PHY131 F Fall 2020
Class 19

Today:

6.7 Collisions in 2D

7.1 Work and Energy

7.2 Conservation of Energy

1

A yellow Hummer (m_H = 3900 kg) was driving South and collided with a blue Toyota (m_T = 1200 kg) which was driving East. The speed limit on both roads is 50 km/hr.

After the collision, the two cars stuck together and the combined mass skidded along the ground.

The police measure that the skid marks are a line 10 m long, angled 32° East of South.

The coefficient of kinetic friction between rubber and road is 0.8.

How fast were the cars going before the collision? Who is at fault?

SKETCH & TRANSLATE.

2

How fast were the cars going before the collision? Who is at fault?

SIMPLIFY & DIAGRAM

REPRESENT MATHEMATICALLY

3

How fast were the cars going before the collision? Who is at fault?

SOLVE & EVALUATE

4

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.

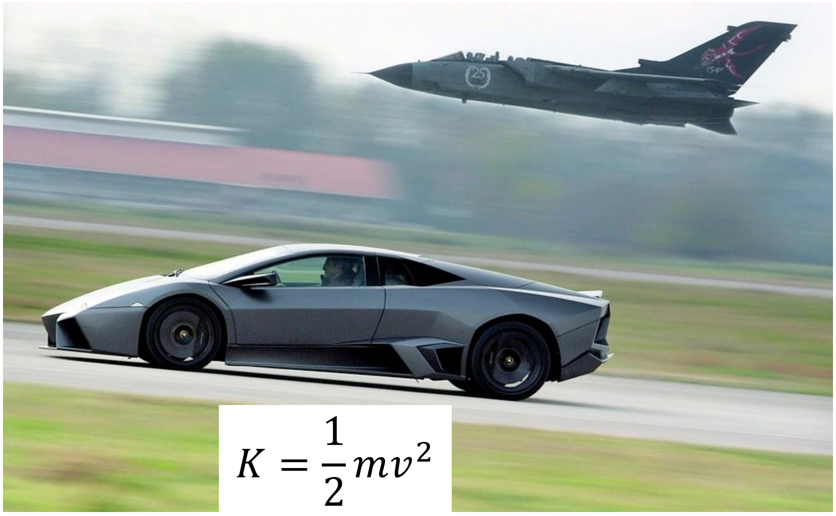
5

What is “energy”?

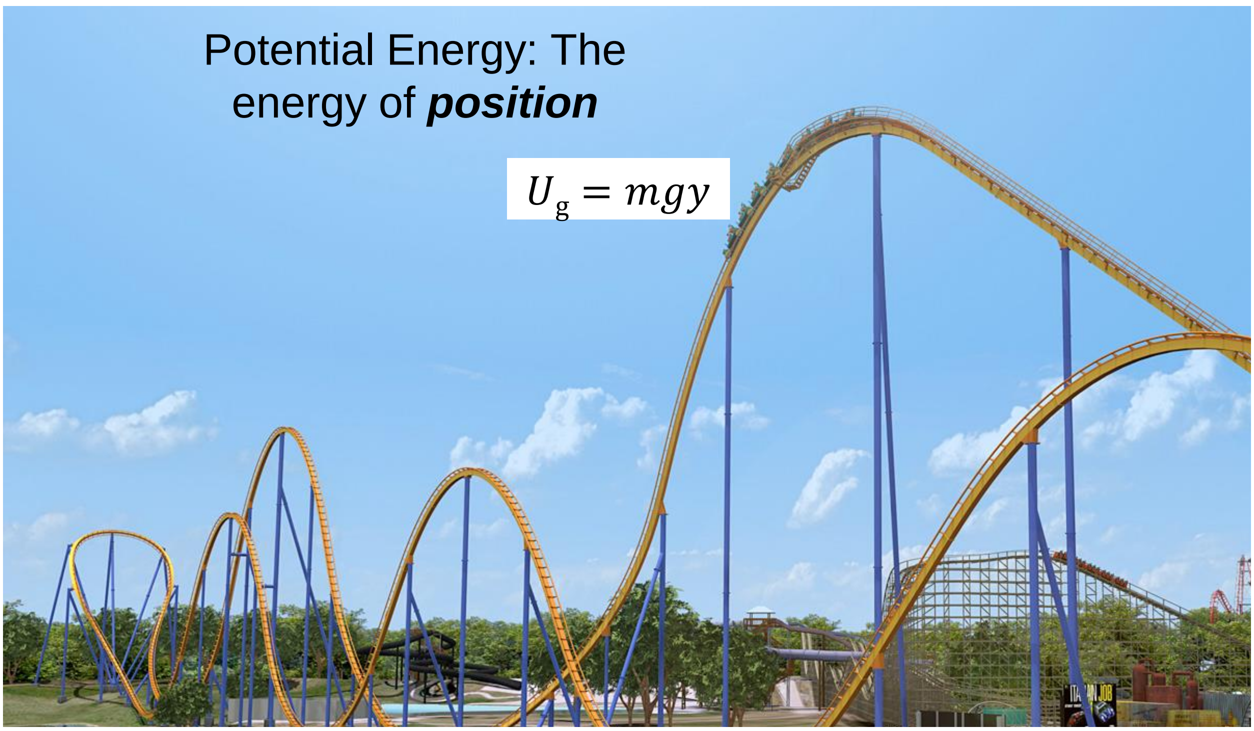
- Energy is a property of an object, like age or height or mass.
- Every object that is moving has some Kinetic Energy K.
- An object in a gravitational field also has some Gravitational Potential Energy U_g.
- Energy has units, and can be measured.
- Energy is *relative*; kinetic energy of car is different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

