PHY131H1F - Hour 19

Today:

7.1 Work and Energy

7.2 Conservation of Energy

Hello!

- My name is Jason Harlow, and I’ll be teaching the rest of this course, up until the final exam in December.
- My email I’d like you to use is phy131@physics.utoronto.ca
- My office hours in MP129, are M2, W3, R11
- I will start each class at 10 after the hour, and stop talking on the hour. After class, I will exit the room through the door to the right, to clear the stage for the next professor.
- I will be available for questions and comments for up to half-an-hour immediately after class in the hallway outside this door.

Who am I?

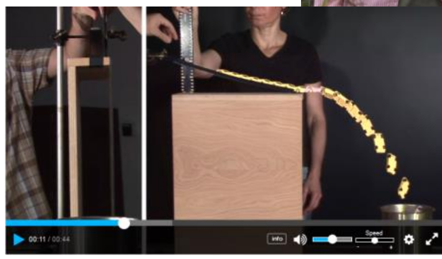
- Here are five random things about me:

1. I ride my bike to work.
2. I have four children and two stepchildren, so 6 total. They range in age from 4 to 23.
3. I discovered a star when I was an undergraduate here at U of T, using the David Dunlap Observatory in Richmond Hill.
4. I have family, through my wife, in Pakistan. I visited Karachi in 2012, and I'm planning another visit next year.
5. My PhD was entitled, "The Faint End of the Stellar Luminosity Function", which I completed at Penn State University.

Okay, Let's Get Going!

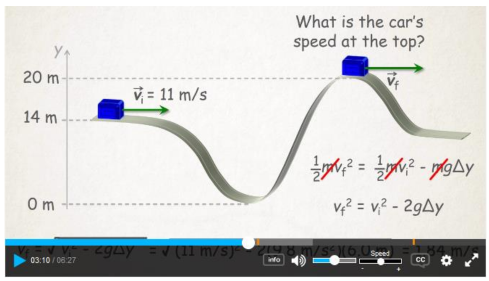
- Brian said he finished up chapters 1-6, so, today I'll start in with Chapter 7 on Work and Energy
- Notice that Homework 7 has been posted on MasteringPhysics. It is due Friday Nov.2.
- Also, I have posted an optional item called "Ch.7 Videos – Optional" which I recommend you check out.

Chapter 7 Videos (Optional)



- These are available on MasteringPhysics – along with conceptual questions based on the videos (all optional – no marks involved).
- (1) The author, Eugena Etikina, actually does the Testing Experiment on page 182.
- (2) “Buzzcut Guy” holds a swinging bowling ball to his chin and lets it go!

Chapter 7 Videos (Optional)



- These are available on MasteringPhysics – along with conceptual questions based on the videos (all optional – no marks involved).
- (3), (4) and (5) are slick Pearson videos explaining Work, Kinetic Energy, and the Work-Energy Principle, using Khan-Academy style drawings and showing solved problems.

What's the Big Idea?

- Last week, Brian asked you about oranges in a bag.
- If you have 10 oranges in your bag, and you give away 2 oranges to your friend, how many are left?
- In your bag: 8
- In the universe: 10!
- So, once you define a "system", you can say that things are conserved or not conserved.
- You could also plant an orange tree in your back yard, in which case oranges can be added to the universe! (Oranges are not conserved in physics..)

