DEVIL PHYSICS
THE BADDEST CLASS ON CAMPUS
IB PHYSICS

TSOKOS LSN 2-2A
THE CONCEPT OF FORCE

Introductory Video

Introducing Sir Isaac Newton

Essential Idea:

- Classical physics requires a force to change a state of motion, as suggested by Newton in his laws of motion.

Nature Of Science:

- Using mathematics: Isaac Newton provided the basis for much of our understanding of forces and motion by formalizing the previous work of scientists through the application of mathematics by inventing calculus to assist with this.
- Intuition: The tale of the falling apple describes simply one of the many flashes of intuition that went into the publication of Philosophiæ Naturalis Principia Mathematica in 1687.

Theory Of Knowledge:

- Classical physics believed that the whole of the future of the universe could be predicted from knowledge of the present state.
- To what extent can knowledge of the present give us knowledge of the future?

Understandings:

- Objects as point particles
- Free-body diagrams
- Translational equilibrium
- Newton’s laws of motion
- Solid friction

Applications And Skills:

- Representing forces as vectors
- Sketching and interpreting free-body diagrams
- Describing the consequences of Newton’s first law for translational equilibrium
- Using Newton’s second law quantitatively and qualitatively

Applications And Skills:

- Identifying force pairs in the context of Newton’s third law
- Solving problems involving forces and determining resultant force
- Describing solid friction (static and dynamic) by coefficients of friction

Guidance:

- Students should label forces using commonly accepted names or symbols (for example: weight or force of gravity or mg)
- Free-body diagrams should show scaled vector lengths acting from the point of application
- Examples and questions will be limited to constant mass
- mg should be identified as weight
- Calculations relating to the determination of resultant forces will be restricted to one- and two-dimensional situations

Data Booklet Reference:

$$F = ma$$

$$F_f \leq \mu_s R$$

$$F_f = \mu_d R$$

Utilization:

- Motion of charged particles in fields (see Physics sub-topics 5.4, 6.1, 11.1, 12.2)
- Application of friction in circular motion (see Physics sub-topic 6.1)
- Construction (considering ancient and modern approaches to safety, longevity and consideration of local weather and geological influences)
- Biomechanics (see Sports, exercise and health science SL sub-topic 4.3)

Aims:

- Aim 6: experiments could include (but are not limited to): verification of Newton's second law; investigating forces in equilibrium; determination of the effects of friction

Overview

- Basic ingredients of mechanics are mass and force
  - Mass is the amount of material in a body whose SI unit is kilograms
  - Force can stretch, deform, rotate, compress, or produce an acceleration on a body

Overview

- Most common force in nature is the gravitational force
  - The gravitational force is expressed as weight ($ma=F_f$)
  - While the gravitational force keeps things from floating away, the normal force prevents things from plunging into the center of the earth

Overview

- The electroweak force comprises the electromagnetic force and the weak nuclear force
- The strong nuclear force, or colour force keeps the quarks in photons and neutrons

Overview

Question I Can't Answer: Why is it that the ***strong*** nuclear force keeps subatomic particles inside atomic particles, while the electro***weak*** force accelerates several ton cars filled with passengers to high speeds at amusement parks?

Overview

- The trend in trendy physics circles is to unite the strong nuclear and electroweak forces into a single ‘unified force’, but we’re not there yet.
- All that being said by way of introduction, there’s only one thing left to say,

Overview

May the force be with you!

Force and Direction

- Force is a vector quantity which means it has a magnitude and direction
- Different directions will affect how forces interact with each other as we saw from vector addition

Force and Direction

- Units for the magnitude of a force is the Newton (N), not the fig (which is named after a small town in Massachusetts, not the scientist), which is a derived unit equal to 1 $kg \cdot m/s^2$
  - If you have trouble remembering this, remember F=ma which is kg x m/s^2

Waddya Know About Weight?

