Main Ideas in Class Today

After today's class, you should be able to:

- Understand gravitational potential energy
- Identify conservative and nonconservative forces
- Utilize conservation of energy
- (If time) Calculate the power of a situation

These are the problems I recommend if you are struggling with this topic: 5.19, 5.21, 5.23, 5.25, 5.27, 5.33, 5.35, 5.37, 5.41, 5.45, 5.47

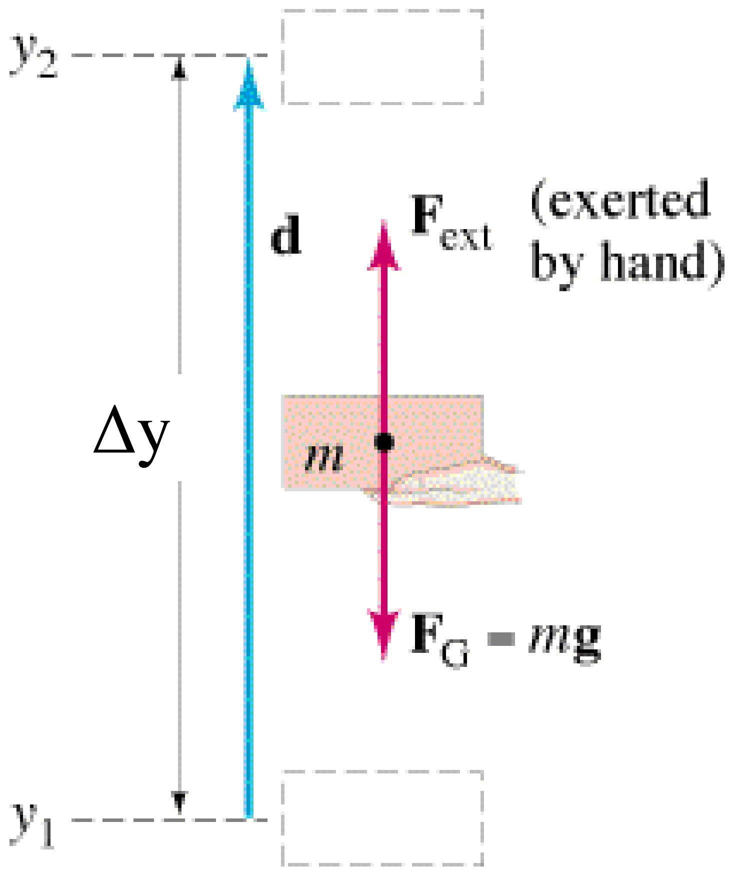
Potential Energy

- Kinetic energy: energy resulting from motion of an object
- Potential energy: energy associated with forces whose work done depends on the **position** or surroundings of an object
  - Potential energy due to gravity
  - Spring potential energy (5.4 & Ch. 13). We will hold off on springs until later.

Gravitational Potential Energy

Work done by gravity when object is lifted to a height *y*:

$$W_G = F_{||}\,\Delta y = (-mg)\Delta y = -mg(y - y_o)$$



If object is released from height *y*, object has the ability (potential) to do an amount of work equal to *mgy*.

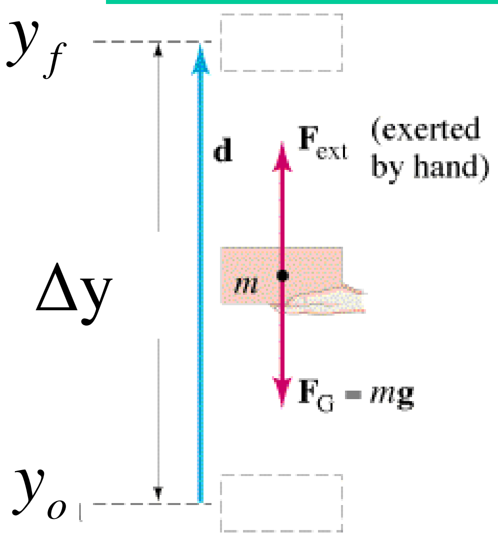
Definition of gravitational potential energy (only when near surface of Earth):

$$PE_{grav} = mgy$$

y is height above some reference level (typically the ground but not necessarily)