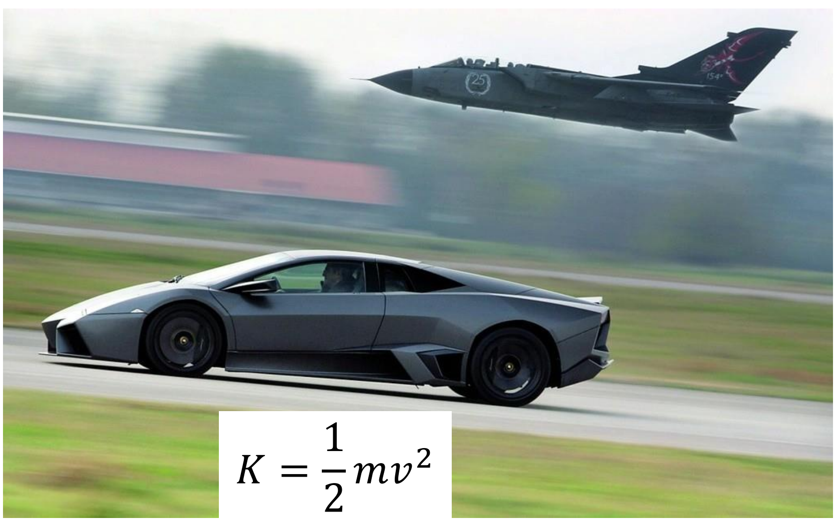
What's the Big Idea?

- Chapters 6 and 7 introduce the principles of **conservation of momentum** and **conservation of energy**. These concepts give us new useful ways of analyzing motion.
- Some quantities stay the same while other things around them change.
- For example, when a dish falls to the floor and shatters, the initial mass of the plate should equal the total final mass of all the pieces. This is "Conservation of Mass": $M_i = M_f$.
- Similarly, we have "Conservation of Momentum" ($\vec{p}_i = \vec{p}_f$), and "Conservation of Energy" ($E_i = E_f$): two new principles which we will use to solve problems.

What is “energy”?

- Energy is a property of an object, like age or height or mass.
- Every object that is moving has some Kinetic Energy K.
- An object in a gravitational field also has some Gravitational Potential Energy U_g.
- Energy has units, and can be measured.
- Energy is *relative*; kinetic energy of car is different for an observer in the car than it is for an observer standing on the side of the road.

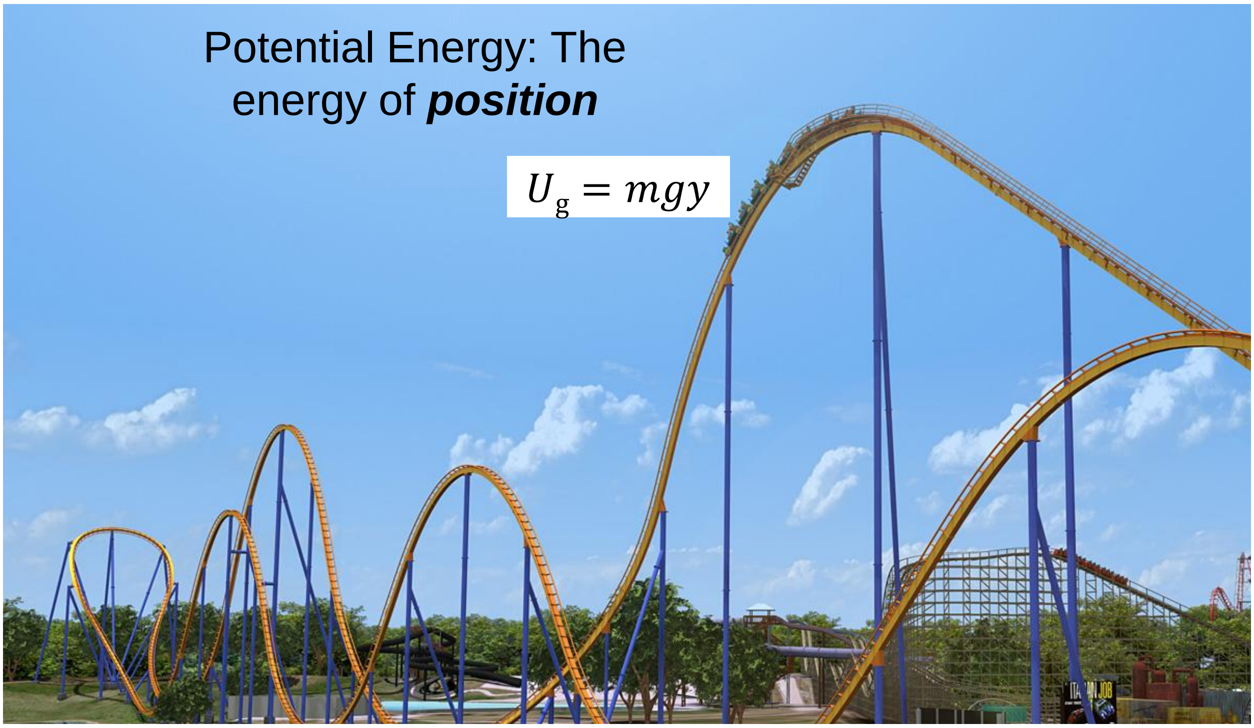
Kinetic Energy: The energy of ***motion***



