DEVIL PHYSICS
THE BADDEST CLASS ON CAMPUS

AP PHYSICS

LSN 4-7: SOLVING PROBLEMS WITH NEWTON'S LAWS, FREE-BODY DIAGRAMS

Questions From Reading Activity?

Big Idea(s):

- The interactions of an object with other objects can be described by forces.

Enduring Understanding(s):

- All forces share certain common characteristics when considered by observers in inertial reference frames.

Essential Knowledge(s):

- 3.A.1: An observer in a particular reference frame can describe the motion of an object using such quantities as position, displacement, distance, velocity, speed, and acceleration.
  - Displacement, velocity, and acceleration are all vector quantities.
  - Displacement is change in position. Velocity is the rate of change of position with time. Acceleration is the rate of change of velocity with time. Changes in each property are expressed by subtracting initial values from final values.
  - A choice of reference frame determines the direction and the magnitude of each of these quantities.

Essential Knowledge(s):

- 3.A.2: Forces are described by vectors.
  - Forces are detected by their influence on the motion of an object.
  - Forces have magnitude and direction.

Essential Knowledge(s):

- 3.A.4: If one object exerts a force on a second object, the second object always exerts a force of equal magnitude on the first object in the opposite direction.
- 3.B.1: If an object of interest interacts with several other objects, the net force is the vector sum of the individual forces.

Essential Knowledge(s):

- 3.B.2: Free-body diagrams are useful tools for visualizing forces being exerted on a single object and writing the equations that represent a physical situation.
  - An object can be drawn as if it was extracted from its environment and the interactions with the environment identified.
  - A force exerted on an object can be represented as an arrow whose length represents the magnitude of the force and whose direction shows the direction of the force.
  - A coordinate system with one axis parallel to the direction of the acceleration simplifies the translation from the free-body diagram to the algebraic representation.

Learning Objective(s):

- (3.A.1.1): The student is able to express the motion of an object using narrative, mathematical, and graphical representations.
- (3.A.1.2): The student is able to design an experimental investigation of the motion of an object.
- (3.A.1.3): The student is able to analyze experimental data describing the motion of an object and is able to express the results of the analysis using narrative, mathematical, and graphical representations.

Learning Objective(s):

- (3.A.2.1): The student is able to represent forces in diagrams or mathematically using appropriately labeled vectors with magnitude, direction, and units during the analysis of a situation.
- (3.A.4.1): The student is able to construct explanations of physical situations involving the interaction of bodies using Newton's third law and the representation of action-reaction pairs of forces.
- (3.A.4.2): The student is able to use Newton's third law to make claims and predictions about the action-reaction pairs of forces when two objects interact.

Learning Objective(s):

- (3.A.4.3): The student is able to analyze situations involving interactions among several objects by using free-body diagrams that include the application of Newton's third law to identify forces.
- (3.B.1.1): The student is able to predict the motion of an object subject to forces exerted by several objects using an application of Newton's second law in a variety of physical situations with acceleration in one dimension.

Learning Objective(s):

- (3.B.1.2): The student is able to design a plan to collect and analyze data for motion (static, constant, or accelerating) from force measurements and carry out an analysis to determine the relationship between the net force and the vector sum of the individual forces.

Learning Objective(s):

- (3.B.1.3): The student is able to re-express a free-body diagram representation into a mathematical representation and solve the mathematical representation for the acceleration of the object.
- (3.B.2.1): The student is able to create and use free-body diagrams to analyze physical situations to solve problems with motion qualitatively and quantitatively.

REVIEW QUIZ

- What is force?

REVIEW QUIZ

- What is force?
  - Any kind of push or pull on an object

REVIEW QUIZ

- Name Newton's First Law of Motion.

REVIEW QUIZ

- Name Newton's First Law of Motion.
  - Every body continues in its state of rest or of uniform speed in a straight line unless acted on by a nonzero net force.

    Or
  - A body at rest tends to remain at rest, and a body in motion tends to remain in motion.

REVIEW QUIZ

- What is inertia?

REVIEW QUIZ

- What is inertia?
  - The tendency of a body to maintain its state of rest or of uniform motion in a straight line.

REVIEW QUIZ

- What is the *chemistry definition of mass* and what is the *physics definition of mass*?

REVIEW QUIZ

- What is the *chemistry definition of mass* and what is the *physics definition of mass*?
  - Chemistry – the amount of matter in an object
  - Physics – the measure of inertia of a body

REVIEW QUIZ

- How does *weight* differ from *mass*?

REVIEW QUIZ

- How does *weight* differ from *mass*?
  - Weight is a force equal to the mass of an object times the acceleration due to gravity acting on the object.

