Friction (and sundry)

Physics 211
Syracuse University, Physics 211 Spring 2015
Walter Freeman

February 24, 2016

Announcements

- Homework 4 due next Friday
- It's a long one – start early!
- Read Chapter 8

Exam 1 recap:

- Averages on physics exams are generally around 65%
- This may seem low, but we ask more of you:
  - We're not just asking you to repeat information or follow steps
  - ... we're asking you to think on your feet and solve problems
- The average on the first pass on Exam 1 was 65%
- The retake improved this to 69%

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- This may seem low, but we ask more of you:
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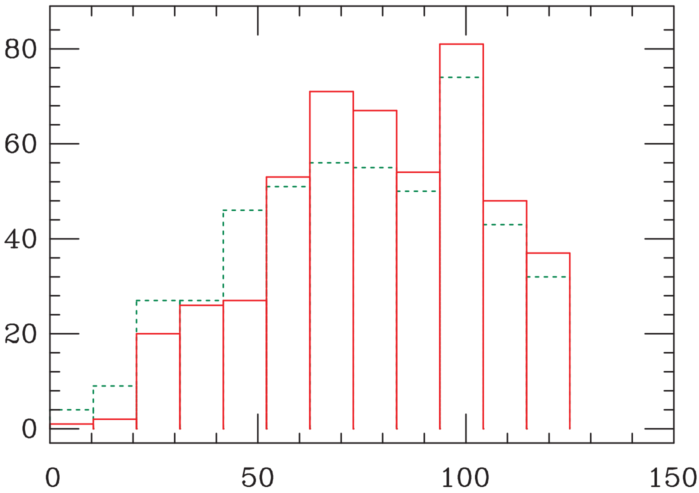
- The average on the first pass on Exam 1 was 65%
- The retake improved this to 69%
- My exams (especially the second one) were more difficult than the norm
- ... many of you did very well, and I'm proud of you!

Exam 1 recap:



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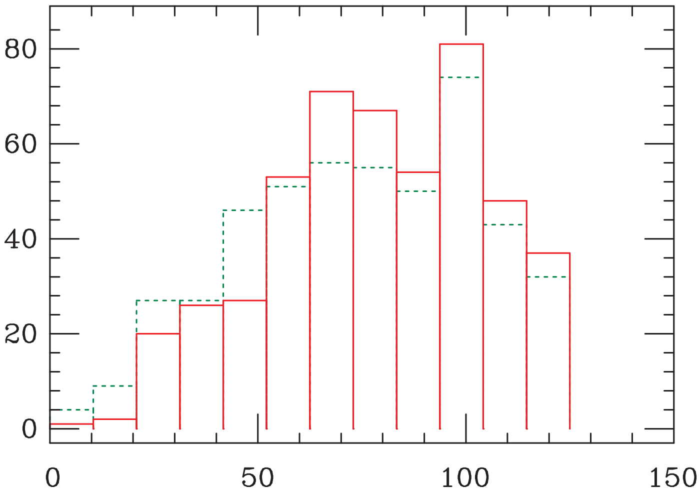

- If you didn't do as well as you had hoped on either exam...
- ... remember you can drop the lowest of your three exam scores.

Rotational motion

Often things in nature are constrained to go in circles:

- Planets orbiting stars; moons orbiting planets (close enough to circles)
- Wheels; things on strings; many others

We'll study "uniform circular motion" here:

- Something moves at a constant distance from a fixed point
- ... at a constant speed.

Rotational motion: a reminder

- Here we take $\alpha = 0$, since that happens so often in nature: the Earth...
- Object moves in a circle of radius r, with its angle changing at a constant rate
- "Position $=$ rate $\times$ time" $\rightarrow$ "Angle $=$ rate $\times$ time"

Rotational motion: a reminder

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- "Position = rate × time" → "Angle = rate × time"

$$\theta = \omega t + \frac{1}{2}\alpha t^2$$

ω (omega) called the "angular velocity"; measured in radians per second

- Angular velocity tells you how fast something spins
- A larger radius does *not* mean something has a higher angular velocity

Rotational motion: description

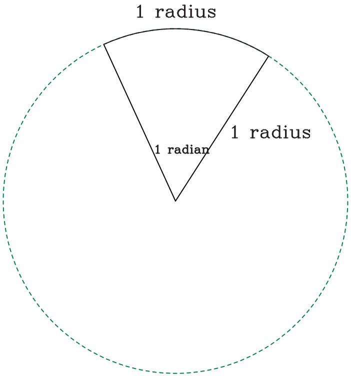
Some new terms:

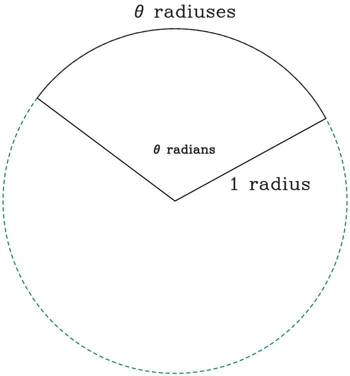
- "Radial": directed in and out of the circle
- "Tangential": directed around the circle
- The radial velocity is 0 (r doesn't change)
- The tangential velocity depends on r and ω, as you'd expect

Radians

The radian: new unit of angle. 2π radians = 360 degrees.

