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King Saud University
College of Science
Physics & Astronomy Dept.

PHYS 103 (GENERAL PHYSICS)

CHAPTER 5: THE LAWS OF MOTION (PART 1)

LECTURE NO. 7

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Lecture Outline

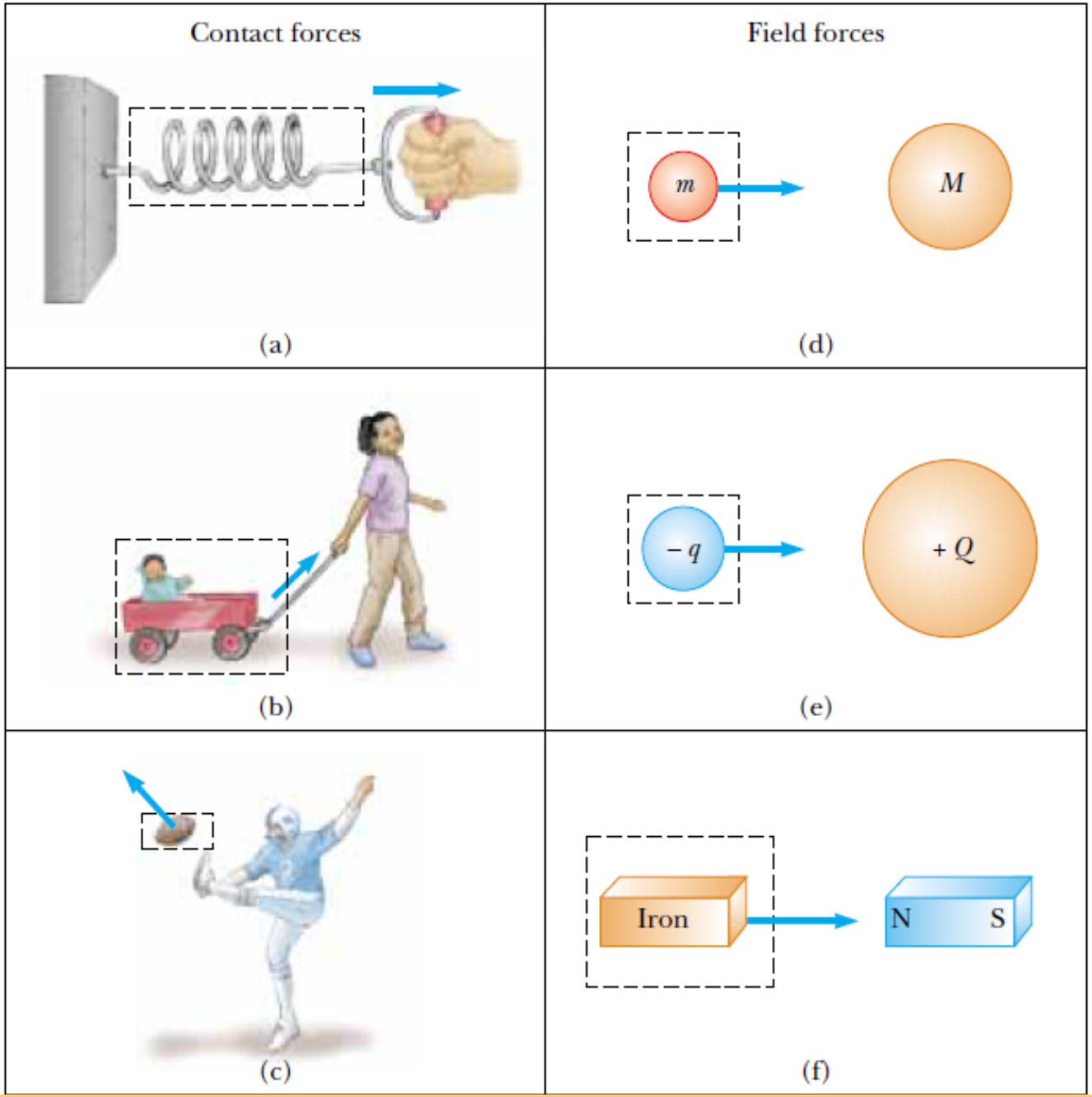
- Here is a quick list of the subjects that we will cover in this presentation. It is based on Serway, Ed. 6

