PHY131H1F - Hour 19


New guy

**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 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.

## Brief Contents



PHY 131



PHY132

Mastering Physics

# What's up on the MyLab and Mastering?

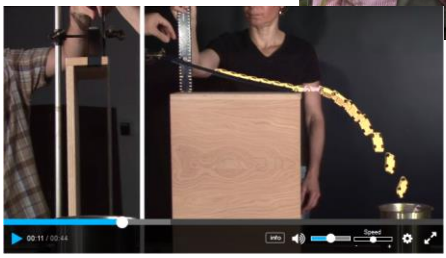
- Notice that Homework 7 has been posted on MasteringPhysics. It is due Friday Nov.2.
- Also, I have posted an optional item called "Ch.7 Videos – Optional" which I recommend you check out.

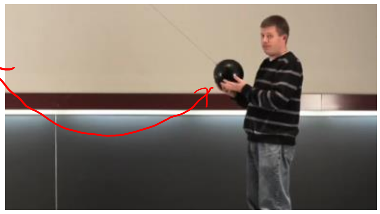
Mastering Physics

The author

# Chapter 7 Videos (Optional)

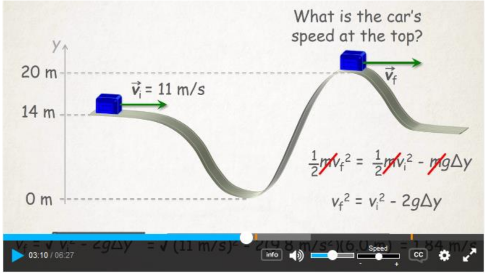
- These are available on MasteringPhysics – along with conceptual questions based on the videos (all optional – no marks involved).
- (1) The author, Eugena Etikina, actually does the Testing Experiment on page 182.
- (2) "Buzzcut Guy" holds a swinging bowling ball to his chin and lets it go!





Mastering Physics

# 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..)

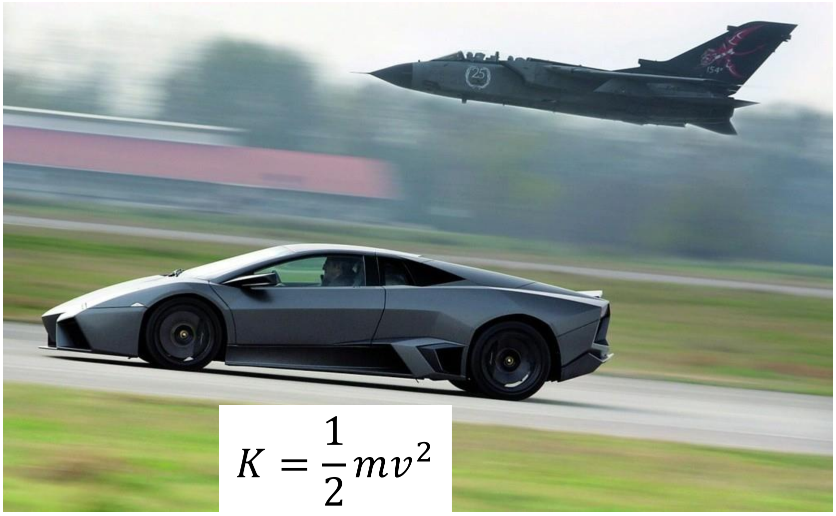
# What's the Big Idea?

- 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"?

