Review and recap

Physics 211
Syracuse University, Physics 211 Spring 2019
Walter Freeman

April 28, 2020

Finishing up the semester

Schedule for the end of the term:

- **Today:** Walter will have help hours 3-5 PM in the Clinic.
- **Wednesday, April 29**: No class. Walter will have help hours 8AM-10AM in the Clinic.
- **Thursday, April 30**: Walter will hold a review session from 1-4 PM on Blackboard Collaborate. HW14 due.
- **Friday, May 1**: Walter will hold a review session from 1-4 PM on Blackboard Collaborate. Papers due at end of day.
- **Saturday, May 2**: Walter will hold a review session from 8-11 PM on Blackboard Collaborate.
- **The following Monday, May 4**: Final exam posted at 9AM
- **Tuesday, May 5, at 11:59PM**: **Exam submissions due on Blackboard.** *(This is a slight change.)*

Final exam format

- Biased toward Unit 4
- The exam will be submitted on Blackboard, like before
- Expect a focus on broad concepts, especially from Units 1-3
- Expect things like:
  - Multiple choice questions of some variety or other:
    - Sometimes/always/never questions
    - Positive/negative/zero questions
  - "I give you the solution; you point out the error"
  - Dimensional analysis/reasoning with units
  - Fermi problem

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- As before, you may use any course materials and your notes, but not outside help

Kinematics concepts

- First derivative of position is velocity; second derivative is acceleration
- Kinematics lets us connect acceleration, velocity, position, and time
- If $\vec{a}$ is constant:

$$s(t) = s_0 + v_0 t + \frac{1}{2} a t^2$$
$$v(t) = v_0 + at$$
$$v_f^2 - v_0^2 = 2a\Delta x$$

- These relations hold separately and independently in x and y
- Acceleration is g downwards **if and only if** an object is in freefall

Kinematics sample problem: the ball-and-table problem

A ball rolls off of a table of height h at speed v. How far does it go?

Use kinematics when:

- You need to connect some combination of position, velocity, acceleration, and time

Force concepts and Newton's second law

- Newton's second law relates the net force $\sum \vec{F}$ to the acceleration $\vec{a}$ of the center of mass of an object
- If an object both rotates and moves, $\vec{F} = m\vec{a}$ gives you $\vec{a}$ of the center of mass
- Newton's third law: forces come in pairs
- Some forces you should know about:
  - Normal forces: as big as they need to be
  - Friction: $F_{\text{fric,static,max}} = \mu_s F_N$, $F_{\text{fric,kinetic}} = \mu_k F_N$
  - Traction: a type of static friction, points in direction chosen by the vehicle
  - Elastic: $F = -k\Delta x$
  - Gravity (Earth): $F = mg$ downward
  - Gravity (general): $F = \frac{Gm_1 m_2}{r^2}$
  - Tension: A rope pulls on both ends

Force diagrams

- Draw all forces acting on the object, as vectors
- If you're going to care about torque, draw the whole object and draw the forces where they act
- Gravity acts at the center of mass
- Draw these diagrams big enough that you can read them clearly and do trig

Uniform circular motion

- If an object is traveling in a circle, you know its acceleration is $a_c = \omega^2 r = \frac{v_T^2}{r}$ toward the center
- Often this will "give you" the right side of $F = ma$, and let you conclude something about the left

Use Newton's second law when:

- You need to connect the forces on an object to its acceleration
- If you don't need $\vec{a}$ directly, and don't care about time, maybe use energy methods instead?

Sample problem: the eraser in the tube

What angular frequency is required to make the eraser not fall?

The work-energy theorem and conservation of energy

- Work-energy theorem comes from the third kinematics relation
- Two formulations, one with potential energy and one without:
  - $KE_i + W_{\text{all}} = KE_f$
  - $KE_i + PE_i + W_{\text{other}} = KE_f + PE_f$
- Draw *clear* before and after snapshots
- Figure out work done in going from one to the other
- Work $= \vec{F} \cdot d\vec{s}$

Use energy methods when:

- You don't know and don't care about time
- You can account for the work done by all forces involved
- This is **not** true at the instant of a collision – use momentum instead

Sample problem: energy

A ball rolls down a hill of height h and across a table. How fast is it moving at the edge of the table?

