PHY 211 Lecture 17

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Welcome to online

- Today is the start of a new experiment
- We are doing our best, but things may not always work smoothly
- We want your feedback, so let us know via one of the different mediums
- All this info subject to change if something is not working
- Communication (with us and each other) is key: one solution we started is a Discord channel `https://discord.gg/dcM4DYM`
- Syllabus addendum on the website: `https://walterfreeman.github.io/phy211/syllabus-addendum.html`

The plan

- We are trying to minimize changes to the class
- We still have live lectures through Blackboard Collaborate video; we will try out recording pieces of it
- We have live recitations on Blackboard Collaborate:
  - If possible, come at your scheduled time (helps us assign enough TAs and coaches)
  - We want you to pick groups to work with so people who communicate well are together
  - We will accommodate offline work if needed
- Will still have homework, just submitted on Blackboard now

Grading

- We want you to submit on Blackboard a brief description of how you worked on the recitation material for attendance grade and feedback to us
- No real changes to homework
- Paper on process of science still on
- Exams will exist but change format to 24-hour exams
- Group exam 3 is now not graded and dropped from the grade total

Getting help

- Professors will host online help sessions to replace old office hours
- Physics clinic is becoming a Zoom meeting: more information on the website. TAs will be there weekdays from 1pm to 7pm EDT
- Talk to other students! Check out the Discord https://discord.gg/dcM4DYM or form your own online groups
- Let us know by email or otherwise if you have any issues with the available online tools and we can work with you to find a solution

Power

- If something does work over time, we say that the average power is

$$\langle P \rangle = \frac{\Delta W}{\Delta t}$$

- Like we did with motion, the instantaneous power is
$$P = \frac{\mathrm{d}W}{\mathrm{d}t}$$

What does power mean?

- The colloquial definition in this case gets us somewhere close
- A car with more engine power gets up to speed faster (smaller Δt for the same ΔW)
- Remember that ΔW tells you the increase of speed from the work energy theorem

$$\frac{1}{2}m\Delta\left(v^2\right) = W_{\text{net}} = P\Delta t \text{ or } \int P\,\mathrm{d}t$$

- Electrical power is similar but we won't deal with the underlying physics of that this semester

Units of energy and power

- Energy has units of force times distance
- From our definition we can see that power will be units of energy / time

The Joule

$$1\,\mathrm{J} = 1\,\mathrm{kg\,m^2/s^2}$$

The Watt

$$1\,\mathrm{W} = 1\,\mathrm{J/s}$$

- Back to the car engine, you may have heard of horsepower, $1 \text{ hp} = 746\,\mathrm{W}$

Example

A 500 kg dragster accelerates from rest to a final speed of 110 m/s in 400 m (about a quarter of a mile) and encounters an average frictional force of 1200 N. What is its average power output if this takes 7.30 s?

image by GSenkow on wikimedia

Work–energy problems

Strategy

1. What forces act on the system?
    1. Draw a free body diagram, then find the components of all the forces
    2. You may have to apply Newton's second law – for example to find the normal force to get the friction
2. What is the direction of the displacement?
3. For each force, write an expression for the work done
4. Add up the work, and set equal to the change in kinetic energy

Another way to calculate power

- Sometimes it can be useful to use this formula

$$P = \frac{\mathrm{d}W}{\mathrm{d}t} = \frac{\vec{\mathbf{F}} \cdot \mathrm{d}\vec{\mathbf{r}}}{\mathrm{d}t}$$

$$= \vec{\mathbf{F}} \cdot \frac{\mathrm{d}\vec{\mathbf{r}}}{\mathrm{d}t} = \vec{\mathbf{F}} \cdot \vec{\mathbf{v}}$$

- Consider the car – it will have some maximum power at its top speed
- P/v will tell you the force it is applying, which must be cancelled by friction and drag

Potential energy

- We've already introduced the idea of kinetic energy, and how work can increase or reduce it
- One force that does work is gravity
- Where does the energy come from?

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- We've already introduced the idea of kinetic energy, and how work can increase or reduce it
- One force that does work is gravity
- Where does the energy come from?
- We say there is a gravitational potential energy that gets converted into kinetic energy through work

$$\Delta U = mg\Delta h$$

Absolute energy?

- I used Δh to emphasize that we only really care about ΔU
- For just U, you can pick the ground as $h = 0$, and above the ground has positive potential energy
- Or you can pick the top of something as $h = 0$, and below that point has negative potential energy
- Either way is fine – this is just like choosing your coordinate system in motion problems

Cat toy problem

A cat toy with a mass m is thrown upward with a speed v. How high does it go? What are the kinetic and potential energies of the toy at various parts of the trip up and down?

Pre-lecture question 2

- An external force acts on a particle during a trip from one point to another and back to that same point. This particle is only affected by conservative forces. How does this particle's kinetic energy and potential energy change during this trip?

