

Exam 2 Review

Physics 211
Syracuse University, Physics 211 Spring 2020
Walter Freeman

February 26, 2020

- 4 questions
 - One question where I present you with an incorrect solution and you must find the mistake
 - At least one question where you must interpret why you perceive objects to move in the ways that they do
- You may bring notes: front and back of a page handwritten by yourself

Extra exam preparation

- Practice exam solutions will be posted over the weekend
- Office hours tomorrow: 9:30-11:30 (I may have to leave a bit early), 1-3
- Review session Sunday, 6-9 PM

Review: overview

- Newton's second law: $\sum \vec{F} = m\vec{a}$
 - Forces (left hand side) cause accelerations (right hand side)
 - Acceleration is not a force; it *results* from forces
- Newton's third law: Forces come in pairs. If A pushes on B, B pushes back on A with the same magnitude in the opposite direction.
- Forces are things you can feel:
 - Normal forces: one thing pushes on another
 - Gravity
 - Tension: a rope pulls on something
 - Friction: opposes things sliding
 - Acceleration is not a force: forces *cause* acceleration
 - “Centripetal force” is not a separate force: it describes one of the above

A few things about these forces: gravity

- On Earth: always acts downward with $F_g = mg$
- The acceleration of an object is *only* g if there are no other forces

$$-mg = ma_y : \text{only if } \sum F_y = -mg!$$

A few things about these forces: gravity

- On Earth: always acts downward with $F_g = mg$
- The acceleration of an object is *only* g if there are no other forces

$$-mg = ma_y : \text{ only if } \sum F_y = -mg!$$

- This is only true on Earth. Elsewhere: all objects attract each other

$$F_g = \frac{Gm_1m_2}{r^2}$$

- m_1 and m_2 are the masses of the two objects; r is the distance between their centers.
- $G = 6.67 \times 10^{-11} \text{N} \cdot \text{m}^2/\text{kg}^2$
- This distance is measured between their centers (for planets)
- On Earth: $F_g = m_1g = \frac{GM_em_1}{r_e^2}$, so $g = \frac{GM_e}{r_e^2}$

A few things about these forces: tension

- Just the force exerted by a rope
- Always goes in the direction of the rope, and is the same throughout
- Can only pull; can never push
- Force is the same on both ends (Newton's 3rd law)
- **Tension is almost always something you will need to solve for, not something you know ahead of time**

A few things about these forces: normal forces

- Stops two things from moving through each other
- Always directed normal (perpendicular) to a surface
- Magnitude is as large as it needs to be to stop objects from “crossing” ($a_{\perp} = 0$)
- Newton’s third law: if A pushes on B, B pushes back on A (the book problem)
- Can only push; can never pull (the frog-in-bucket problem)
- “Apparent weight”: the normal force exerted by whatever you are standing on
- **Normal force is almost always something you will need to solve for, not something you know ahead of time**
 - $F_N = mg$ only if you’re standing on a level surface and there are no other vertical forces:
 $F_N - mg = ma_y = 0$
 - That is often not true!

A few things about these forces: friction

Friction depends on a property of the surfaces called the **coefficient of friction** μ

- Roughly: “how sticky things are”.
- Force of kinetic friction = $\mu_k F_N$
- Max force of static friction = $\mu_s F_N$
- Friction points in whichever direction opposes the tendency to slide
- Static friction *can* make objects move (cars, people walking)

Rotational motion

- “Uniform circular motion”: object steadily moving in a circle
- Angular velocity: how fast does the thing turn? (RPM’s, degrees per second, **radians per second**)
- Constant speed does *not* mean constant velocity or zero acceleration!

$$a = \omega^2 r = \frac{v^2}{r} \text{ toward the center of the circle}$$

Rotational motion

- “Uniform circular motion”: object steadily moving in a circle
- Angular velocity: how fast does the thing turn? (RPM’s, degrees per second, **radians per second**)
- Constant speed does *not* mean constant velocity or zero acceleration!

$$a = \omega^2 r = \frac{v^2}{r} \text{ toward the center of the circle}$$

- “How many force problems and how many circular motion problems will we have?”

Rotational motion

- “Uniform circular motion”: object steadily moving in a circle
- Angular velocity: how fast does the thing turn? (RPM’s, degrees per second, **radians per second**)
- Constant speed does *not* mean constant velocity or zero acceleration!

$$a = \omega^2 r = \frac{v^2}{r} \text{ toward the center of the circle}$$

- “How many force problems and how many circular motion problems will we have?”
- They’re the same: circular motion just tells you that $a = \omega^2 r$. You do these problems in *exactly the same way*.