Weight

- Weight is a force that results from the gravitational attraction between a mass and the mass of the earth, when on the earth
- On the surface of the earth, on average, $g = 9.81$ N/kg, or the more common, m/s^2

Weight

- The force is always oriented toward the center of mass which, in most frames of reference, is down
- Mass is the same everywhere, but weight is dependent on gravitational attraction at a given point
  - A mass of 70kg has a weight of 687 N on the surface of the earth
  - It weighs 635 N when 250km above the earth's surface
  - And only 623 on the surface of Venus

Waddya Know About Tension?

Tension

- Tension is a force within a body when the body is stretched
- It results from the electromagnetic interactions between the molecules of the material making up the body

Tension

- For a mass hanging by string from the ceiling,
  - At the top point of attachment, the tension force pulls down on the ceiling
  - At the bottom point of attachment, the force acts upward on the mass
- Tension is the same for every point in the material

Waddya Know About Hooke's Law?

Hooke's Law

- When we try to expand or compress (some springs at least), there is a force attempting to restore the spring back to its original location
- The amount of tension (T) in the spring is related to the displacement of the spring (x) and the spring constant (k) by the equation:

$$T = kx$$

Waddya Know About the Normal / Reaction / Contact Force?

Normal Reaction (Contact) Force

- When one body touches another body, there is a reaction or contact force between the two
- The force acts perpendicular to the body exerting the force

Waddya Know About Drag Forces?

Drag Forces

- Forces that oppose motion through a fluid (gas or liquid)
- Operate opposite to the velocity of the object
- Normally dependent on both the speed and the shape of the object

Waddya Know About
Upthrust (Buoyant) Force?

Upthrust (Buoyant) Force

- An object in a fluid experiences an upward force opposite to the weight
- The depth to which an object will sink is related to both the mass and the volume of the object in comparison to the buoyant force

Waddya Know About Frictional Force?

Frictional Force

- Forces that oppose the motion of a body in contact with another surface
- For objects in motion, sliding or kinetic friction (also called dynamic friction) opposes that motion
- Force that opposes the start of motion of a body is static friction
- Which is more, dynamic or static?

Frictional Force

$$F_f \leq \mu_s R$$

$$F_f = \mu_d R$$

$$F_f = F_N \mu$$

Frictional Force

$$F_f = \mu_d R$$

- The area of contact between the two surfaces does not affect the frictional force.
- The force of dynamic friction is where R is the normal reaction force between the surfaces and μ_d is the coefficient of dynamic friction.
- The force of dynamic friction does not depend on the speed of the sliding.

Frictional Force

- The ***maximum*** force of static friction that can develop between two surfaces is

$$F_f = \mu_s R$$

where R is the normal reaction force between the surfaces and μ_s is the coefficient of static friction.

- Added: The ***coefficients*** don't change with mass.

Waddya Know About Free-Body Diagrams?