(a) They are both different at the end. (11%)
(b) They change during the trip, but are both the same at the end. (75%) ✓
(c) They are each the same throughout the trip. (8%)
(d) Only the potential energy changes, while the kinetic energy remains the same. (6%)

Conservation of (mechanical) energy

Change in mechanical energy

$$W_{\text{non-cons.}} = \Delta(K + U)$$

- If the non-conservative forces are zero or do no work, then $W_{\text{non-cons.}} = 0$

Gravity example

$$0 = \Delta(K + U)$$

$$\frac{1}{2}mv_i^2 + mgh_i = \frac{1}{2}mv_f^2 + mgh_f$$

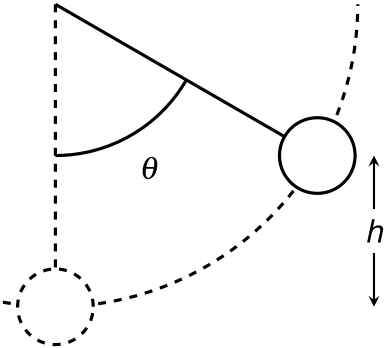
Pre-lecture question 3

- Which of the following statements about the energy of an object in motion is true?

(a) The object's potential energy is always conserved. (6%)
(b) The object's total energy is always conserved. (24%)
(c) If there are no dissipative (non-conservative) forces, then the object's kinetic energy is conserved. (8%)
(d) If there are no dissipative (non-conservative) forces, then the object's total energy is conserved. (59%) ✓

The pendulum

A pendulum of mass *m* with a string of length 1.0 m is pulled back so that it makes an angle of 30° with the vertical. What will be its velocity at the bottom of the arc?



Pre-lecture question 1

- For which of the following forces can we write down an expression for potential energy?

(a) Normal force (10%)

(b) Friction (1%)

(c) Tension (4%)

(d) Spring force (85%) ✓

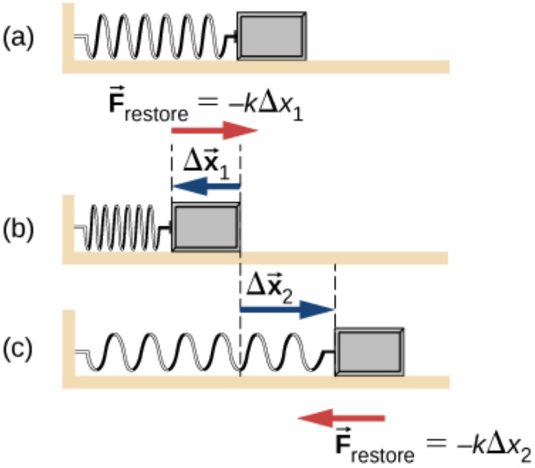
Spring forces

- Springs don't want to be stretched or compressed
- Create a restoring force that is linear in displacement

Hook's law

$$\vec{\mathbf{F}} = -k\Delta\vec{\mathbf{x}}$$

- k is the "spring constant" and depends on the actual construction of the spring



Elastic potential energy

or spring potential energy

- Since the spring applies its force over some distance, it does work
- Where does the energy come from?

Elastic potential energy

or spring potential energy

- Since the spring applies its force over some distance, it does work
- Where does the energy come from?
- It was stored as potential energy inside the stretched or compressed spring

$$U_{\text{spring}} = \frac{1}{2}k(\Delta x)^2$$

- We almost always choose the “natural” spring length as the zero of this potential
- Note this potential is always positive

Other types of potential energy

- Previous two examples are the main ones for problems in this class
- There are other types of potential energy that you should be able to recognize:
  - Electromagnetic potential energy
  - Chemical energy

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- There are other types of potential energy that you should be able to recognize:
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  - Chemical energy
- We won't be quantifying these with an easy formula, but consider:

Image of Antares Orb-3 explosion by NASA

Energy conservation

Extra information

- In reality, energy is always conserved
- But when we're doing problems in this class, we don't keep track of it all
- This is similar to what we said about momentum:
  - It was conserved if there were no external forces

Is energy conserved?

How do we know?

- Are the only forces acting conservative? Yes, energy is conserved
- Is there any other external force acting on the combined system?
  - If there is a net force it can add energy to or subtract it from the system if it does work No, energy is not conserved
  - But if they do no work, *e.g.* normal force when sliding on a track Yes, energy is conserved
- Are there dissipative forces like friction acting, even between objects inside the combined system? No, not conserved
  - Main things to look for are friction, objects becoming deformed, or objects sticking together
- Occasionally we will use words that indicate energy conservation — *e.g.* we will discuss elastic collisions next week

Throwing a rock

Say you want to throw a rock off a bridge into the water. No matter which direction you throw, it always leaves your hand with the same speed. Air resistance is negligible. Which way should you throw to make the rock have the highest speed when it hits the water?

(a) Angled up

(b) Straight ahead

(c) Angled down

(d) It doesn't matter

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- Think about the problem using energy instead of projectile motion

Spring example

Assume that the force of a bow on an arrow behaves like the spring force. In aiming the arrow, an archer pulls the bow back 50 cm and holds it in position with a force of 150 N. If the mass of the arrow is 50 g and the “spring” is massless, what is the speed of the arrow immediately after it leaves the bow?

Image by Jakub Jankiewicz on flickr