$$K = \frac{1}{2}mv^2$$

Potential Energy: The energy of ***position***

$$U_g = mgy$$



Potential Energy: The energy of ***position***

$$U_s = \frac{1}{2}kx^2$$

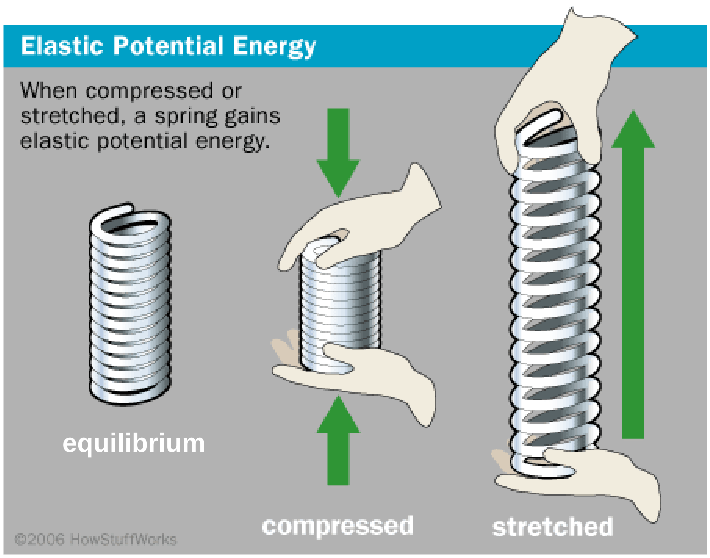
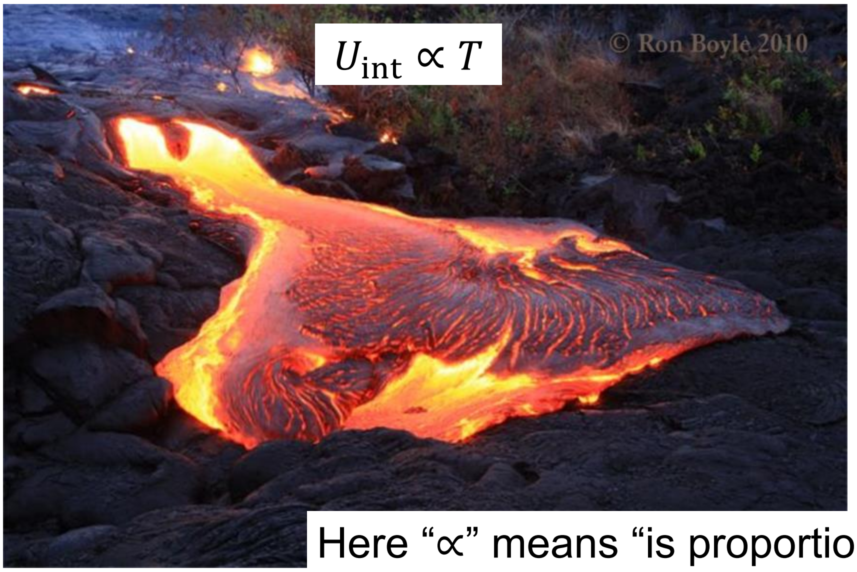


Image from https://energyeducation.ca/encyclopedia/Elastic_potential_energy

Internal Energy: The energy of
microscopic thermal vibrations



Here "∝" means "is proportional to"

Dominoes

- A domino is a rectangular solid which can be balanced on its edge
- When standing upright, its gravitational potential energy is a maximum

- This is a state of **unstable equilibrium**: a small perturbation can cause the domino to fall, transforming its gravitational potential energy into kinetic energy
- As it is falling, it can perturb its neighbor, which then releases its potential energy: a ***chain reaction*** can ensue!