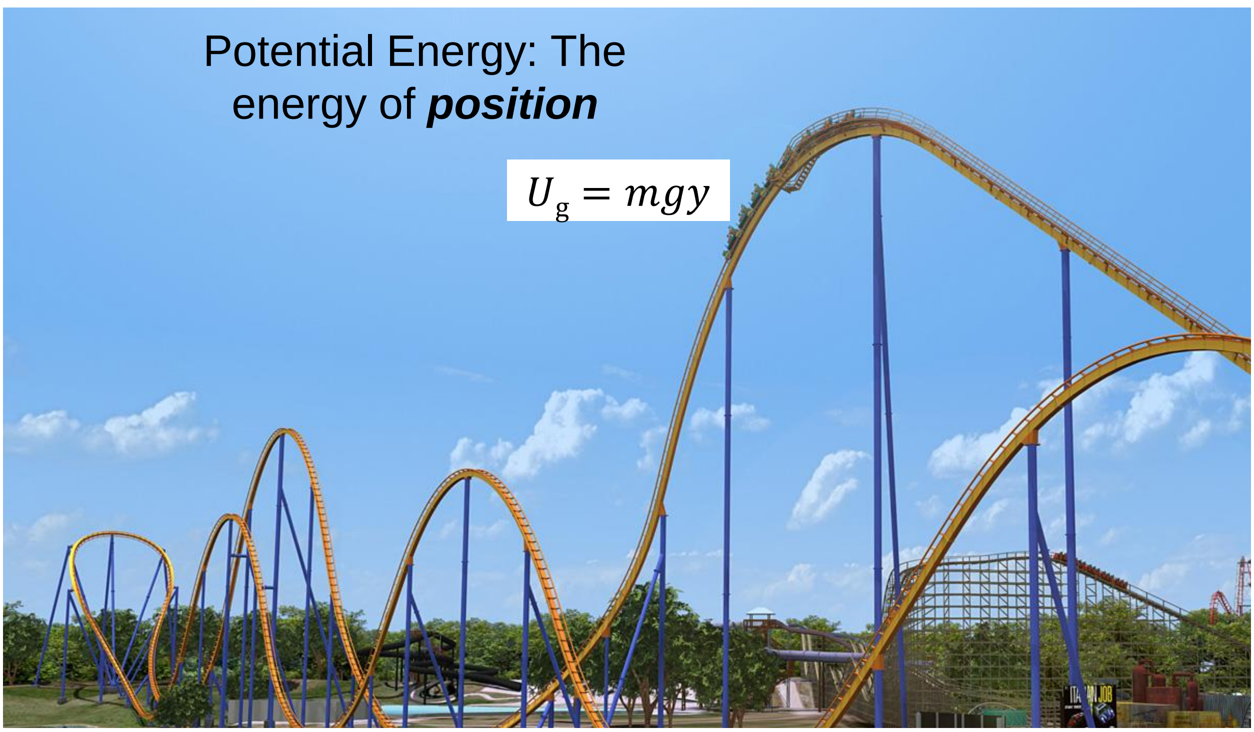
- Energy is a property of an object, like age or height or mass.
- Every object that is moving has some Kinetic Energy $K$.
- An object in a gravitational field also has some Gravitational Potential Energy $U_g$.
- Energy has units, and can be measured.
- Energy is *relative*; kinetic energy of car is 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***