Gravitational Potential Energy

$$PE_{grav} = mgy$$



$$W_G = -mg\Delta y = -mg(y - y_o)$$

Compare to change in potential energy

$$\Delta \mathbf{PE} = \mathbf{PE_f} - \mathbf{PE_i} = mgy - mgy_o = mg\Delta y$$

$$W_G = -\Delta PE$$

Work done by gravity in going between two points is equal to the negative of the change in PE

Note:

1. Origin to measure *y* is arbitrary, thus so is PE (ΔPE is not)
2. Gravity does work only in the vertical direction, so work done by gravity in going from point 1 to point 2 only depends on *y*, **independently of path taken**

Dropping Something Down A Well

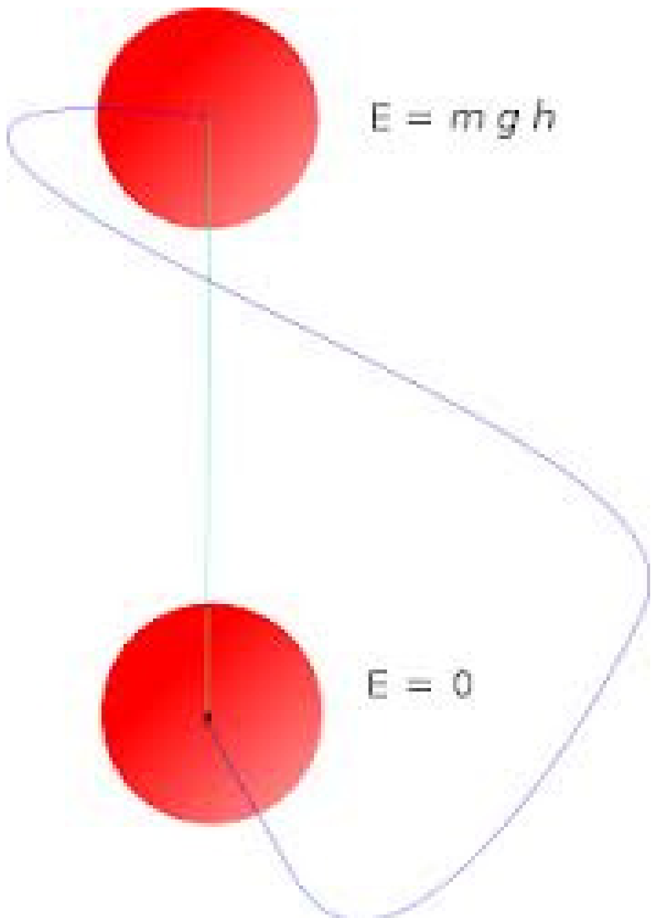
A 0.2-kg stone is held 1.3 m above the top edge of a water well and then dropped into it. The well has a depth of 5.0 m. (a) Taking $y = 0$ at the top edge of the well, what is the gravitational potential energy of the stone before the stone is released?

(b) Taking $y = 0$ at the top edge of the well, what is the gravitational potential energy of the stone when it reaches the bottom of the well?