The most basic form of energy: **Work**

- involves force and distance.
- is force × distance.
- in equation form: $W = F\, d \cos\theta$
- Here θ is the angle between the force and displacement

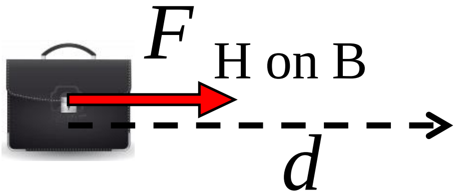
Two things occur whenever work is done:

- application of force
- movement of something by that force

SI Unit of work:
newton-meter (N·m)
or joule (J)

Work can be positive, zero or negative

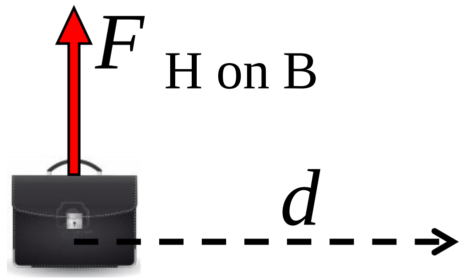
- Your hand (H) pulls a briefcase (B) to the right and it moves to the right.
- When the force and the distance are in the *same* direction, you are *helping* the motion with the force, so the work done on the object is **positive**.
- The force is *adding energy* to the object + environment.
- Maybe this force is speeding the object up.



Work can be positive, zero or negative

- Your hand (H) supports a briefcase (B) with an upward force, as the briefcase moves to the right.
- When the force and the distance are *at right angles*, you are *not* helping the motion with the force, so the work is **zero**.
- This force is *not changing* the energy of the object.

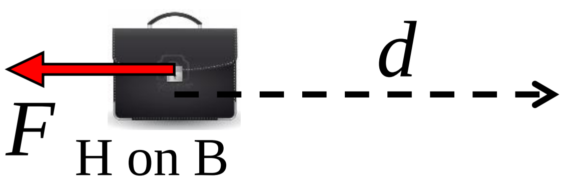
- This force won't speed the object up or slow it down.



Work can be positive, zero or negative

- Your hand (H) pulls a briefcase (B) to the left, while, for some reason, the briefcase moves to the right.
- When the force and distance are in *opposite* directions, you are *hindering* the motion with the force, so the work done on the object is **negative**.
- This force is *reducing* the energy of the object.

- Maybe this force is slowing the object down.



Discussion Question

- Justin is doing a bench press, and he slowly pushes the bar up a distance of 0.30 m while pushing upwards on the bar with a force of 200 N. The bar moves with a constant velocity during this time.
- During the upward push, how much **work** does Justin do on the bar?

A. 60 J
B. 120 J
C. 0 J
D. -60 J
E. -120 J

Discussion Question

- Justin is doing a bench press, and he slowly lowers the bar down a distance of 0.30 m while pushing upwards on the bar with a force of 200 N. The bar moves with a constant velocity during this time.
- During the downward lowering, how much **work** does Justin do on the bar?

A. 60 J
B. 120 J
C. 0 J
D. -60 J
E. -120 J

Discussion Question

- Justin is doing a bench press, and he slowly lowers the bar down a distance of 0.30 m while pushing upwards on the bar with a force of 200 N. He then pushes it up slowly the same distance of 0.30 m back to its starting position, also pushing upwards on the bar with a force of 200 N.
- During the complete downward and upward motion, how much total **work** does Justin do on the bar?