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

x = distance of end from equilibrium

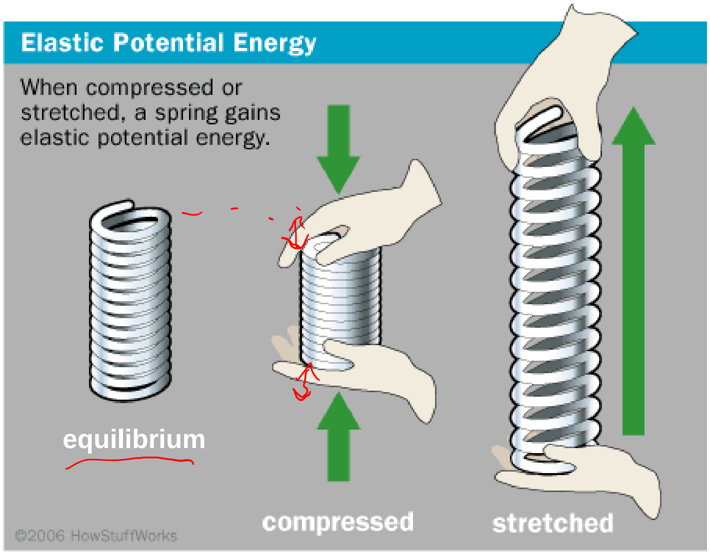
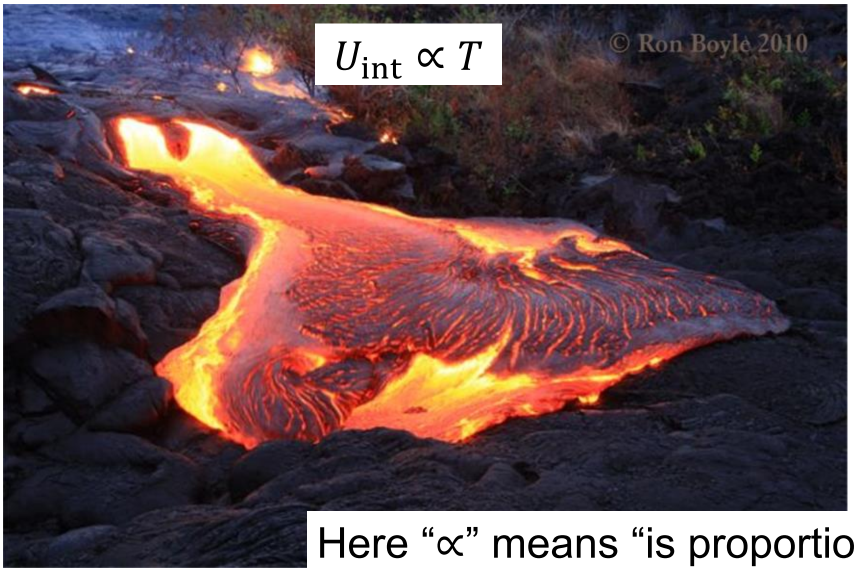



Image from https://energyeducation.ca/encyclopedia/Elastic_potential_energy

## Internal Energy: The energy of ***microscopic thermal vibrations***

$$U_{\text{int}} \propto T$$




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

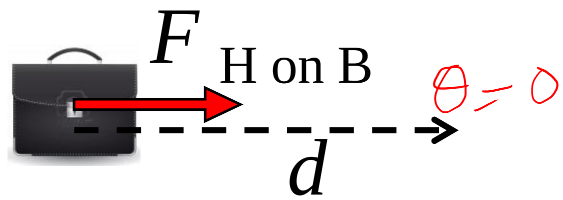
Two things occur whenever work is done:

- application of force
- movement of something by that force

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

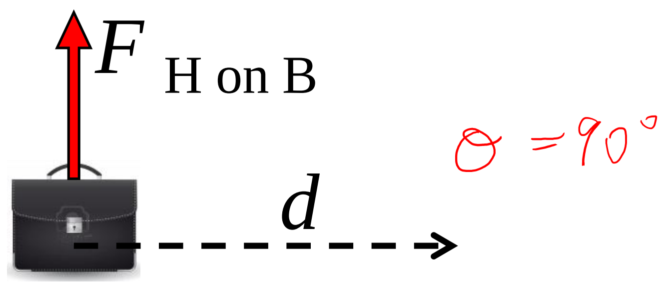
## Work can be positive, zero or negative

- 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.