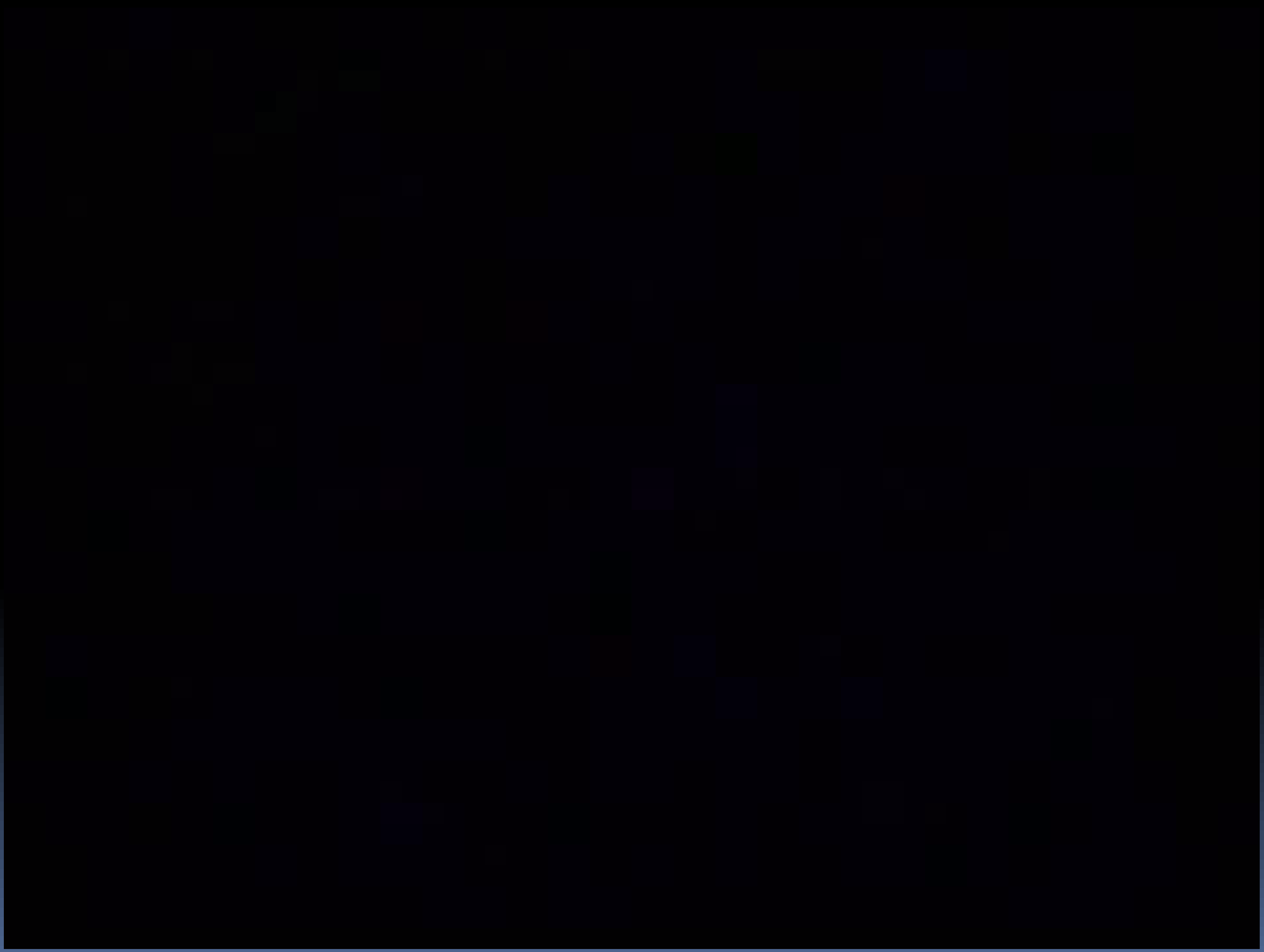
TOK: Is anything truly free?

Free-Body Diagrams

- A diagram showing the magnitude and direction of all forces acting on a chosen body, free of its surroundings
- Important to isolate a body and the forces acting on it before attempting to solve some problems
- For most problems, we treat all objects as point particles with forces acting through the center of mass

Waddya Know About Newton's First Law?

Introductory Video



Newton’s First Law

1. A body at rest tends to remain at rest and a body in motion tends to remain in motion.
2. When no forces act on a body, that body will either remain at rest or continue to move along a ***straight line*** with ***constant speed***.
3. When the net force on a body is zero, the body will move with constant velocity (which may be zero).

Newton’s First Law

- When no forces act on a body, that body will either remain at rest or continue to move along a straight line with constant speed.
- What happens when a force acts on a body or when existing forces become unbalanced?