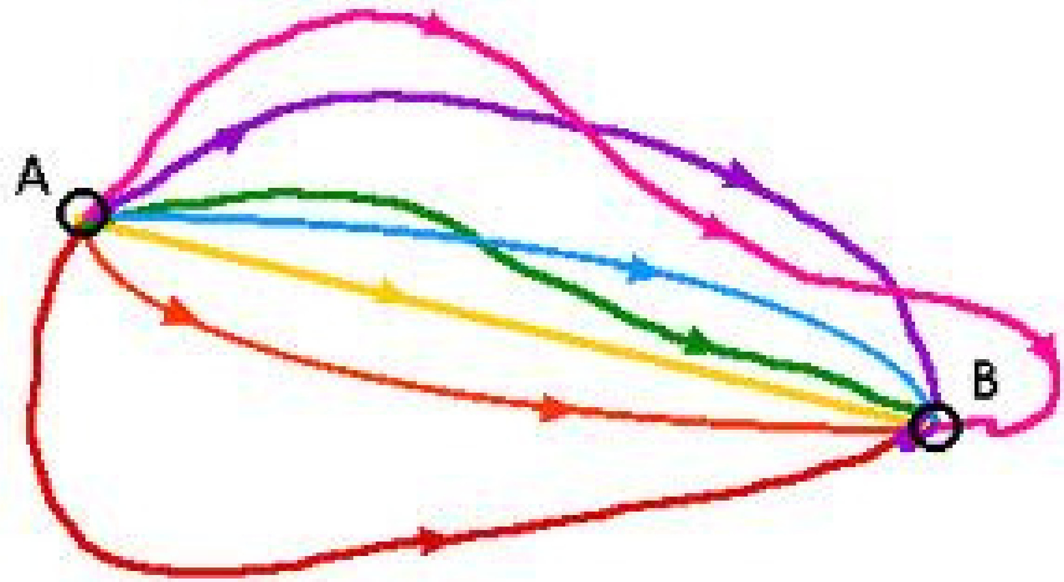
(c) What is the change in gravitational potential energy from release to reaching the bottom?

Based on our last class, is the work done by vity gravity (**A**) positive, (**B**) negative or (**C**) 0?

Q60



Conservative Forces

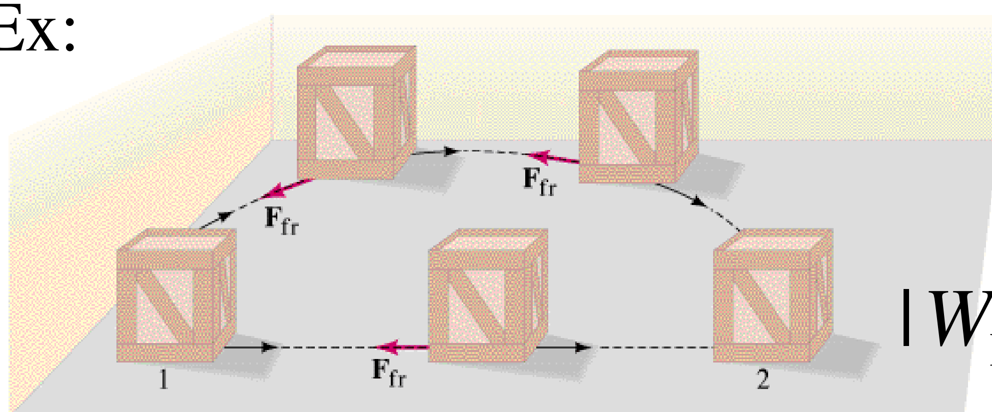


- Work done by a conservative force is independent of the path taken
  - Gravity, springs (in 102, electric and magnetic forces)
  - Work done by conservative forces can always be represented as a potential energy: $W_C = -\Delta PE$

Nonconservative Forces

- Nonconservative force: work done depends on path taken
  - Friction, air resistance, propulsive forces such as for a plane

Ex:



$$|W_{\text{Fr, curved path}}| > |W_{\text{Fr, straight path}}|$$

When nonconservative forces are involved, the full work-energy theorem must be used.

$$W_{net} = W_C + W_{NC} = W_C + Heat$$

Mechanical Energy

Last Time: Work-energy principle $W_{net} = \Delta KE$

Separate net work done into work done by conservative and nonconservative forces:

$$W_{net} = W_{NC} + W_C = \Delta \mathrm{KE}$$

But W_C = -ΔPE

$$W_{NC} + (-\Delta \mathrm{PE}) = \Delta \mathrm{KE}$$

$$W_{NC} = \Delta \mathrm{PE} + \Delta \mathrm{KE}$$

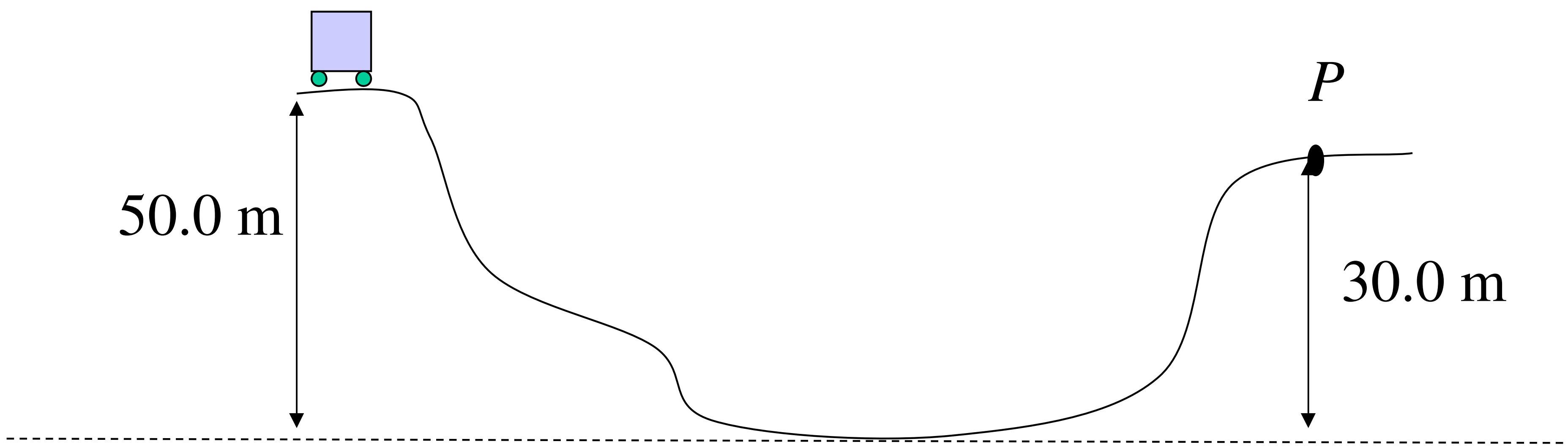
If $W_{NC} = 0$,

$$0 = \Delta \mathrm{PE} + \Delta \mathrm{KE} = (\mathrm{PE_f} - \mathrm{PE_i}) + (\mathrm{KE_f} - \mathrm{KE}_i) = 0$$

$$\mathrm{PE_i} + \mathrm{KE_i} = \mathrm{PE_f} + \mathrm{KE_f}$$

Mechanical energy (PE + KE) of an object remains the same (is conserved) if **only** conservative forces act on the object

A rollercoaster car is at the top of a hill. If its speed at the top of the hill is 2.0 m/s, calculate the speed ignoring friction at the point *P* shown below:



A child on a sled could be treated the same way.

Nonconservative example

A 40.0 N crate starting at rest slides down a rough 6.00 m long ramp, inclined at 30.0° with the horizontal. The magnitude of the force of friction between the crate and the ramp is 6.0 N.

a) What is the total work done on the crate?

b) What is the speed of the crate at the bottom of the incline?

There is more than one way to do the speed part of this problem. (Chapter 4 or Chapter 5 ideas)

A child in a sled with combined mass of 50 kg slide down a frictionless hill. If the sled starts from rest and has a speed of 3.0 m/s at the bottom, what is the height of the hill?

