Review and recap

Physics 211
Syracuse University, Physics 211 Spring 2019
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May 3, 2022

Announcements

Extra office hours and reviews ahead of the exam:

- Thursday, 9:00-2:00, room to be announced
- Saturday, 12:00-5:00, room to be announced
- Monday, 10-3, room to be announced

Homework 9 is due tomorrow – if you need an extension, ask your TA.

On grades – a final reminder

- I've asked you to do challenging things this semester
  - This helps you learn more
  - ... but I know they're challenging and the grading scale takes that into account

- Most grades will be A's and B's
- If you've been keeping up (going to recitation, doing homework) it's overwhelmingly likely you'll pass

Final exam format

- Covers the whole semester
- No messy mathematics – we want you to think more and calculate less
- 8 questions plus a short set of multiple choice questions about the basic nature and dimensions of what we've studied

Unit 1: Kinematics

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- Slope of position graph is velocity; slope of velocity graph is acceleration
- Area under acceleration graph is change in velocity; area under velocity graph is change in position

- If $\vec{a}$ is constant:

$$\begin{aligned} \vec{s}(t) &= \vec{s}_0 + \vec{v}_0 t + \frac{1}{2}\vec{a}t^2 \\ \vec{v}(t) &= \vec{v}_0 + \vec{a}t \\ v_f^2 - v_0^2 &= 2a\Delta x \end{aligned}$$

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

Problem-solving guide: kinematics

- Draw a clear diagram and choose your coordinate system (where is the origin?)
- Write down the kinematics relations for $x(t)$, $y(t)$, $v_x(t)$, $v_y(t)$
  - You'll need to think about what a, v_0, and x_0, etc., are
  - You may need to decompose a vector into x and y components
- Determine what instant in time you care about, and write down a sentence like:

  "What is the value of x at the time that $y = -h$?"
- Substitute in what you know and do the algebra your sentence directs you to do

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

Unit 2: 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

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- 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

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- Often tension and normal forces are unknowns you solve for along the way

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: Car driving around a curve

How fast can a car drive around a curve with a radius of curvature R?

Unit 3a: 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
- Add in rotational kinetic energy if things rotate
- 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?

Unit 3b: 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

Often we need to know the conditions for something to be balanced, and neither rotate nor translate:

- 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
- If you're affected by the Calc/Physics exam scheduling nonsense, tell SU!

The power of mechanics

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This computer program does the following:

Repeat forever:

- Calculate the net force on each atom
- Determine the acceleration on it from $\vec{F} = m\vec{a}$
- Use kinematics to calculate where it is some small amount of time later
- After some amount of time, calculate pressure from the average force on the walls
- The temperature is just the average kinetic energy of the particles

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- **Atoms that are somewhat close attract!**

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What if the gas isn’t diffuse or “hot”?

Cooling things down

What happens if we change the temperature?

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 (We just did this!)
- Relativity mixes up space and time, changing the coordinates on us
- Quantum mechanics mixes up "particle" and "wave" and gives a new lens on mechanics

Research at Syracuse Physics

We apply the ideas of physics to all kinds of things:

- Astrophysics
  - How do black holes and neutron stars shake the fabric of spacetime when they collide?
  - How do extreme tidal forces rip apart objects that get too close to stars?
  - How can we reconcile quantum mechanics with gravity to understand the Big Bang? (my work)
- Biophysics
  - What are the dynamics of the microtubules inside our cells?
  - Can we build better sensors to detect minute amounts of things in blood?
  - How does cognition in primitive brains work?
- Soft and active matter
  - Can we model people in a mosh pit? (really!)
  - How do grains of sand "jam up"?
  - Much more stuff I don't quite understand/know about :)
- Particle physics
  - What are the elementary particles and forces in nature?
  - How do we make the LHC and other detectors work even better?
  - How do we detect "ghost particles" (neutrinos)?
- Quantum computing, nuclear physics, advanced imaging...

Approaches

Each of these fields 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 (my class in the fall – all of you are qualified!)
  - Modern physics (quantum mechanics, relativity, atoms)
  - Waves and vibrations: light and sound
  - Advanced laboratory
  - Physics education (how do we teach physics?)
  - ... 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 and you can count ECS classes toward a physics degree)

- 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! (I'll be contacting many of you over the summer with a job offer, but if you're interested, get a head start and talk to me!)

And, finally...

... thank you all; you have been an absolutely wonderful class. We're just getting back from the pandemic; we have hit the ground running. You've done challenging things, learned a vast amount, and I'm proud of all of you.

Think about how far you've come since January!

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

Final words

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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!