A. 60 J
B. 120 J
C. 0 J
D. -60 J
E. -120 J

Generalized work-energy principle:

- The sum of the initial energies of a system plus the work done on the system by external forces equals the sum of the final energies of the system:

$$E_i + W = E_f$$

- This is similar to $E_i = E_f$, except now you can have positive or negative energy added by outside forces.
- You only use W if the outside force is something other than gravity or spring-force.
- That's because gravity and spring force have potential energy U which takes into account their work already.

Demonstration

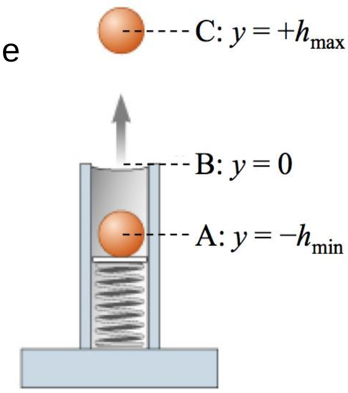
A spring-loaded toy gun is used to shoot a ball of mass m straight up in the air. The spring has spring constant k. The ball has speed v_B at point B.

- The Spring has potential energy U_s, and the ball/earth system has gravitational potential energy U_g, and the ball has kinetic energy K. The energy conservation equation is:

$$E_i + W = E_f$$

$$U_{si} + U_{gi} + K_i + W = U_{sf} + U_{gf} + K_f$$

- Here W is the work done by forces that don't have a potential energy associated with them, like a hand pushing or sliding friction with the floor.
- In this demonstration, we assume $W = 0$.

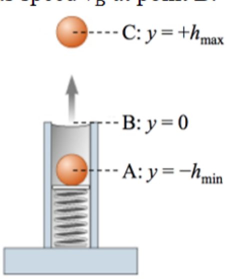


[go to Doc-Cam notes]

Energy Bar Charts

A spring-loaded toy gun is used to shoot a ball of mass m straight up in the air. The spring has spring constant k. The ball has speed v_B at point B.

Consider time A to time B.

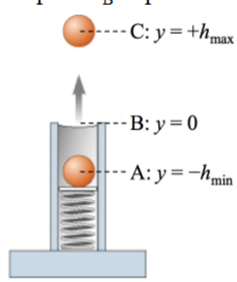


$$U_{sA} + U_{gA} + K_A + W = U_{sB} + U_{gB} + K_B$$

Energy Bar Charts

A spring-loaded toy gun is used to shoot a ball of mass m straight up in the air. The spring has spring constant k. The ball has speed v_B at point B.

Consider time B to time C.

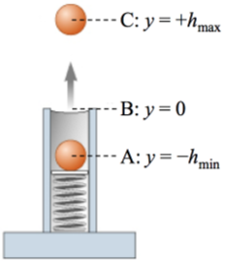


$$U_{sB} + U_{gB} + K_B + W = U_{sC} + U_{gC} + K_C$$

Energy Bar Charts

A spring-loaded toy gun is used to shoot a ball of mass m straight up in the air. The spring has spring constant k. The ball has speed v_B at point B.

Or, if you want, you can even skip B and consider time A to time C!



$$U_{sA} + U_{gA} + K_A + W = U_{sC} + U_{gC} + K_C$$

Generalized work-energy principle:

- 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 × distance).

Learning Catalytics Question (from a former PHY131 final exam)
Yesterday in my office I pushed a box, initially at rest, across the rough floor to the other side of my office, where it now rests. Which statement below is true concerning this motion of the box?

(A) I did positive work on the box, friction did negative work on the box, there was net positive work done on the box.

(B) I did positive work on the box, friction did negative work on the box, there was net negative work done on the box.

(C) I did positive work on the box, friction did negative work on the box, there was net zero work done on the box.

(D) I did zero work on the box, friction did negative work on the box, there was net positive work done on the box.

(E) I did zero work on the box, friction did positive work on the box, there was net zero work done on the box.