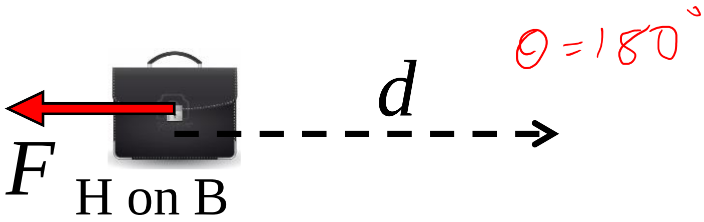

## Work can be positive, zero or negative

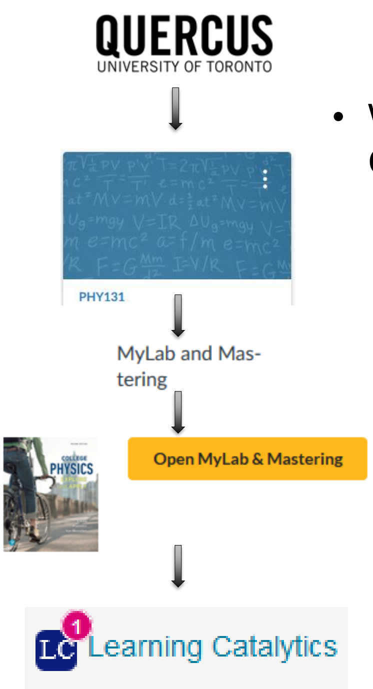
- Your hand (H) supports a briefcase (B) with an upward force, as the briefcase moves to the right.
- When the force and the distance are *at right angles*, you are *not* helping the motion with the force, so the work is **zero**.
- This force is *not changing* the energy of the object.
- This force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




# Survey Question (not for marks)

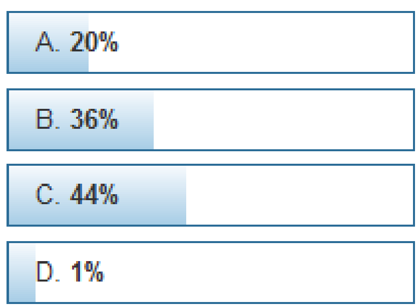
- What kind of device are you doing this Learning Catalyltics question on?

A. I am using my phone.

B. I am using a laptop or tablet because I prefer it to a phone.

C. I am using a laptop or tablet because because I believe/know there are technical difficulties with doing Learning Catalytics on a phone.

D. Other / prefer not to answer



F, d = 0.3 m

$\theta = 0^\circ$

$W = Fd\cos\theta$

$= (200)(0.3)$

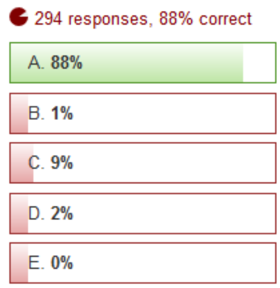
$= 60\ N\cdot m$

$= 60\ J$

## 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




$\vec{F}_{J\ on\ B}$

$\theta = 180^\circ$

d

$W = Fd\cos 180$

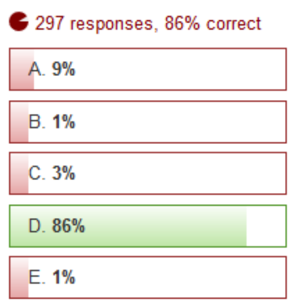
$= -(200)(0.3)$

$= -60\ J$

## 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?

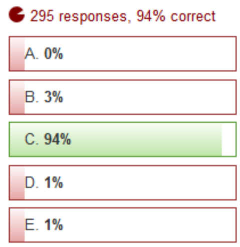
A. 60 J
B. 120 J
C. 0 J
D. -60 J
E. -120 J




# 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 **Work, *W***: positive or negative energy added by outside nonconservative forces.

# Demonstration

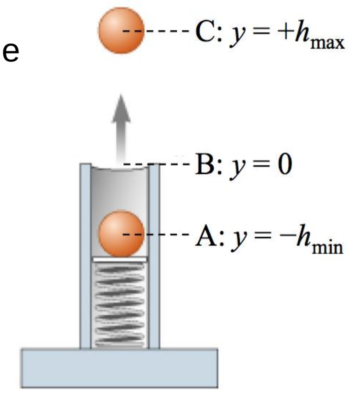
A spring-loaded toy gun is used to shoot a ball of mass $m$ straight up in the air. The spring has spring constant $k$. The ball has speed $v_B$ at point B.

- 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 $W = 0$.