Newton's First Law

- When no forces act on a body, that body will either remain at rest or continue to move along a straight line with constant speed.
- What happens when a force acts on a body or when existing forces become unbalanced?
  - Change in direction or change in speed of the object
  - Acceleration – because it is a change in the velocity vector – magnitude OR direction

Newton’s First Law

- Also called the *Law of Inertia*
- Reluctance of a body to change its state of motion

Inertial Frames of Reference

- A system on which no forces act (inert)
- Observers in all reference frames should come up with the same answers
- Are you an inertial reference frame?

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  - With the orbit of the earth around the sun, we have a tangential speed of $3x10^4$ m/s

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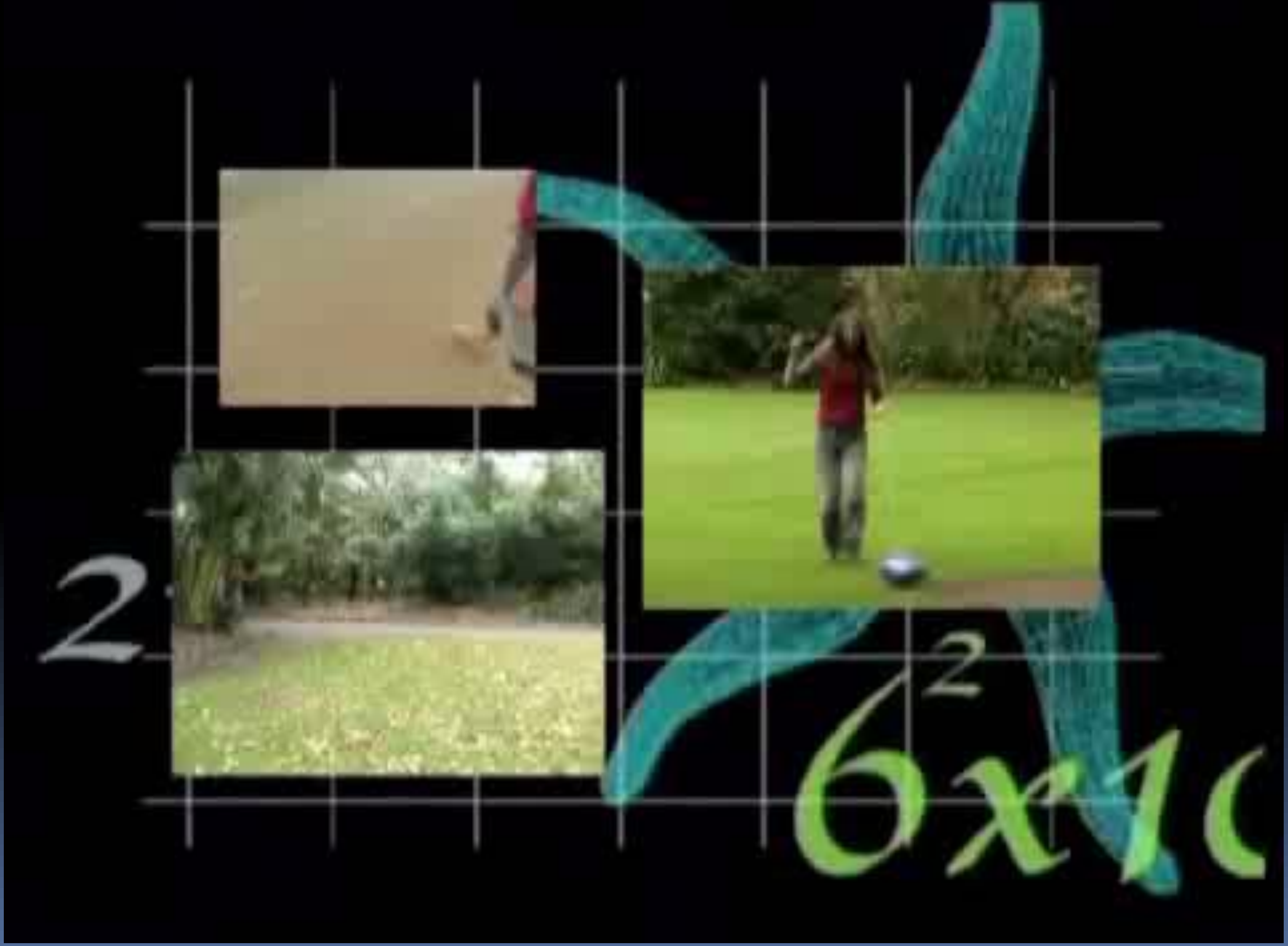
- Are you an inertial reference frame?
  - With the rotation of the earth, you have a tangential speed of 464 m/s
  - With the orbit of the earth around the sun, we have a tangential speed of 3×10^4 m/s
  - However, because of the radii involved, the acceleration over short periods of time is minimal