A piece of fruit falls straight down. As it falls,

A. the gravitational force does positive work on it and the gravitational potential energy increases.

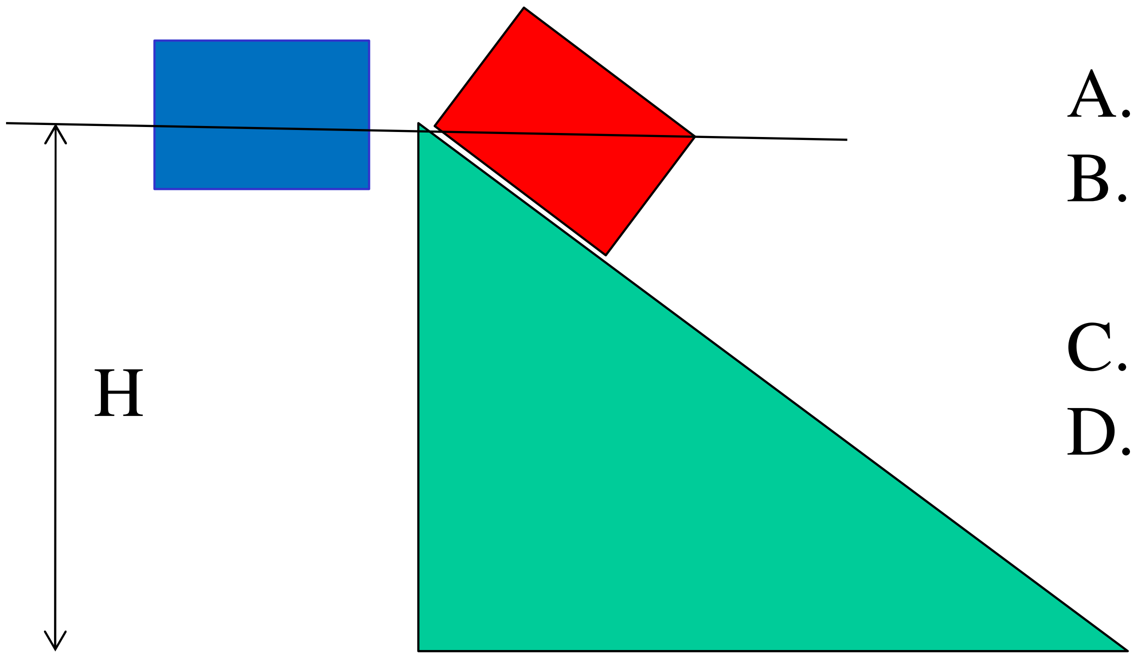
B. the gravitational force does positive work on it and the gravitational potential energy decreases.

C. the gravitational force does negative work on it and the gravitational potential energy increases.

D. the gravitational force does negative work on it and the gravitational potential energy decreases.

Q62

Two identical boxes fall a distance H. One falls directly down; the other slides down a frictionless incline. Which has the larger speed at the bottom?



A. The one falling vertically
B. The one sliding down the incline
C. Impossible to determine
D. It's the same

Q63

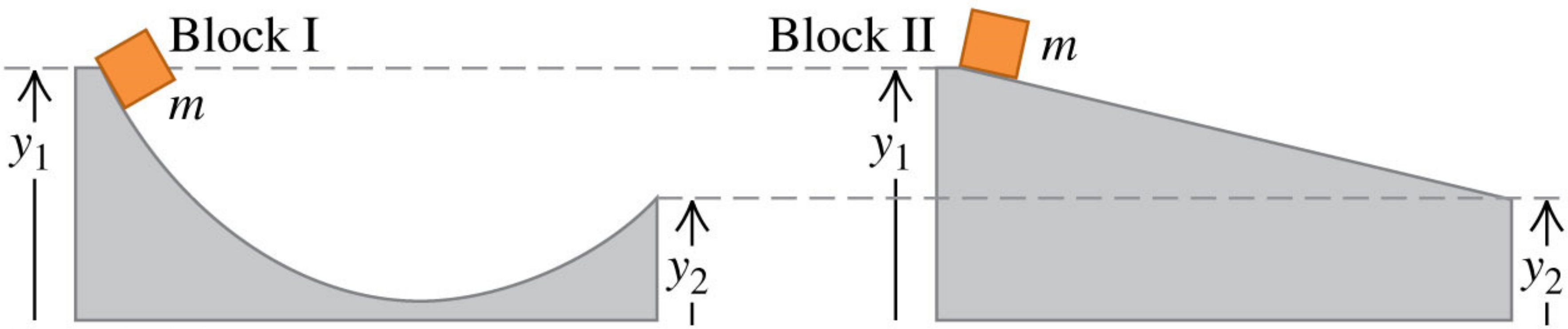
$W_c = -\Delta PE$ and Total Work $= W_c + W_{nc} = \Delta KE$ $\quad (KE = \frac{1}{2} mv^2)$

What if we turn friction back on? (**Q64**)

If frictionless, which takes the shortest time to travel that distance? (**Q65**)

Work and energy ideas are powerful for forces, distances, speeds, but not times.

