From last time

- Work = Force x Distance
- Energy = an object’s ability to do work
- Kinetic energy of motion: $E_{kinetic}$=(1/2)mv^2
- Work - energy relation:

  Change in kinetic energy of a single object
  = net work done on it by all forces.

- Many types of energy, e.g.

Exam 1: Wednesday, Review Monday,
Scantron with 20 questions, bring #2 pencil
Chapters 1 and 3-6
1 Page, front only, equation sheet allowed

Today…

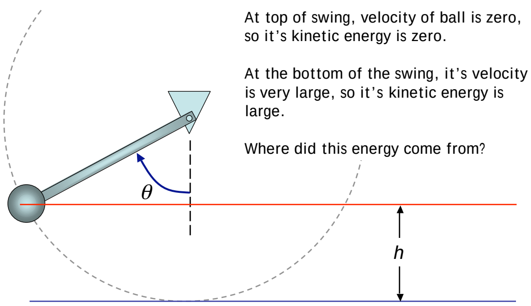
- Potential energy
  - An additional form of energy
  - Can store energy in a system, to be extracted later.
- Conservation of energy: energy is never lost, but just changes form.
- Power: How fast work is done.
- Measurements and applications of power.

The bowling ball

At top of swing, velocity of ball is zero, so it’s kinetic energy is zero.

At the bottom of the swing, it’s velocity is very large, so it’s kinetic energy is large.

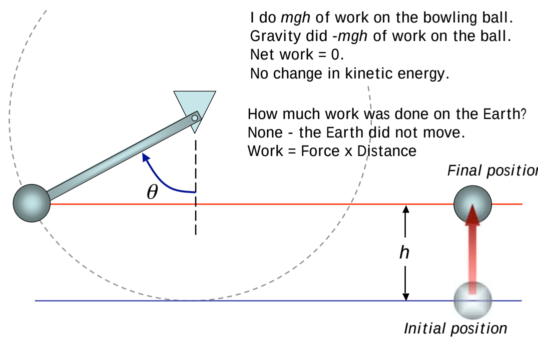
Where did this energy come from?



Work

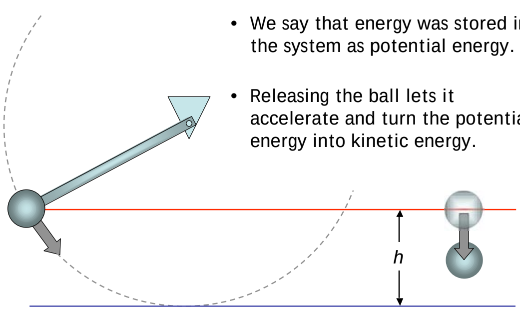
I do *mgh* of work on the bowling ball.
Gravity did -*mgh* of work on the ball.
Net work = 0.
No change in kinetic energy.

How much work was done on the Earth?
None - the Earth did not move.
Work = Force x Distance



Now release the ball

- We say that energy was stored in the system as potential energy.
- Releasing the ball lets it accelerate and turn the potential energy into kinetic energy.



Where’s the energy?

- When I did work, I transferred energy to the ball.
- But zero net work done on the ball.
- Ball’s kinetic energy has not changed.
- Energy is ‘stored’ as potential energy.
- Can think of this as energy stored in the gravitational field.

Potential energy

- The potential energy of a system is the work required to get the system into that configuration.
- Some examples
  - For a pendulum, it is the work required to move the bob to the top of its swing.
  - For a falling apple, it is the work required to lift the apple.
  - For a spring, it is the work required to compress the spring

Storing energy

Water tower and pumphouse

Water is pumped into tower when electricity cost is low

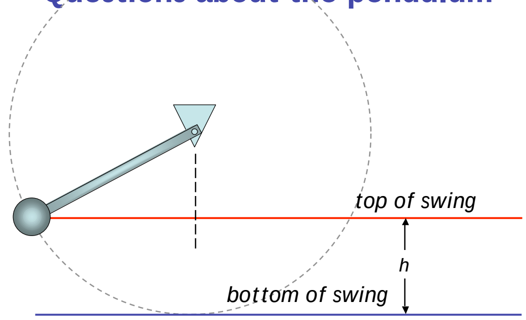
Electrical energy transformed into potential energy.

Work is extracted when needed to transport the water to homes.

Energy conservation

- In Newtonian mechanics, it is found that the total energy defined as the sum of kinetic (visible) and potential (invisible) energies is conserved.
- E = K + U = constant
- Many situations become much clearer from an energy perspective.

Questions about the pendulum



Conservation of energy

- This was an example of conservation of energy.
- Energy was converted from potential to kinetic.
- As the pendulum swings, energy is converted back and forth, potential to kinetic.

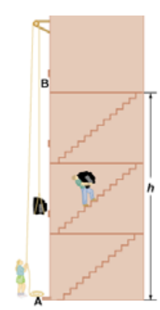
Work Done by Gravity

- Change in gravitational energy,

  Change in energy = *mgh*

  true for any path : *h*, is simply the height difference, $y_{final} - y_{initial}$

- A falling object converts gravitational potential energy to its kinetic energy
- Work needs to be done on an object to move it vertically up - work done is the same no matter what path is taken

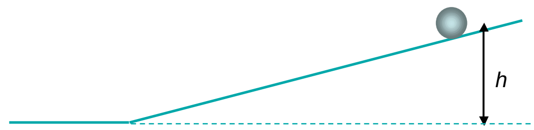


Potential E independent of path

- Since the gravitational force is pointed directly downward, only the vertical distance determines the potential energy.
- We say it is 'independent of the path'
- This is true for most 'non-contact' (field) forces.
  - Gravity
  - Electromagnetism
  - Nuclear forces

Testing conservation of energy

- Speed at bottom of ramp should be related to change in potential energy.
- On flat section, use timer and distance traveled to determine speed.



Power

$$P = \frac{Work}{time}, \quad \frac{\text{Joules(J)}}{\text{second(s)}} \equiv \text{Watts (W)}$$

Power is the rate at which work is done

It is measured in Watts.

(also Horsepower, 1 horsepower = 750 Watts)

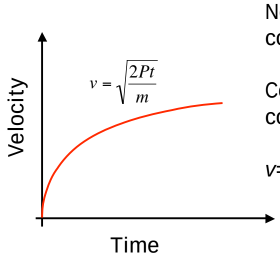
Example

- Suppose the engine of a car puts out a fixed power *P*.
- How would the velocity of the car change with time if all that power went directly to moving the car?

Power is energy transfer / unit time.
Energy appears as kinetic energy of car $E_{kinetic}=(1/2)mv^2$

So $E_{kinetic}$ increases at constant rate, $E_{kinetic} = Pt$
Then $v^2=2Pt/m$, $v = \sqrt{\frac{2Pt}{m}}$

Velocity for fixed power



Not the same as a constant force.

Constant force gives constant acceleration

$v=at$ (constant force)

Can get back to total energy

- (Power)x(time) = Energy
- If power is in kilowatts = 1000 J/sec, Then can talk about a kilowatt-hour
- 1 kW-hour = (1000 J / sec)x(3600 sec) = $3.6\text{x}10^6$ J = 3,600,000 J

Energy is also measured in other ways

- Thermal energy sometimes measured in calories.
- 1 calorie ~ 4200 J = amount of thermal energy required to raise 1 kg of water 1˚C.
- But all energy is equivalent.
- Many times it changes form.