REVIEW QUIZ

- Newton's Second Law of Motion is best described by an equation. What is that equation?

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- Newton's Second Law of Motion is best described by an equation. What is that equation?

$$\Sigma \vec{F} = m\vec{a}$$

REVIEW QUIZ

- What does the "$\Sigma\vec{F}$" in the above equation mean?

REVIEW QUIZ

- What does the "$\Sigma\vec{F}$" in the previous equation mean?
  - The vector sum of all forces.

REVIEW QUIZ

- What is the SI unit for force and what is it composed of?

REVIEW QUIZ

- What is the SI unit for force and what is it composed of?
  - Newton (N), $kg \cdot m/s^2$
  - Remember:
    - $F = ma$
    - $F\ (N) = m\ (kg)\ a\ (m/s^2)$

REVIEW QUIZ

- What is Newton's Third Law of Motion?

REVIEW QUIZ

- What is Newton's Third Law of Motion?
  - Whenever one object exerts a force on a second object, the second exerts an equal and opposite force on the first.

    Or,
  - For every action, there is an equal and opposite reaction.

DIFFERENCE BETWEEN 4-1 TO 4-6 AND 4-7???

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FORCES ARE NOT NECESSARILY IN THE SAME DIRECTION!!!

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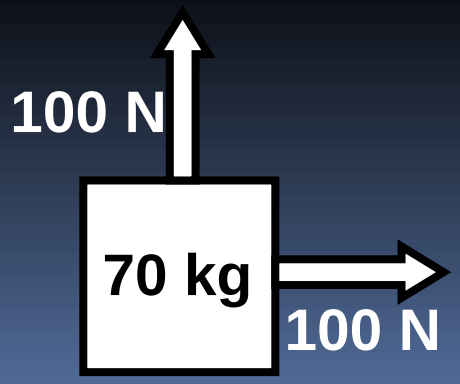
AAARRRGGGHHH!!!

Vector Forces and Free-Body Diagrams

- Newton's Second Law, $\Sigma\vec{F} = m\vec{a}$, says that the acceleration of an object is proportional to the net sum of the vector forces acting on the object. *What will be the acceleration on the box below?*



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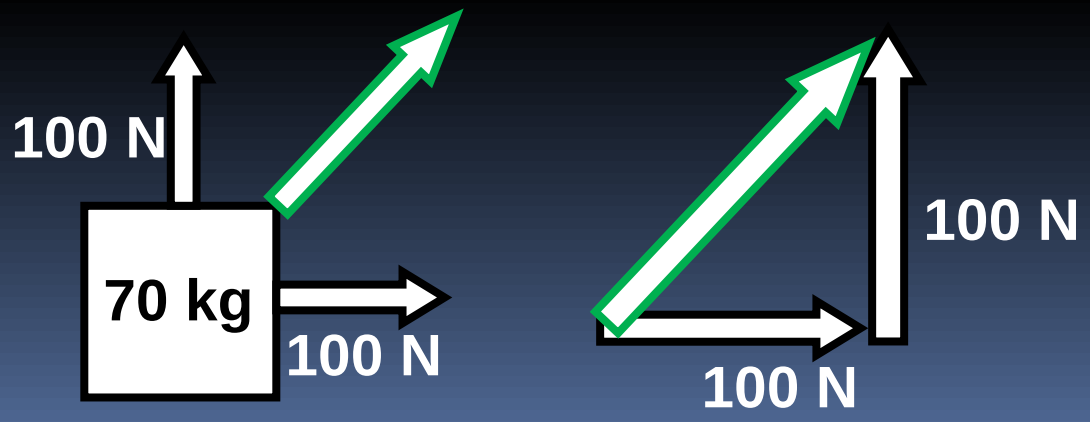

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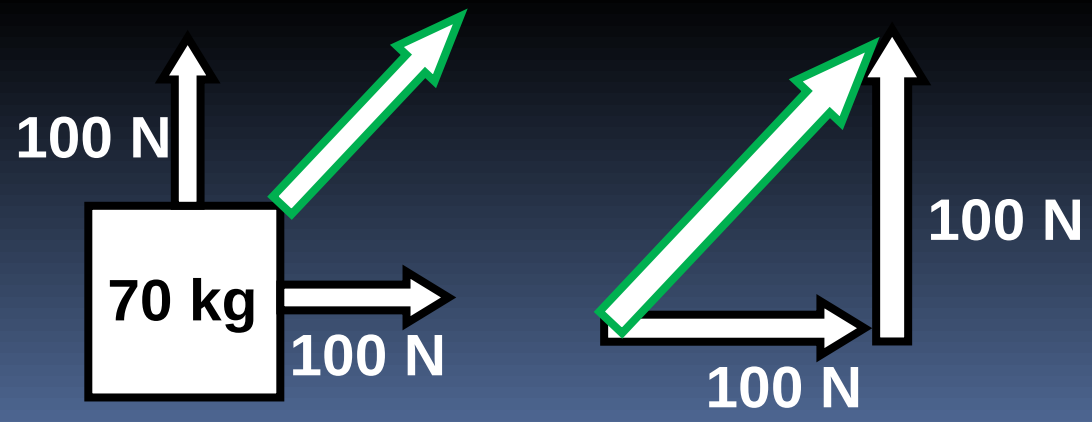