Waddya Know About Newton's Third Law?

Video: Newton's Third Law of Motion



Newton’s Third Law of Motion

- If Body A exerts a force F on Body B, then Body B exerts an equal but opposite force F on Body A.

Newton’s Third Law of Motion Examples

- Pushing against a wall while wearing rollerskates.
- Stepping off a boat onto a dock.
- A helicopter hovering.
- A book sitting on a table.

Newton's Third Law of Motion Examples

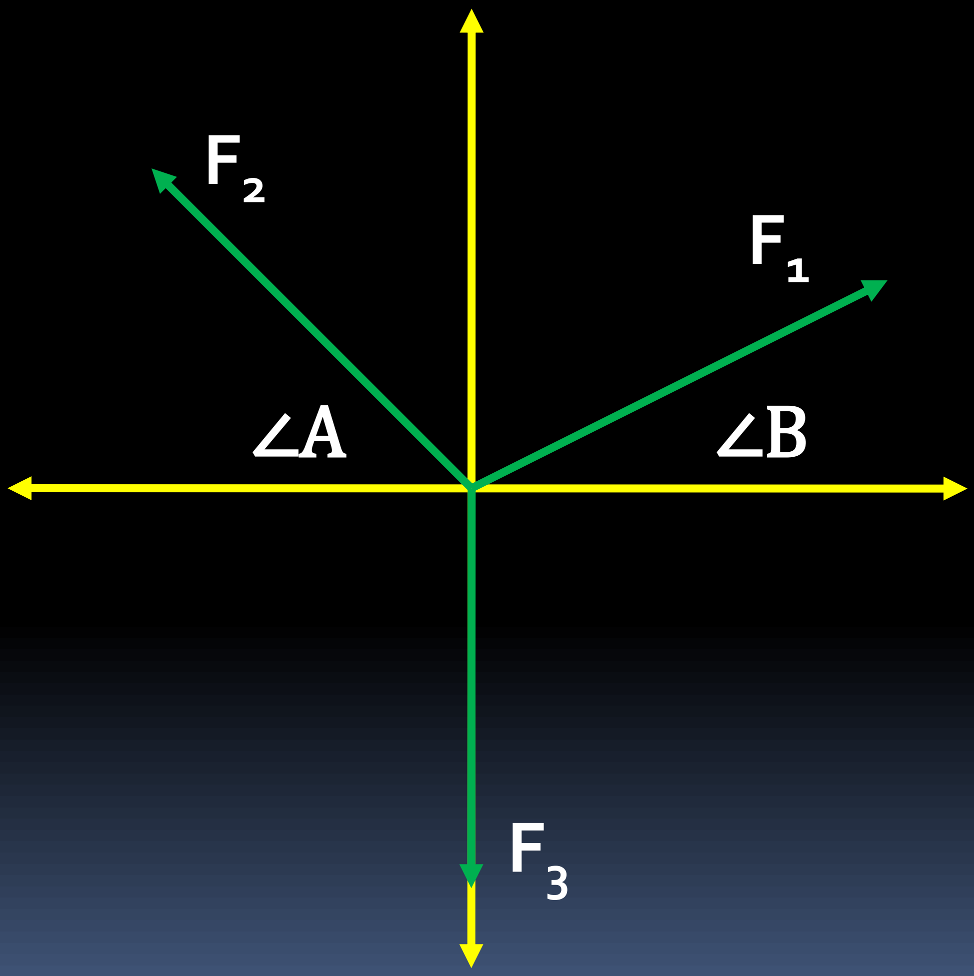
- Also applies when there is not contact between the objects
  - Electric force
  - Gravitational force
  - Magnetic force