6

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



7



8

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

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

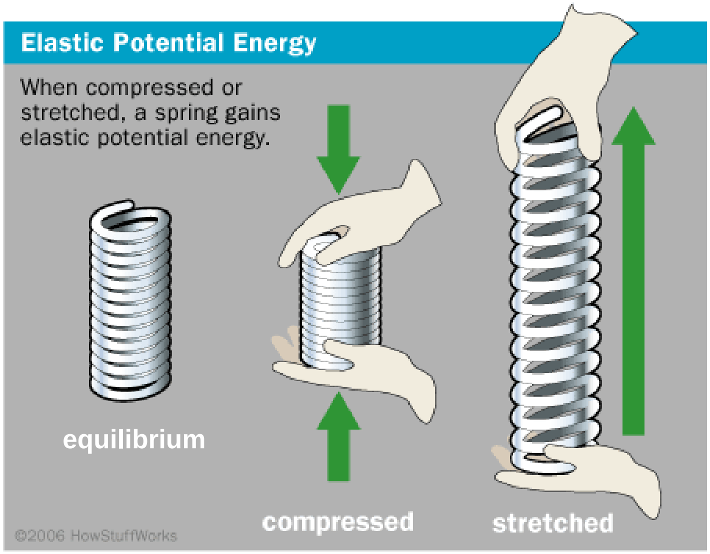
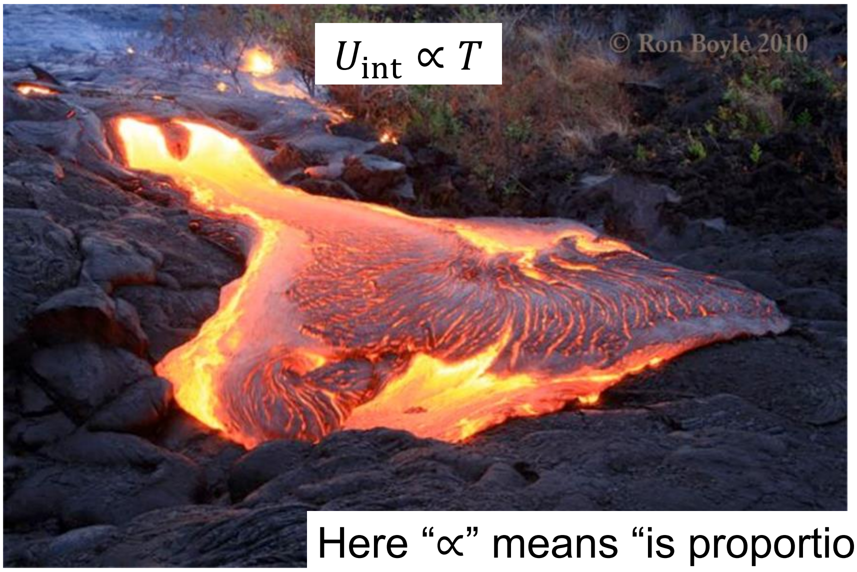


Image from https://energyeducation.ca/encyclopedia/Elastic_potential_energy

9

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



Here "∝" means "is proportional to"

10

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!

11

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

- involves force and distance.
- is force $\times$ 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

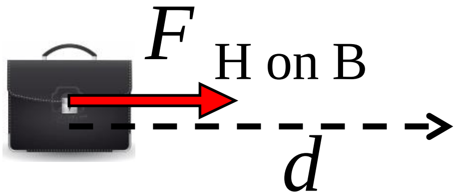
SI Unit of work: newton-meter (N·m) or joule (J)

12

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.

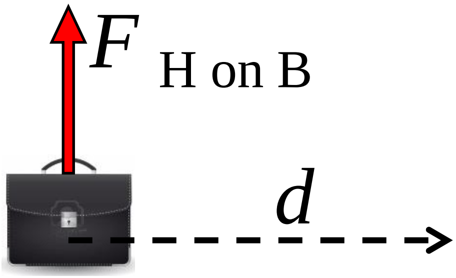


13

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.

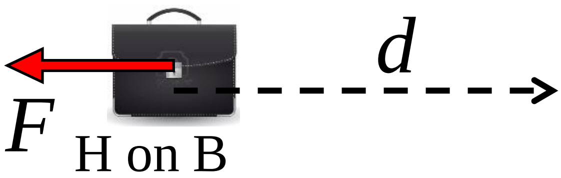


14

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.



15

Poll 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

16

Poll 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

17

Poll 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

18

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.