Conservation of momentum

- In the absence of external forces, $\vec{p} = m\vec{v}$ is conserved
- This is a consequence of Newton's third law
- Collisions and explosions are short enough that external forces are small
- Momentum is a vector and is conserved separately in x and y

Use conservation of momentum when:

- You have a collision or explosion and need to connect the velocities before to the velocities after

Rotation

Many ideas here, most analogous to translational motion:

- Torque plays the role of force: $\tau = F_\perp r = F r_\perp$
- Moment of inertia plays the role of mass: $I = \lambda m r^2$
- $\vec{F} = m\vec{a} \to \tau = I\alpha$: "Newton's second law for rotation"
- Rolling motion is translation plus rotation: $v = \pm\omega r$, $a = \pm\alpha r$
- **You must think about the signs here**
- Rotational kinetic energy: $KE_{\text{rot}} = \frac{1}{2}I\omega^2$
- Angular momentum: $L = I\omega$

Static equilibrium problems

- Net torque is zero about any pivot
- Net force is zero (you may not need this)
- Torque due to any force applied **at** the pivot is zero

Final reminders

- Huge amounts of extra review available; use it
- Get some rest during finals week and take care of yourselves

The power of mechanics

The things we've studied in this class are more powerful than you think.
If you call up a chemist, she'll tell you the approximate force law between two noble gas atoms:

$$F(r) = \frac{\alpha}{r^{12}} - \frac{\beta}{r^6}$$

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Put this into a computer and let it go:

We can understand freezing, melting, and boiling just with $\vec{F} = m\vec{a}$!
... we can even get the ideal gas law for free along the way!

The rest of physics

The other disciplines of physics are variants on what you've learned already:

- Electromagnetism (PHY 212) introduces a new force – just another $\vec{F}$
- All you'll do in that class is apply the work-energy theorem and so on to this new force
  - Light is just a particular manifestation of that force
- Statistical mechanics uses statistics to understand $\vec{F} = m\vec{a}$ acting on a great many particles at once
- Relativity mixes up space and time, changing the coordinates on us
- Quantum mechanics mixes up "particle" and "wave"

Each of these disciplines is supported by a "three-legged stool":

- Theory: understanding principles and using pen and paper to study them in simple situations (this class)
- Experiment: designing tests for these principles and building machines to carry them out (221)
- Computation: using computers to simulate those principles in more complicated situations and study their consequences (my field and class in the fall)

Two invitations

Like what you've done here? We have multiple options for you to study more physics!

You could get a physics minor. This involves:

- Physics 211 (you have this now!)
- Physics 212 (you will probably take this next semester!)
- Four more classes at the 300 level of your choice. For instance:
  - Biophysics: the physics of living things – how do cells do what they do?
  - Cosmology: the history and future of the Universe!
  - Astrophysics
  - Computational physics (all of you are qualified to take this already!)
  - Modern physics (quantum mechanics, relativity, atoms)
  - Waves and vibrations: light and sound
  - Advanced laboratory
  - ... and others I'm forgetting!

Two invitations

... or maybe you want to be a physics major! (Come to the dark side – we have both cookies and the cheat-codes to the Universe!)

Bachelor of Arts

This degree program prepares you for jobs in industry, and is also a great double major option with engineering, computer science, education, and all sorts of things:

- Physics 211/212
- 300-level class on modern physics (quantum mechanics, relativity, atoms – the good stuff!)
- 300-level lab class
- 5 more elective classes (astrophysics, computational physics, biophysics, cosmology... lots of stuff)
- 30 physics credits total (you have four, plus four if you took AST101)

Bachelor of Science

This degree program prepares you for the most technically demanding industry jobs, as well as graduate study in physics or related fields.
It is also a good double major option for other STEM fields, in particular engineering (there are overlaps in the required classes)

- Physics 211/212
- 300-level class on modern physics (quantum mechanics, relativity, atoms – the good stuff!)
- 300-level lab class
- Rigorous courses in computational physics, electromagnetism, quantum mechanics, thermodynamics, and others
- 39 physics credits total (you have four now!)

Two invitations

If you've done reasonably well in this course, and have strong communication skills, Physics 211 wants to offer you a job!

We're always looking for good people to work for us as coaches in future years. Want to help next year's class, have fun, earn some money, and get a job that looks great on your resume?

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Come talk to us!

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"All science is either physics or stamp collecting." (E. Rutherford)

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"Poets say science takes away from the beauty of the stars – mere globs of gas atoms. Nothing is "mere". I too can see the stars on a desert night, and feel them. But do I see less or more? The vastness of the heavens stretches my imagination – stuck on this carousel my little eye can catch one-million-year-old light. A vast pattern – of which I am a part... What is the pattern, or the meaning, or the why? It does not do harm to the mystery to know a little about it. For far more marvelous is the truth than any artists of the past imagined!"

–Richard Feynman, from *Lectures on Physics*

Thanks for a wonderful semester!