The two ramps shown are both frictionless. The heights y_1 and y_2 are the same for each ramp. A block of mass m is released from rest at the left-hand end of each ramp. Which block arrives at the right-hand end with the greater speed?



A. the block on the curved track

B. the block on the straight track

C. Both blocks arrive at the right-hand end with the same speed.

D. The answer depends on the shape of the curved track.

Q66

A satellite is moving around the Earth in a circular orbit. Over the course of an orbit, the Earth's gravitational force

A. does positive work on the satellite.

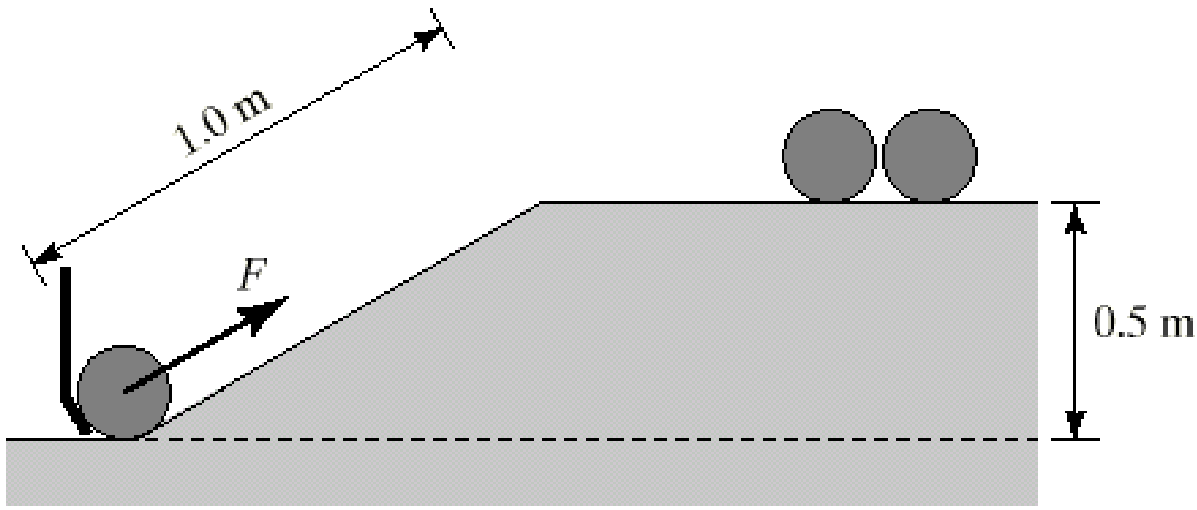
B. does negative work on the satellite.

C. does positive work on the satellite during part of the orbit and negative work on the satellite during the other part.

D. does zero work on the satellite at all points in the orbit.

Q67

At the bowling alley, the ball-feeder mechanism must exert a force to push the bowling balls up a 1.0-m long ramp. The ramp leads the balls to a chute 0.5 m above the base of the ramp. Approximately how much force must be exerted on a 5.0-kg bowling ball?



A. 200 N
B. 50 N
C. 25 N
D. 5.0 N
E. impossible to determine

Q68

More conservative examples:

Springs (ignoring friction)

Any example in Chapter 2-4 (ignoring friction)

In this class, friction and air resistance are the main nonconservative forces we will use. In general, it is defined as nonconservative if you cannot get that energy back (like if you push something).

Clicker Answers

Clicker #=Answer

60=A, 61=B, 62=B, 63=D, 64=A, 65=A, 66=C, 67=D, 68=C

Power not tested

- Due to lack of time, power is not tested. However, it’s a pretty easy topic (just work divided by time) and it can help you understand how your electricity bill works.
- Its ease is why I drop it. You can figure it out on your own. The other material we cover needs a little more guidance.
- I include some stuff on it below in case you want to see what I would teach if I had time.