Rotational motion

- A rotating object has an *angular velocity* – how fast it's turning, measured in radians per second
- The tangential speed of a point on the object is given by $v_T = \omega r$
- The angular velocity is related to the time it takes to rotate by
$$\tau = \frac{2\pi}{\omega}$$

If an object is traveling in a circle, you immediately know that its acceleration is $\omega^2 r$ or v^2/r toward the center.

Problem solving strategies (the important thing!)

- 1. Force diagrams (“Accounting”)
 - Draw all forces and only forces (things you can feel)
 - Choose a pair of axes (tilted axes are sometimes helpful, like for things on ramps)
 - Break forces into components along these axes, if needed

Problem solving strategies (the important thing!)

- 1. Force diagrams (“Accounting”)

- Draw all forces and only forces (things you can feel)
- Choose a pair of axes (tilted axes are sometimes helpful, like for things on ramps)
- Break forces into components along these axes, if needed

- 2. Newton’s laws (“Physics”)

- Write down $\sum F = ma$ for **each object** in **each direction**. You can read this off your diagram. For instance:

$$T_1 \cos \theta - T_2 = ma_x$$

$$T_1 \sin \theta - mg = ma_y$$

- Forces (real things) go on the left side; acceleration goes on the right
- Put in things you know about the acceleration
- Different objects : different acceleration variables (are they related?)
 - Sometimes $a = 0$
 - Circular motion: $a_r = \omega^2 r = \frac{v^2}{r}$ toward the center

Problem solving strategies (the important thing!)

• 1. Force diagrams (“Accounting”)

- Draw all forces and only forces (things you can feel)
- Choose a pair of axes (tilted axes are sometimes helpful, like for things on ramps)
- Break forces into components along these axes, if needed

• 2. Newton’s laws (“Physics”)

- Write down $\sum F = ma$ for **each object** in **each direction**. You can read this off your diagram. For instance:

$$T_1 \cos \theta - T_2 = ma_x$$

$$T_1 \sin \theta - mg = ma_y$$

- Forces (real things) go on the left side; acceleration goes on the right
- Put in things you know about the acceleration
- Different objects : different acceleration variables (are they related?)
 - Sometimes $a = 0$
 - Circular motion: $a_r = \omega^2 r = \frac{v^2}{r}$ toward the center

• 3. Algebra (“Math”)

- Put in the stuff you have, solve for the stuff you need
- Need at least as many equations as unknowns
- “Systems of equations”: solve by substitution

Sample problems: elevator

A 100 kg person stands in an elevator. What is their apparent weight if the elevator is accelerating upward at 3 m/s^2 ?

A 100 kg person stands in an elevator. What is their apparent weight if the elevator is accelerating upward at 3 m/s^2 ?

- Sum of forces goes on the left, acceleration goes on the right
- Remember, apparent weight is the normal force applied by the thing you're standing on
- We know the acceleration; we don't know one of the forces \rightarrow solve for it!

Sample problems: Mass on a string

A 2 kg mass hangs on a string 1m long, which is being spun in a vertical circle once per second. What is the tension force at the bottom of the arc?

Sample problems: Mass on a string

A 2 kg mass hangs on a string 1m long, which is being spun in a vertical circle once per second. What is the tension force at the bottom of the arc?

- This is the same idea as the last problem; we just know the acceleration in an indirect way
- 1 revolution per second = 2π radians per second

Sample problems: Mass on a string

A 2 kg mass hangs on a string 1m long, which is being spun in a vertical circle once per second. What is the tension force at the top of the arc?

Sample problems: Mass on a string

A 2 kg mass hangs on a string 1m long, which is being spun in a vertical circle once per second. What is the tension force at the top of the arc?

- Remember, the acceleration goes toward the center of the circle: think about your signs!

Sample problems: Mass on a ramp

A block sits on a ramp inclined at an angle of 40 degrees. The coefficient of kinetic friction is 0.3. What is its acceleration?

Sample problems: Mass on a ramp

A block sits on a ramp inclined at an angle of 40 degrees. The coefficient of kinetic friction is 0.3. What is its acceleration?

- Tilted coordinate axes
- Break gravity into components (remember how this goes!!)

Sample problems: your request!