Exam 3 review

Physics 211
Syracuse University, Physics 211 Spring 2015
Walter Freeman

April 9, 2015

Announcements

- Review times set for next Tuesday's exam
  - Today: Eggers 018, 2:00 to 5:00
  - Friday: Sims 337, 10:00 to 4:00
  - **Sunday: the Clinic, moving to Stolkin if necessary, 2:00-5:00**
- No recitation next Wednesday (we'll be grading)

Exam 3

- Topics covered:
  - Conservation of energy and the work-energy theorem
  - Conservation of momentum
  - Rotational dynamics:
    - Torque and angular acceleration
    - Rolling motion
    - Static equilibrium
    - Angular momentum
- Four or five problems
- Possibly a “sometimes/always/never” or “positive/negative/zero” section
- Extra credit

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”
- Write down the conservation of energy relation and solve

Review: momentum

- Momentum: $\vec{p} = m\vec{v}$ (a vector quantity!)
- A few things to know about momentum related to its definition:
  - Newton's second law can also be written $\vec{F} = m\frac{\partial \vec{v}}{\partial t} = \frac{\partial \vec{p}}{\partial t}$
  - For constant force: $\Delta\vec{p} = \vec{F}t$ (impulse-momentum theorem)
- **Momentum is conserved in the absence of external forces**
- Particularly common cases where we don't care about external forces: **collisions and explosions**

Review: collisions and explosions

- Collisions and explosions happen so fast that external forces can be ignored for that instant
- "Total momentum before = total momentum after"
- Three sorts of collisions:
  - Elastic collisions: no KE lost
  - Partially inelastic collisions: some amount of KE lost, but the objects don't stick together
  - Fully inelastic collisions: objects stick together

Solving problems: collisions and explosions

- Write down conservation of momentum in each direction (x,y) that's relevant
- For instance, for an explosion: $(m_1 + m_2)v_i = m_1 v_{1,f} + m_2 v_{2,f}$
- Often we have composite problems: something happens, a collision or explosion, then something else happens
  - Use conservation of momentum to connect "right before the collision" to "right after"
  - Use another technique for the other aspects of the motion (when there are external forces)

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: $I = \lambda M R^2$
$\vec{F} = m\vec{a}$	$\tau = I\alpha$
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 $L = I\omega$

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

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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

The Atwood's machine, for real (for 9:30)

A solid pulley of mass M and radius r has a mass m hanging from one side. How fast does it accelerate?

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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, the tension 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?