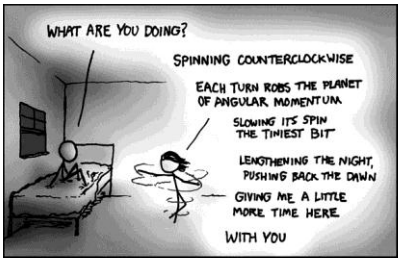
PHY131 - Course Review

- Significant Figures, Measurements, Errors
- Equations of constant acceleration
- Forces and Newton's 3 Laws
- Free Body Diagrams
- Circular Motion, Centripetal Force



https://xkcd.com/162/

1

Significant Figures

- A car travels 30.09 m along a straight line in 5 seconds. What is its average speed in this time?

A. 6.018 m/s
B. 6.000 m/s
C. 6.0 m/s
D. 6.02 m/s
E. 6 m/s

2

When do I round?

- The final answer of a problem should be displayed to the correct number of significant figures
- Numbers in intermediate calculations should ***not*** be rounded off
- It's best to keep lots of digits in the calculations to avoid round-off error, which can compound if there are several steps

3

Significant Figures when errors are involved

- A spherical tumor is measured from a lung x-ray to have a diameter of 2.9501 mm. You know that the error in such a measurement is ± 1.5 mm. How should you report the measurement?

A. 2.90 ± 1.5 mm
B. 2.95 ± 1.5 mm
C. 2.95 ± 1.50 mm
D. 3.0 ± 1.5 mm
E. 3 ± 1.5 mm

4

Significant Figures when errors are involved

- There are two general rules for significant figures used in experimental sciences:

1. Errors should be specified to one, or at most two, significant figures.
2. The most precise column in the number for the error should also be the most precise column in the number for the value.

- So if the error is specified to the 1/100th column, the quantity itself should also be specified to the 1/100th column.

5

The 4 Equations of Constant Acceleration:

1. $\boxed{v_f = v_i + at}$ Does not contain position!

2. $\boxed{x = v_i t + \frac{1}{2}at^2}$ Does not contain v_f!

3. $\boxed{v_f^2 = v_i^2 + 2ax}$ Does not contain t!

4. $\boxed{x = \left(\frac{v_i + v_f}{2}\right)t}$ Does not contain a! (but you know it's constant)

Note: In these equations, x is the change in position, and t is the change in time.

6

The 4 Equations of Constant Acceleration

If the question is:

A car is driving along at 30 m/s. The driver sees a deer. He slams on the brakes and locks all four wheels, so the car continues to slide forward (kinetic friction). How far does the car travel before stopping?

which of the following do you ***not*** care about?

A. x
B. v_f
C. t
D. a

The 4 Equations of Constant Acceleration

If the question is:

You peer down into a pit and wonder how deep it is. You drop a rock and measure that it takes 1.2 seconds before it hits the bottom.

which of the following do you ***not*** care about?

A. y
B. v_f
C. t
D. a

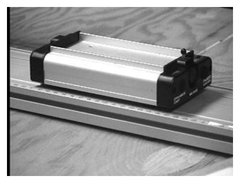
Thinking About Force

- Forces exist due to interactions happening *now*, not due to what happened in the past
- Consider a flying arrow
- A pushing force was required to accelerate the *arrow as it was shot*
- However, *no force* is needed to keep the arrow moving forward as it flies

- It continues to move because of inertia

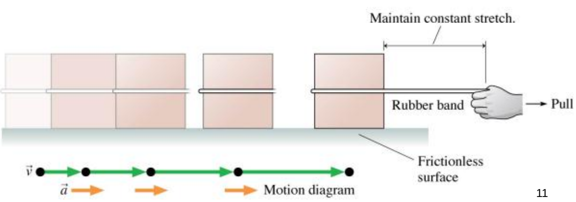
N1 Newton's First Law

The natural state of an object with no net external force on it is to either remain at rest or continue to move in a straight line with a constant velocity.