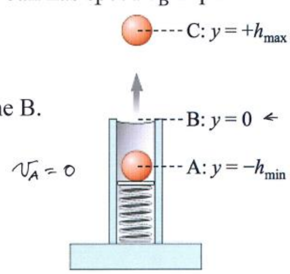



[go to Doc-Cam notes]

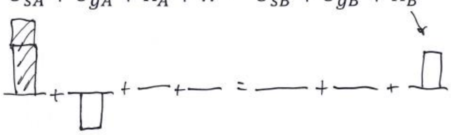
## ① Energy Bar Charts

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.




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



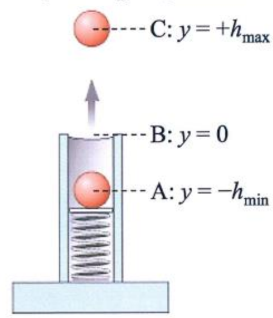
$$\frac{1}{2}kx_A^2 + (mg(-h_{min})) + 0 + 0 = 0 + 0 + \frac{1}{2}mv_B^2$$

$$\frac{1}{2}kh_{min}^2 - mgh_{min} = \frac{1}{2}mv_B^2$$

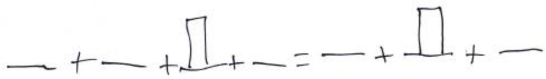
## ② Energy Bar Charts

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.




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

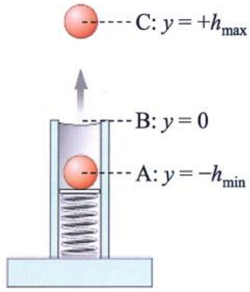


$$\frac{1}{2}mv_B^2 = mgh_{max}$$

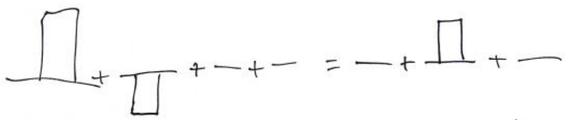
## ③ Energy Bar Charts

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!

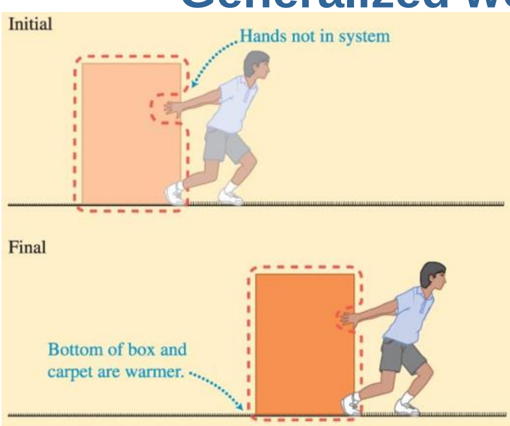



$$U_{sA} + U_{gA} + K_A + W = U_{sC} + U_{gC} + K_C$$

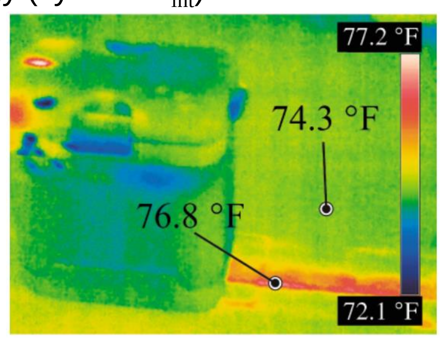


$$\frac{1}{2}k h_{min}^2 - mgh_{min} = mgh_{max}$$

## Generalized work-energy principle:




- If a object slides on a surface, the surfaces in contact can become warmer.
- Structural changes in an object can occur when an external force is applied.
- The energy associated with both temperature and structure is called internal energy (symbol $U_{int}$).




- A “thermal camera” detects infrared waves (just like light waves, but human eyes are not sensitive to these wavelengths)
- Warm things glow in the infrared

**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.