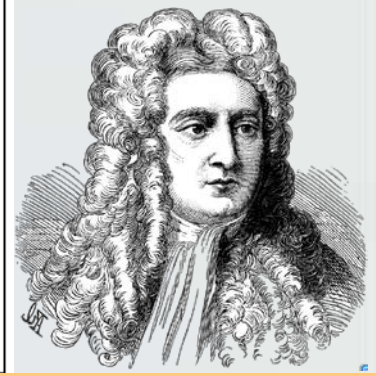
- *5.1 The Concept of Force*
- *5.2 Newton's First Law and Inertial Frames*
- *5.3 Mass*
- *5.4 Newton's Second Law*
- *5.5 The Gravitational Force and Weight*
- *5.6 Newton's Third Law*
- *Examples*
- *Lecture Summary*
- *Quizzes*
- *YouTube Video*

5.1 The Concept of Force

- An object accelerates due to an external force.
- If the net force exerted on an object is zero, the acceleration of the object is zero and its velocity remains constant.
- When the velocity of an object is constant (*including when the object is at rest*), the object is said to be in equilibrium.
- There are 2 types of forces:
  - Contact forces (e.g. when you pull a spring or press it)
  - Field forces (e.g. the force between earth and the moon)
- The only known *fundamental* forces in nature are all field forces: (1) *gravitational forces* between objects, (2) *electromagnetic forces* between electric charges, (3) *nuclear forces* between subatomic particles, and (4) *weak forces* that arise in certain radioactive decay processes.