$$\Sigma F = \sqrt{100^2 + 100^2}$$

$$\Sigma F = 141N$$

$$\Sigma\vec{F} = m\vec{a}$$

$$\frac{\Sigma\vec{F}}{m} = \vec{a} = \frac{141}{70}$$

$$\vec{a} = 2\,m/s^2$$

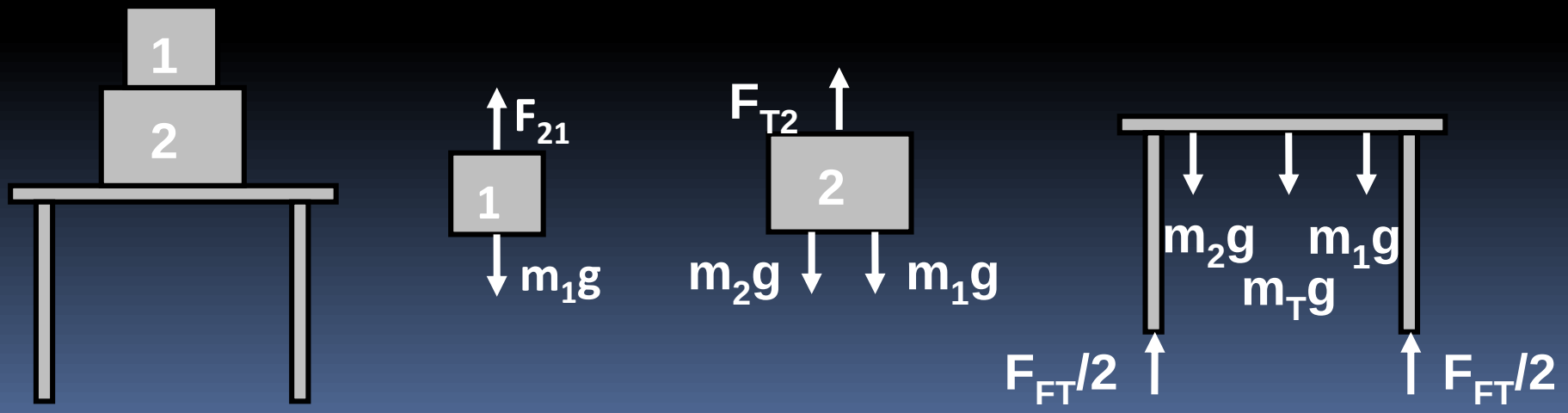
$$\theta = 45^\circ$$

Free-Body Diagram or Force Diagram

- When solving these types of problems, it is ***extremely*** important to draw free-body diagrams for each object and analyze the forces acting on that object.
- Free-body diagrams only show the ***forces*** acting ***on that object***.

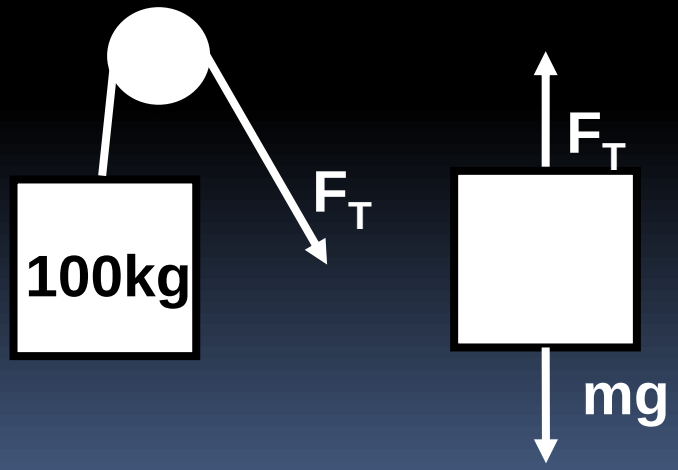
Free-Body Diagram or Force Diagram

- When objects are in contact with each other, they will exert a reaction force on each other in equal and opposite directions.