What Do Forces Do? A Virtual Experiment

- Attach a stretched rubber band to a 1 kg block
- Use the rubber band to pull the block across a horizontal, frictionless table
- Keep the rubber band stretched by a fixed amount
- We find that the block moves with a **constant acceleration**



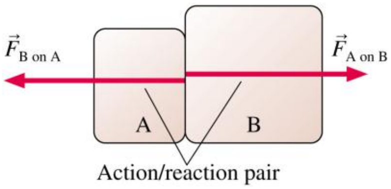
N2 Newton's Second Law

The acceleration of an object is directly proportional to the net force acting on it, and inversely proportional to its mass.

$$\boxed{\vec{a} = \frac{\vec{F}_{\text{net}}}{m}}$$

Interacting Objects

- If object A exerts a force on object B, then object B exerts a force on object A.
- The pair of forces, as shown, is called an **action/reaction pair**.



N3 Newton's Third Law

If object 1 acts on object 2 with a force, then object 2 acts on object 1 with an equal force in the opposite direction.

$$\boxed{\vec{F}_{1\,\text{on}\,2} = -\vec{F}_{2\,\text{on}\,1}}$$

A car is driving along at 30 m/s. The driver sees a stop sign up ahead. He steps on the brakes and slows down to a complete stop.

Which of the following external forces on the car causes the car to slow down? [Choose the *best* answer. If more than one of these forces is present, choose the largest.]]

A. Static friction
B. Rolling friction
C. Kinetic friction
D. Drag
E. Spring force

Rolling Without Slipping

- If you slam on the brakes so hard that the car tires slide against the road surface, this is kinetic friction (Very rare, and impossible to do if you have ABS.)
- Under normal driving conditions, the portion of the rolling wheel that contacts the surface is *stationary*, not sliding

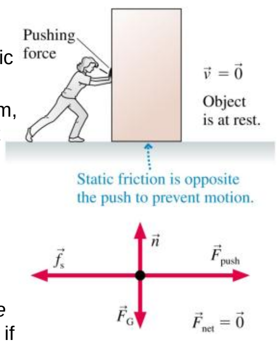
- If your car is accelerating or decelerating or turning, it is *static friction* of the road on the wheels that provides the net force which accelerates the car

Static Friction

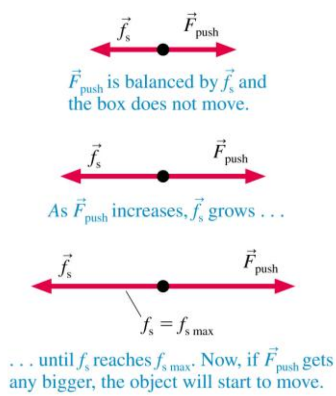
- The figure shows a person pushing on a box that, due to static friction, isn't moving
- Looking at the free-body diagram, the *x*-component of Newton's first law requires that the static friction force must exactly balance the pushing force:

$$f_s = F_{\text{push}}$$

- $\vec{f}_s$ points in the direction *opposite* to the way the object would move if there were no static friction



Static friction acts in *response* to an applied force.



Maximum Static Friction

• Many experiments have shown the following approximate relation usually holds:

$$f_{\text{s max}} = \mu_s n$$

where n is the magnitude of the normal force, and the proportionality constant μ_s is called the "coefficient of static friction".

- A static friction force $f_s > f_{\text{s max}}$ is not physically possible.

19

"Kinetic Friction" $\vec{f}_k$

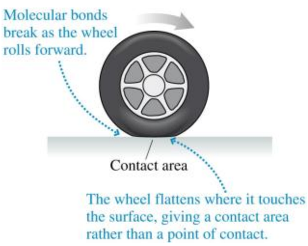
- Also called "sliding friction"
- When two flat surfaces are in contact and sliding relative to one another, heat is created, so it slows down the motion (kinetic energy is being converted to thermal energy).
- Many experiments have shown the following approximate relation usually holds for the magnitude of f_k:

$$f_k = \mu_k n$$

where n is the magnitude of the normal force.