19

Example

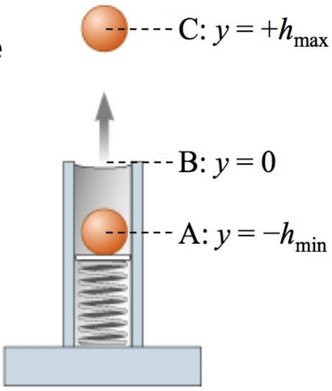
A spring-loaded toy gun is used to shoot a ball of mass m straight up in the air. The spring has spring constant k. The ball has speed v_B at point B.

- 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 example, we assume $W = 0$.

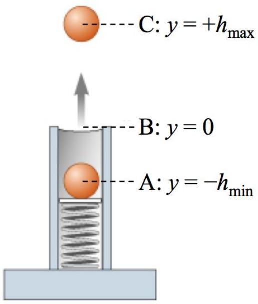


20

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.



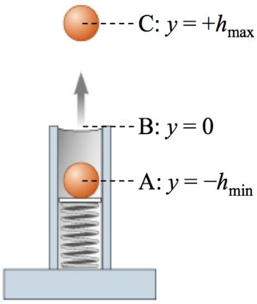
$$U_{sA} + U_{gA} + K_A + W = U_{sB} + U_{gB} + K_B$$

21

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.

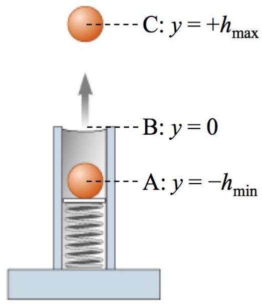


$$U_{sB} + U_{gB} + K_B + W = U_{sC} + U_{gC} + K_C$$

22

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.

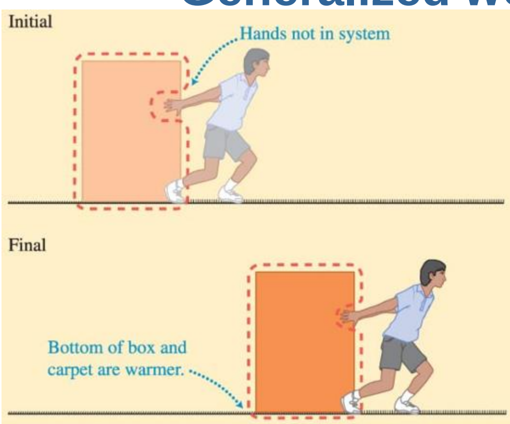


Or, if you want, you can even skip B and consider time A to time C!

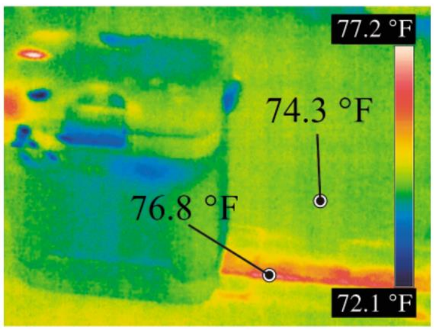
$$U_{sA} + U_{gA} + K_A + W = U_{sC} + U_{gC} + K_C$$

23

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

24

Poll 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.

25

Midterm Assessment #3

- Each online half-hour assessement is worth between 10% and 12.5% of your mark in this course.
- The lowest of five assessment scores will be dropped.
- The assessment will become available on Quercus to start at 8:10pm tomorrow evening, Toronto time (ie 32 hours from right now)
- If you are registered for the alternate sitting, then you do the whole thing exactly 2 hours later.
- If you miss the assessment, you get a zero.

26

Midterm Assessment #3

- The assessment is "open book"; allowed aids include your course notes, the textbook, videos, google-searches for static web-pages, a calculator, Excel, Python, etc.
- You must work on the assessment **individually**.
- No group work or chats with other students are allowed during the assessment.
- Once you start there will be a 30-minute timer
- The assessment ends when your personal 30-minute timer elapses, or 8:45pm, whichever comes *first*.

Midterm Assessment #3

- You will see one question at a time, in a random order.
- You must submit each answer by clicking Next in order to see the next question; you will **not** have the ability to go back change any answer after it has been submitted.
- After completing all 10 questions you must click Submit Quiz before the time has ended.
- There are 4 conceptual questions and 6 numerical questions.
- You **will** need a calculator, or Excel or something to do these. You should have pencil and paper ready for rough work.

Midterm Assessment #3

- All questions are Multiple Choice, marked automatically.
- The average time per question is 3 minutes, but numerical questions will likely take longer than conceptual, so do not linger long on the conceptual questions.
- Material will cover mostly questions and problems from Chapters 5 and 6 from Etkina. Chapters 2-4 are also important to remember, but are not specifically tested in this assessment.
- There will be at least one question based on your work in Practicals 2a and b and 3a.

29

Before Class 20 on Wednesday

- Please read:
- 7.3 Kinetic Energy, Gravitational Potential Energy
- 7.4 Elastic Potential Energy
- 7.5 Work of Sliding Friction

- Good luck on tomorrow's test! 24 + 8 hours from right now!

30