1 \text{ kWh} = (10^3 \text{ W}) \cdot (3600 \text{ s})$$
$$= (10^3 \text{ J/s}) \cdot (3600 \text{ s}) = 3.6 \cdot 10^6 \text{ J}$$

kWh is a unit of energy, not power!

Commonwealth Edison
Post Office Box 784
Chicago, Illinois 60690

ELECTRIC SERVICE BILL
RECEIVED JUN - 3 1988

EVANSTON IL 60204

SERVICE ADDRESS
CHICAGO

ACCOUNT NUMBER

ACCT #
DUE DATE JUNE 16, 1988

NOM DUE
\$ 142,999.52

AFTER 6-16-88 PAY \$ 143,186.82

RETURN THIS PORTION WITH PAYMENT
ALLOW 5 DAYS FOR MAIL DELIVERY

000000

DATE OF BILL
JUNE 2, 1988

FOR SERVICE FROM 4-06-88 TO 5-05-88

RATE 6L RIDER 7.25

N 3

TOTAL BILL \$ 142,999.52
PAST DUE AFTER 6-16-88
AFTER 6-16-88 PAY \$ 143,186.82

CUSTOMER COPY

DESCRIPTION	AMOUNT
LARGE GENERAL SERVICE - TIME OF DAY	
MONTHLY CUSTOMER CHARGE	\$ 484.60
DEMAND CHARGE	249.8 KM 2605.41
PEAK ENERGY CHARGE	35856 KWHRS # 1818.26
OFF-PEAK ENERGY CHARGE	52944 KWHRS # 1067.35
NON-T.O.D. ENERGY CHARGE	13809 KWHRS # 453.07
SPACE HEATING SERVICE	109920 KWHRS # 4480.34
METER RENTAL RIDER 7	483.65
STATE TAX	579.88
CITY TAX	513.86
PREV BALANCE	
CURRENT BILL	12486.42
TOTAL BILL	\$ 142999.52

CONTINUED ON PAGE 2

RATE INFORMATION IS AVAILABLE AT ANY OF OUR OFFICES

Get a feeling for the value of energy

How many hamsters running on wheels would it take to provide enough power for a house?

Let's assume a hamster weighing 50 grams can run up a 30-degree slope at 2 m/s.



120 hamsters to keep a 60-watt bulb lit

Average hamster probably spends $\sim 5\%$ of its life running, so we would need 2,400 hamsters just for lightbulb

The average household needs a constant power consumption of about ~ 2.5 kW. Each house would need $\sim 100,000$ hamsters.



Summary

- If non-conservative forces can be neglected, the sum of potential and kinetic energy will be conserved.

- $KE_i + PE_{gi} = KE_f + PE_{gf}$

- Typical problems that can be solved by **energy conservation**: Rollercoasters, Pendulums, Jumping.

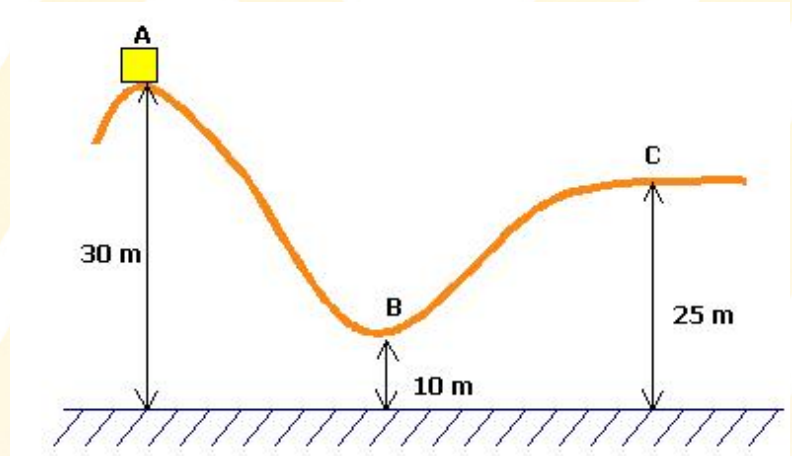
- **Power** is defined as the rate of energy transfer with time (scalar quantity):

$$\bar{P} = \frac{W}{\Delta t} = F\bar{v} \quad \text{Unit: } 1 \text{ W} = 1 \text{ J/s}$$

- 1 **horsepower** is an alternative unit for power (non SI-unit): $1 \text{ hp} = 746 \text{ W}$

- 1 **kilowatt-hour** is a unit for energy. It is the energy consumed within 1 hour at the rate of 1 W:

$$1 \text{ kWh} = 3.6 \cdot 10^6 \text{ J}$$



Example problem: Horsepower

An advertisement claims that a certain 1200 kg car can accelerate from rest to a speed of 25 m/s in a time of 8.0 s. What power (in units of horsepower) must the motor produce in order to cause this acceleration?

Ignore losses due to friction. (1 hp=746 W)



Example problem: Cost of Energy

What is the cost of forgetting to turn off your bathroom light for the day?

Let's say you have three 75W bulbs in this light and you are gone for 12 hours.

Electricity costs about \$0.10 per kWh.