1 complete circle is 2π radians; 1 complete circumference is 2π radiuses ($C = 2\pi r$).
1 radian thus has an arc length of 1 radius.
θ radians therefore have an arc length of $r\theta$.





$\rightarrow$ Tangential movement (in meters) = angular movement (in radians) times the radius

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- The radial velocity is 0 (r doesn't change)
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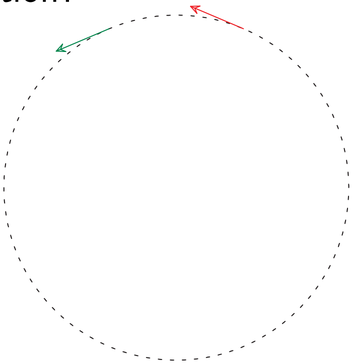
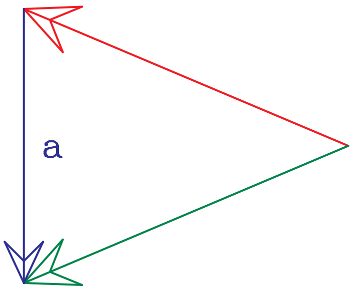
- $v_T = \omega r$: "meters per second = radians per second times meters per radian"

Clearly an object moving in a circle is accelerating. What's the acceleration?





Kinematic challenge: what's the acceleration

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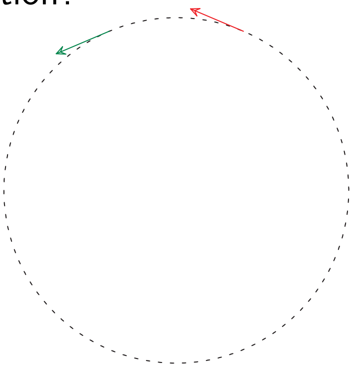

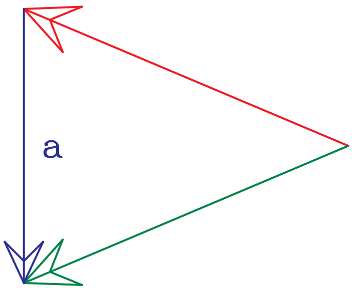

Near the top of the circle, the y-component of the velocity decreases; we expect then that $\vec{a}$ points downward.

Can we make this rigorous?

Some math

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Differentiate to get v_x and v_y:

$$\begin{aligned} v_x(t) &= -\omega r\sin(\omega t) \\ v_y(t) &= \omega r\cos(\omega t) \end{aligned}$$

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$\rightarrow \vec{a} = -\omega^2\vec{r}$

An object in uniform circular motion accelerates toward the center of the circle with

$$\rightarrow a = \omega^2 r = v^2/r \leftarrow$$

Uniform circular motion, consequences

If you know an object is undergoing uniform circular motion, you know something about the acceleration:

$a = \omega^2 r$ or $a = v^2/r$ toward the center of the circle.

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Circular motion problems aren't scary; they are just like any other force problem.

- Equilibrium problem: $\sum F_x = ma_x = 0$ and $\sum F_y = ma_y = 0$
- Circular motion problem: $\sum F_T = ma_T = 0$ and $\sum F_r = ma_r = v^2/r$

$\rightarrow$ If we tell you that a thing is in uniform circular motion, we're just telling you something about its acceleration.

Centripetal force

"Centripetal" means "toward the center" in Latin.

- If something is going to accelerate toward the center, a force must do that.
- Centripetal force is not a "new" force. No arrows labeled "centripetal force"!
- "Centripetal" is a word that describes a force you already know about.
- Centripetal force: describes a force that holds something in a circle
- It can be lots of things:
  - Tension (see our demos)
  - Normal force (platform, bucket demos)
  - Friction (Ferris wheel)
  - Gravity (the moon!)

Clicker questions

What does the force diagram on the water look like while the bucket is at the bottom?

- A: acceleration upward, normal force upward, gravity downward
- B: centripetal force upward, normal force upward, gravity downward
- C: gravity downward, normal force upward
- D: gravity downward, velocity to the left, normal force upward

Clicker questions

Why doesn't the water in the bucket fall at the top?

- A: It *is* falling, but the bucket falls along with it, so it stays in
- B: The normal force pushes it up
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- D: Mr. Sampere is in the back chanting "wingardium leviosa!"

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- A: acceleration downward, normal force upward, gravity downward
- B: normal force upward, gravity downward
- C: gravity downward, normal force downward
- D: normal force downward, gravity downward, centrifugal force upward

Sample problems

(from demos)