Exam 3 review

Physics 211
Syracuse University, Physics 211 Spring 2015
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April 27, 2016

Exam 3

Topics covered:

- The work-energy theorem
- Potential energy and conservation of energy
- Elasticity and Hooke's law
- Torque and rotational motion

You may expect:

- More conceptual problems (no hard math) similar to the multiple choice questions last time
- Problems involving the work-energy theorem in combination with force diagrams or rotation
- Very few problems that require calculator-work

Exam prep schedule

- Thursday: office hours 1:30-3:30, possibly extended
- Friday: office hours and/or review 10-12 (Clinic), 1-4 (Archbold Gym 210)
- Saturday: review 4-8 (Clinic/Stolkin)
- Sunday: review 2-5
- Monday: Office hours by appointment; dealing with exam printing
- Tuesday: grading all day
- Wednesday: grading all day, calculating your provisional grades
- Thursday: I hope to have provisional grades available to you after noon
- Friday: review 10-4 (location TBA)
- Saturday: review 2-6 (Physics Clinic/Stolkin)
- Monday: Exam 3 Retake
- Tuesday: GTA's have exams...
- Wednesday: Grading
- Final grades should be done by Friday, May 13

Exam 3 preparation

This is an enormous amount of extra help; use it!

Homework questions

Any questions about HW7, HW8, or the practice exam?

Review: the work-energy theorem

- The work-energy theorem: $\frac{1}{2}mv_f^2 - \frac{1}{2}mv_i^2 = \sum W$
- Change in kinetic energy = sum of work done by all forces
- How do we calculate work done?
  - Most general case: $W = \int \vec{F} \cdot d\vec{s}$ (hard to do this – it's a line integral!)
  - Constant force: $W = \vec{F} \cdot \Delta\vec{s}$
  - Two ways to compute the dot product
    - $W = F_{||}\Delta s$: "Work is the distance moved, times the force in that direction"
    - $W = F(\Delta s)_{||}$: "Work is the force, times the distance moved in the direction of the force"
  - Forces perpendicular to the motion do no work
  - Forces in the direction of motion do positive work
  - Forces opposite the direction of motion do negative work

Review: potential energy

- Potential energy is an accounting device for keeping track of work done by "conservative" forces
- Instead of writing down the work done by certain forces, you can associate them with a potential energy

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$$KE_i + U_{g,i} + U_{e,i} + W_{\text{others...}} = KE_f + U_{g,f} + U_{e,f}$$

Conservation of energy methods: useful for when you don't know and don't care about time

Solving problems: energy methods

- One of the easier techniques in our class
- Ensure you have very clear pictures of "before" and "after" snapshots (draw cartoons!)
- Figure out terms for kinetic and potential energy in each
- Figure out the work done by other forces (friction...) in going from "before" to "after"
- Remember that, for each force, you **either** include it as a potential-energy term, **or** calculate the work that it does
- Write down the conservation of energy relation and solve

How fast does the car go?

How fast is the car traveling at each photogate?

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$$\frac{1}{2}mv_f^2 = mg(y_0 - y_f)$$

Choose a problem for me to do...

- A spring of spring constant k is compressed a distance d and used to shoot a marble at an angle θ above the horizontal. How far does it go?
- A spinning wheel has angular velocity ω; it is compressed by brake pads with coefficient of friction μ_k with a force F on each side. How many more times does it spin before it stops?
- A mass m is suspended by two springs, stretching them each a distance d. One of them breaks. How much further will the mass fall before it bounces back up?

Review: rotational motion

- Most ideas in rotational motion are identical to ones you already know about
- The big new ones:
- Torque is the rotational analogue of force
  - $\tau = F_\perp r = F r_\perp$; $\vec{r}$ is the vector from the pivot to the point of force
- Moment of inertia is the rotational analogue of mass
  - $I = mr^2$ for an object that is at a uniform distance from the pivot (a ring, or a single mass)
  - $I = \lambda mr^2$ for an extended object; λ is some fraction that comes from calculus