The direction of $\vec{f}_k$ is opposite the direction of motion.

20



Rolling Friction

- A car with no engine or brakes applied does not roll forever; it gradually slows down
- This is due to rolling friction
- The force of rolling friction can be calculated as

$$f_r = \mu_r n$$

where μ_r is called the coefficient of rolling friction.

- The rolling friction direction is opposite to the velocity of the rolling object relative to the surface

21

Dynamics of Uniform Circular Motion

- An object in uniform circular motion is *not* traveling at a constant velocity in a straight line
- Consequently, the particle must have a net force acting on it

$$\vec{F}_{\text{net}} = m\vec{a} = \left(\frac{mv^2}{r}, \text{ toward center of circle}\right)$$

- Without such a force, the object would move off in a straight line tangent to the circle
- The car would end up in the ditch!

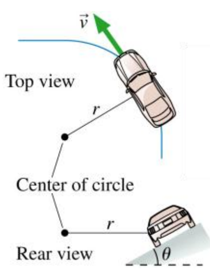
Highway and racetrack curves are banked to allow the normal force of the road to provide the centripetal acceleration of the turn.

22

Banked Curves

A car goes around a curve in the road that is banked, as shown. What are all the possible external forces in the *r-z* plane acting on the car at this moment? (*z* is vertically upward)

A. normal force, gravity
B. static friction, normal force, gravity
C. static friction, normal force, gravity, centripetal force
D. static friction, rolling friction, normal force, gravity
E. static friction, rolling friction, normal force, gravity, centripetal force

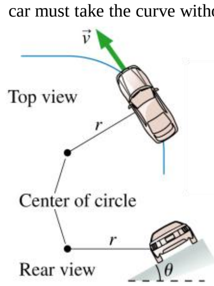


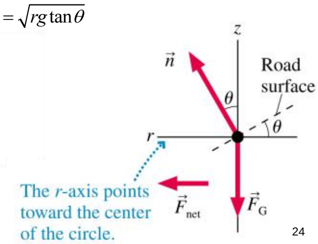
23

Banked Curves

- Real highway curves are *banked* by being tilted up at the outside edge of the curve
- The radial component of the normal force can provide centripetal acceleration needed to turn the car
- For a curve of radius r banked at an angle θ, the exact speed at which a car must take the curve without assistance from friction is

$$v_0 = \sqrt{rg\tan\theta}$$

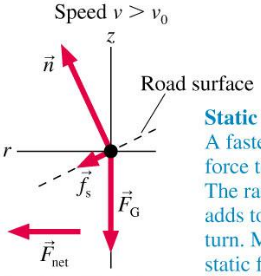




24

Banked Curves

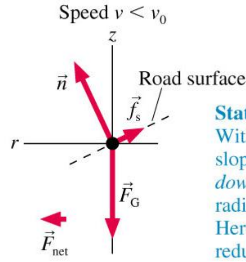
- Consider a car going around a banked curve at a speed *higher* than $v_0 = \sqrt{rg\tan\theta}$
- In this case, static friction must prevent the car from slipping *up* the hill



Static friction must point downhill: A faster speed requires a larger net force toward the center of the circle. The radial component of static friction adds to n_r to allow the car to make the turn. Maximum speed occurs when the static friction force reaches its maximum.

Banked Curves

- Consider a car going around a banked curve at a speed *slower* than $v_0 = \sqrt{rg\tan\theta}$
- In this case, static friction must prevent the car from slipping *down* the hill



Static friction must point uphill: Without a static friction force *up* the slope, a slow-moving car would slide *down* the incline! Further, n_r is too much radial force for circular motion at $v < v_0$. Here the radial component of static friction reduces the net radial force.