Understanding Your Electricity Bill

Power is rate at which energy is transformed:

Average power:

$$\overline{P} = \frac{\text{Work}}{\text{time}} = \frac{W}{\Delta t}$$

Units: J/s = Watt (W)

Also: since $W = F_{||}\Delta x$,

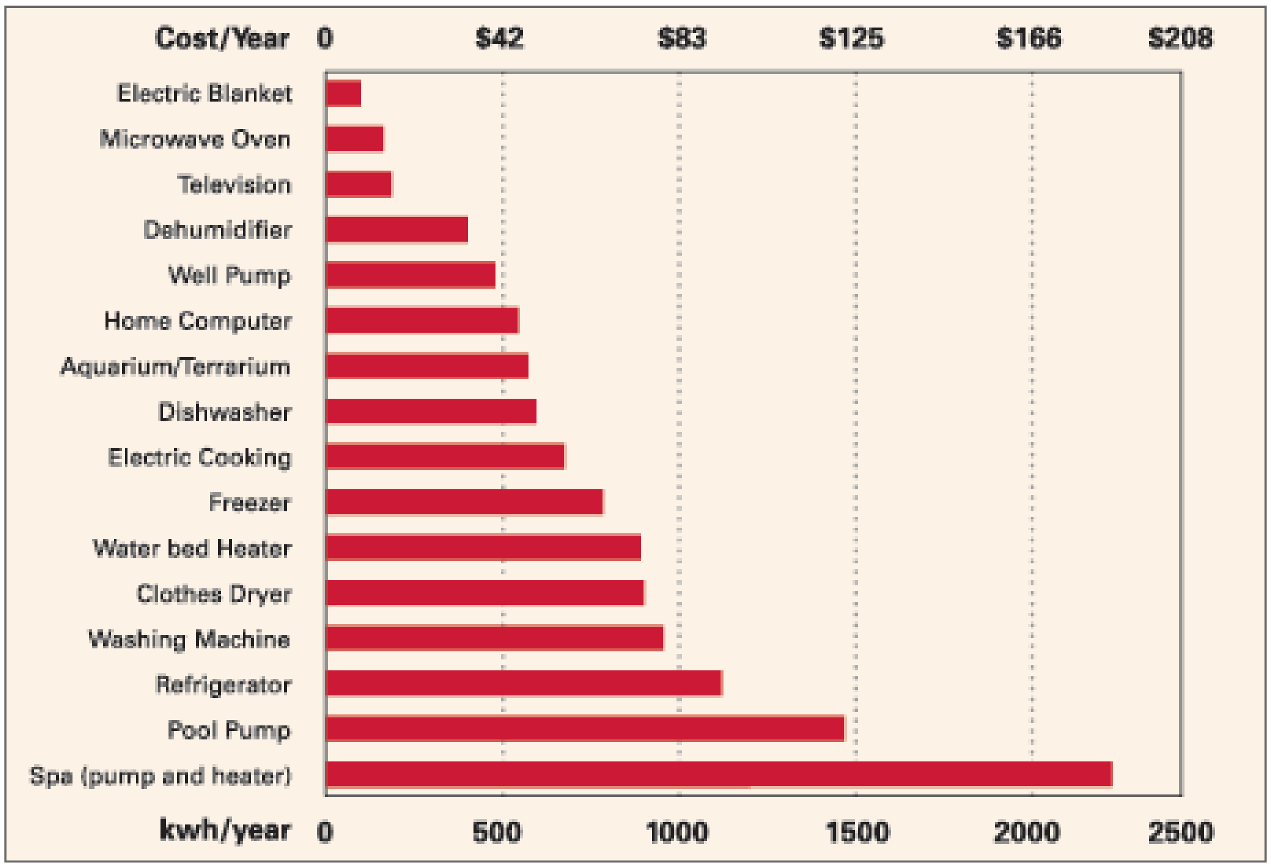
$$\overline{P} = \frac{F_{||}\Delta x}{\Delta t} = F_{||}\overline{v}$$

Note: Power is **not** energy. Power is the **rate** at which energy is transformed/used.

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)

About how much does it cost to run a 1.8 kW heater for 1 month if it is used 3 hours each day. Electricity costs about $0.10 per kWh.