The correspondence table

Translation	Rotation
Position x	Angle θ
Velocity v	Angular velocity ω
Acceleration a	Angular acceleration α
$v(t) = v_0 + at$	$\omega(t) = \omega_0 + \alpha t$
$x(t) = x_0 + v_0 t + \frac{1}{2}at^2$	$\theta(t) = \theta_0 + \omega_0 t + \frac{1}{2}\alpha t^2$
$v_f^2 - v_0^2 = 2a\Delta x$	$\omega_f^2 - \omega_0^2 = 2\alpha\Delta\theta$
Force $\vec{F}$	Torque: $\tau = F_\perp r$
Mass m	Moment of Inertia: $I = \lambda MR^2$
$\vec{F} = m\vec{a}$	$\tau = I\alpha$
Work $= \vec{F} \cdot \Delta\vec{s}$	Work $= \tau\Delta\theta$
Kinetic energy $\frac{1}{2}mv^2$	Kinetic energy $\frac{1}{2}I\omega^2$
Power ($\vec{F}$ constant) $= \vec{F} \cdot \vec{v}$	Power (τ constant) $= \tau\omega$
Momentum $\vec{p} = m\vec{v}$	Angular momentum $L = I\omega$

Rotational motion, overview ("torque problems")

- Draw "extended" force diagrams for everything
  - Draw the object, and then also label **each force** at the **location it acts**
  - Choose a pivot point, at a location that makes the torques of forces you don't care about zero
- $\vec{F} = m\vec{a}$ is true for all objects that move (or might move)
- $\tau = I\alpha$ is true for all objects that rotate (or might rotate)
- Sometimes you don't need $\vec{F} = m\vec{a}$
- Write down these equations for every object to which they apply
- Calculate the net torque: $\sum \tau = \sum F_\perp r$
  - Remember to find the components of each force vector perpendicular to the radius vector
  - Remember signs: CCW is positive, CW is negative
- Put in what you know, solve for what you need
- You'll often have both a's and α's; often they're related by $a = \alpha r$, but **you must think about the signs** here

Static equilibrium problems

- Often we are presented with a situation where nothing moves, and we have to solve for something
- No acceleration of the center of mass: $\sum \vec{F} = 0$
- No angular acceleration: $\sum \tau = 0$ about *any* pivot point
- Can generate enough equations this way to solve for all unknowns

Static equilibrium problems

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- No acceleration of the center of mass: $\sum \vec{F} = 0$
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- Can generate enough equations this way to solve for all unknowns
- Strategy: choose the pivot to be aligned with a force you don't know and don't care about

Choose a sample problem for me to do...

- A solid pulley of mass M and radius r has a mass m hanging from one side. How fast does it accelerate?
- A basketball rolls down a ramp at angle θ. How fast does it accelerate?
- A basketball rolls down a ramp at angle θ. How steep can the ramp be for it to roll and not skid?
- The Yo-yo problem from recitation

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Strategy: same as for our linear motion problems.

- 1. Draw force diagrams for everything
- 2. Write $\vec{F} = m\vec{a}$ for things that have translational motion
- 3. Write $\tau = I\alpha$ for things that have rotational motion
  - Here, ¡insert variable here¿ is another unknown variable appearing in both equations
- 4. Use constraints to relate α's to a's
- 5. Solve the system of equations

Your questions...

What questions on the homeworks, practice exam, and recitations would you like to review?

(Don't forget the myriad review sessions I'm doing for more personal help!)

Beyond mechanics

What else is there in physics?

- Acoustics and waves: just the mechanics of flexible things...
- Electrodynamics: electricity, magnetism, light **(Physics 2!)**
  - All of mechanics still applies; you're just learning about a few new forces
- Thermodynamics: temperature, heat, phase changes, gases, pressure...
  - Ordinary mechanics, just applied to a great many particles at once, using statistics to do the math
- Condensed matter: crystals, the structure of matter
- Quantum mechanics: atoms, very small things, chemistry
- Astrophysics and cosmology: what is the Universe and where is it going?
  - I'm teaching Astronomy 101 in the Fall (very little math involved, gen-ed course)
- Biophysics
  - Probably the fastest-growing and one of the most promising areas of current research

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- Biophysics
  - Probably the fastest-growing and one of the most promising areas of current research
- Computational physics (my course for Fall 2015)

And, finally...

... thank you all; you've made my second year at SU a great one already.

Feel free to contact me at wafreema@syr.edu for help in Physics 2 or anytime in the future, letters of recommendation, etc.

Fin

Poets say science takes away from the beauty of the stars - mere globs of gas atoms. 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 it. (R. Feynman)

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