Free-Body Diagram or Force Diagram

- Free-body/Force diagrams are especially helpful in seeing the advantages of using pulleys
- Tension in a rope is always the same at all points along the rope



$$\Sigma \vec{F} = m\vec{a}$$

$$F_T - mg = ma$$

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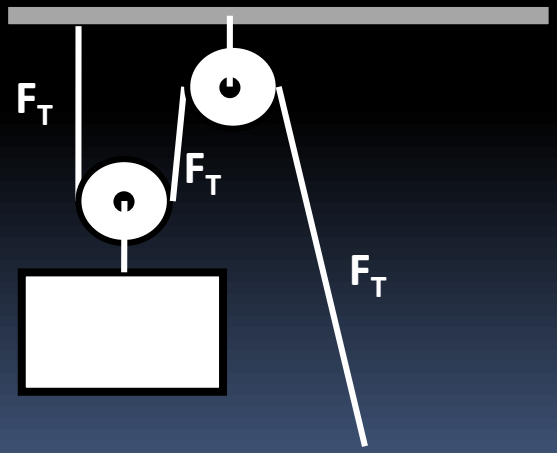
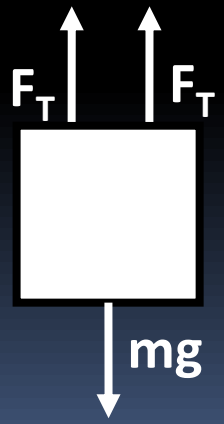




$$\Sigma \vec{F} = m\vec{a}$$

$$2F_T - mg = ma$$

Problem Solving Process (Pg 85)

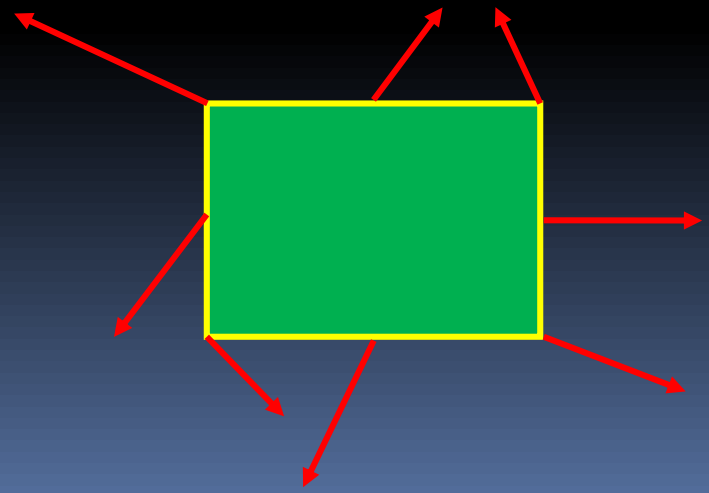
- Example 4-11

Problem Solving Process (Pg 85)

- Other examples by request

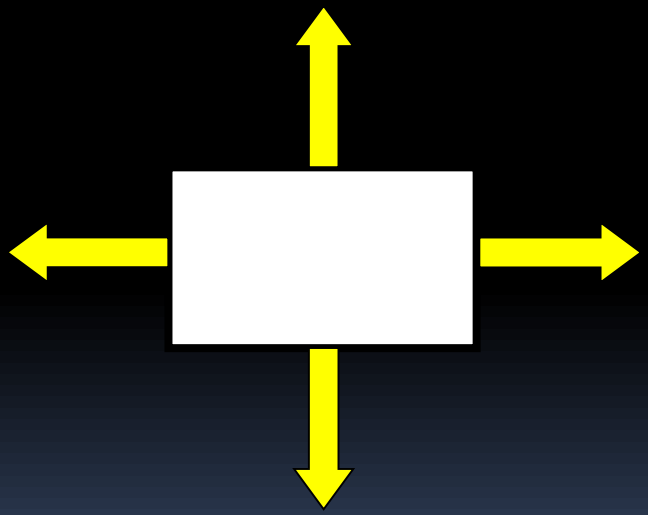
Σary Review

- Can you interpret and apply Newton's three laws of motion?
- Can you use vector addition to find the net force on an object and relate it to the resultant acceleration?



Σary Review

- Can you draw free-body/force diagrams of an object or collection of objects?



Σary Review

- **Can you use free-body/force diagrams to analyze forces on an object?**

$$\Sigma \vec{F}_{vertical} = m\vec{a}_{vertical}$$

$$\Sigma \vec{F}_{horizontal} = m\vec{a}_{horizontal}$$

- **Do you appreciate how pulleys can reduce the amount of force required to lift an object?**

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QUESTIONS?

Homework

#19-32