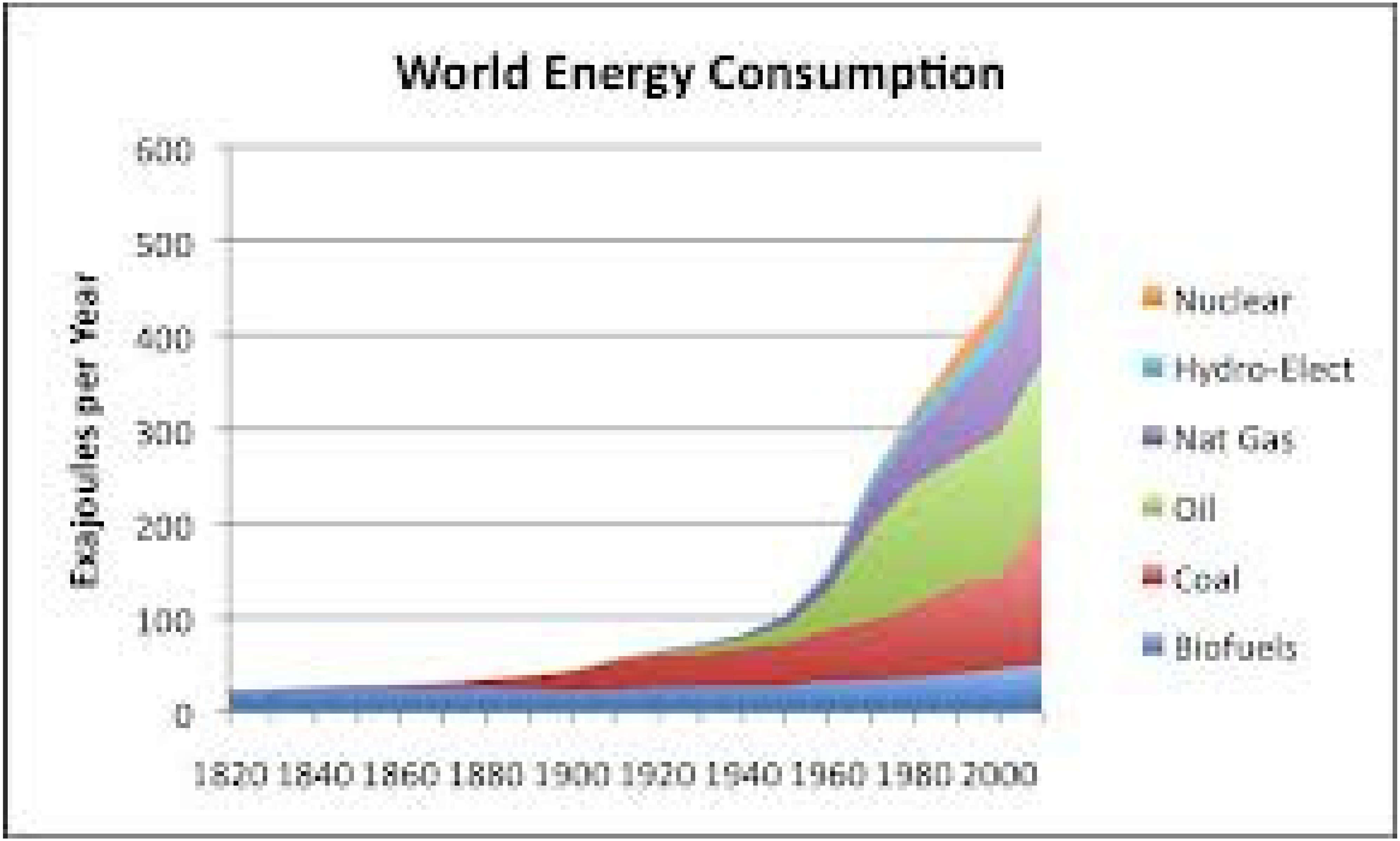


Yearly cost of powering household items.

Multiply the item's power times the time it is used.

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. Again, electricity costs about $0.10 per kWh.

1 Exajoule (EJ) = 10^{18} J



The "All of the Above" Policy: We need to increase our energy production from all sources!

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 ~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 ~100,000 hamsters.

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?

$$\overline{P} = \frac{\text{Work}}{\text{time}} = \frac{W}{\Delta t}$$

A. A

B. B

C. They both use the same amount of power.

D. Impossible to determine.

Q61

Average 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?