Equilibrium

- Net force on a body is zero
- Denoted by $\Sigma F = 0$
- Newton's First Law is the result of equilibrium
  - Static Equilibrium – object doesn't move
  - Dynamic Equilibrium – object doesn't change direction or speed
- Forces are balanced
- ***Sum of the forces is key!***

Solving Equilibrium Problems

- Solving equilibrium problems usually involves finding components.
- *If F_2, F_3, and ∠A are known, what are the values of F_1 and ∠B?*



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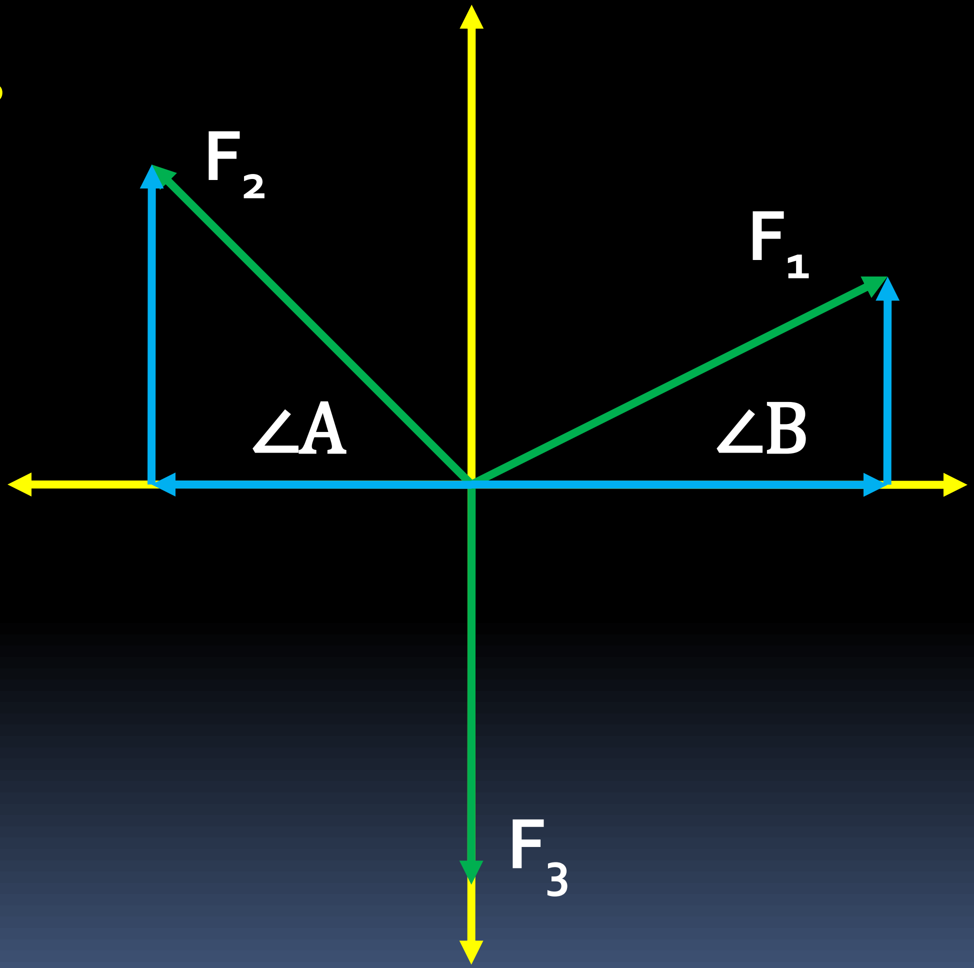


Solving Equilibrium Problems

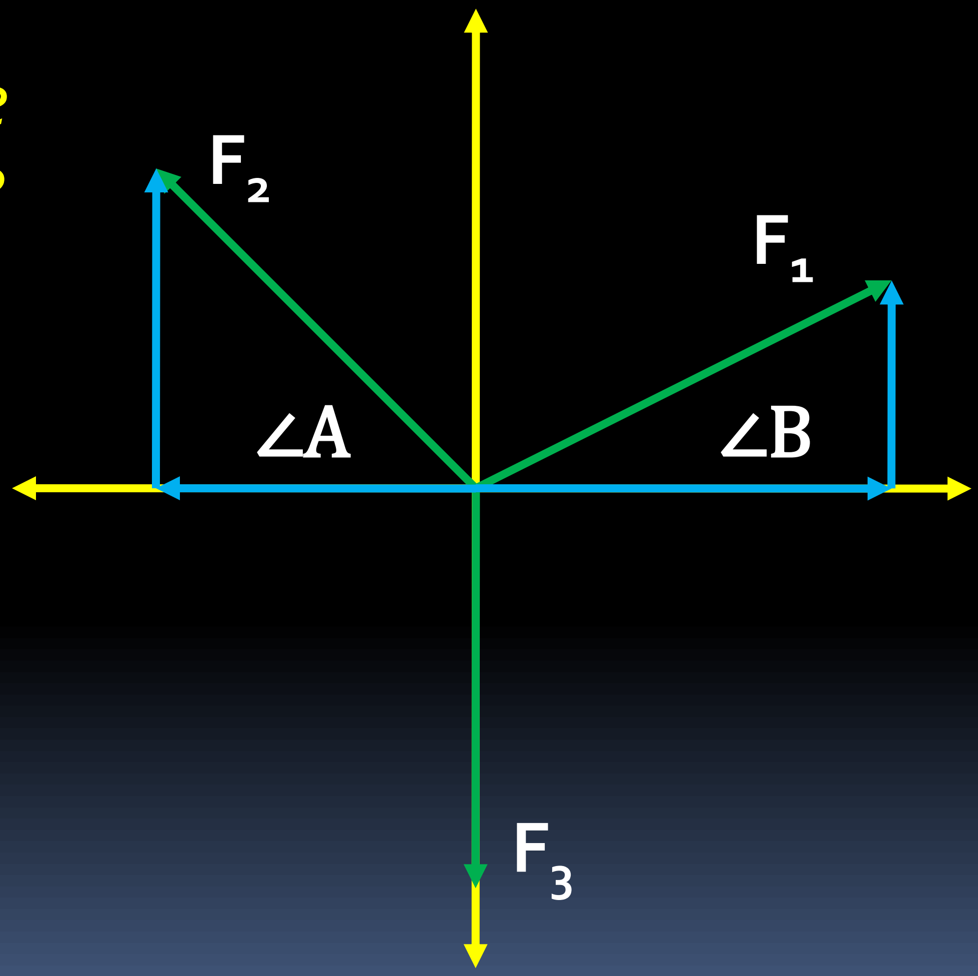
- *If F_2, F_3, and ∠A are known, what are the values of F_1 and ∠B?*

$$F_{1_x} = F_{2_x}$$

$$F_{1_y} = F_{2y} + F_3$$

$$F_1 = \sqrt{\left(F_{1_x}\right)^2 + \left(F_{1_y}\right)^2}$$

$$\angle B = \tan^{-1} \frac{F_{1_y}}{F_{1_x}}$$



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QUESTIONS?

Homework

- Pg. 76-77, #34-46