5.1 Examples of Contact and Field forces

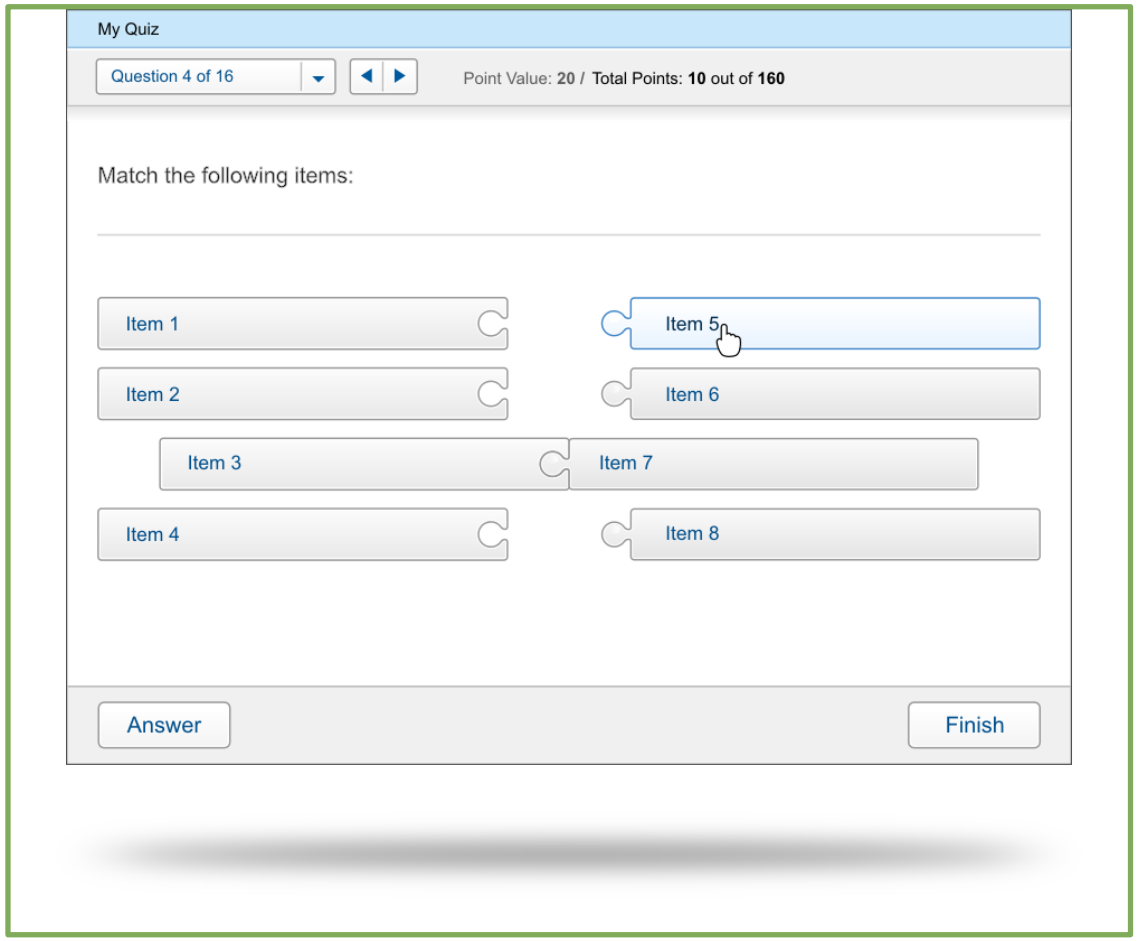




5.2 Newton's First Law

- *In the absence of external forces, when viewed from an inertial reference frame, an object at rest remains at rest and an object in motion continues in motion with a constant velocity.*
- In simpler terms, we can say that when no force acts on an object, the acceleration of the object is zero.
- If nothing acts to change the object's motion, then its velocity does not change.
- From the *first law*, we conclude that any isolated object (one that does not interact with its environment) is either at rest or moving with constant velocity.
- The tendency of an object to resist any attempt to change its velocity is called *inertia*.

Quiz



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5.3 Concept of Mass

- **Mass** is that property of an object that specifies how much resistance an object exhibits to changes in its velocity, the SI unit of mass is the kilogram.
- The greater the mass of an object, the less that object accelerates under the action of a given applied force.
- Mass is an inherent property of an object and is independent of the object's surroundings.
- Mass should not be confused with **weight**. Mass and weight are two different quantities. The weight of an object is equal to the magnitude of the gravitational force exerted on the object and varies with location.
- On the other hand, the mass of an object is the same everywhere: an object having a mass of 2 kg on the Earth also has a mass of 2 kg on the Moon.

5.4 Newton's Second Law

- *Acceleration of an object is directly proportional to the force acting on it.*
- In mathematical form: we can write this law as:

$$\sum \boldsymbol{F} = m\boldsymbol{a} \qquad (5.2)$$

$$\Rightarrow$$

$$\sum F_x = ma_x \qquad \sum F_y = ma_y \qquad \sum F_z = ma_z \qquad (5.3)$$

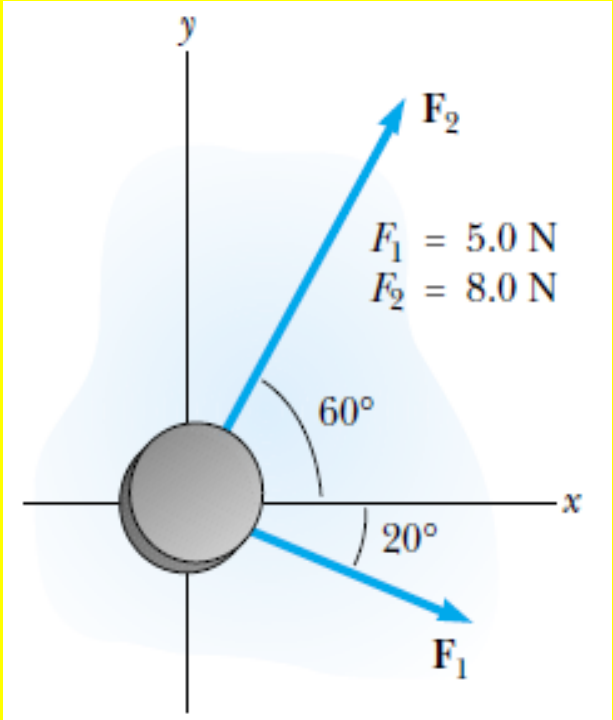
- Units:

Units of Mass, Acceleration, and Force[a]

System of Units	Mass	Acceleration	Force
SI	kg	m/s^2	$N = kg \cdot m/s^2$
U.S. customary	slug	ft/s^2	$lb = slug \cdot ft/s^2$

Example 5.1 An Accelerating Hockey Puck

- A hockey puck having a mass of 0.30 kg slides on the horizontal, frictionless surface. Two hockey sticks strike the puck simultaneously, exerting the forces on the puck shown in the figure. The force $\boldsymbol{F}_1$ has a magnitude of 5.0 N, and the force $\boldsymbol{F}_2$ has a magnitude of 8.0 N. *Determine both the magnitude and the direction of the puck's acceleration*
- Solution:
- To analyze the problem, we resolve the force vectors into components.



We should find first x-component of the net force
Then, y-component. We then find x and y comp.
Of the acceleration a and find its mag. And direction

Example 5.1 (Continued)

$$\sum F_x = F_{1x} + F_{2x}$$

$$= F_1 \cos(-20) + F_2 \cos(60) = 5 \times 0.94 + 8 \times 0.5 = 8.7\,N$$

$$\sum F_y = F_{1y} + F_{2y}$$

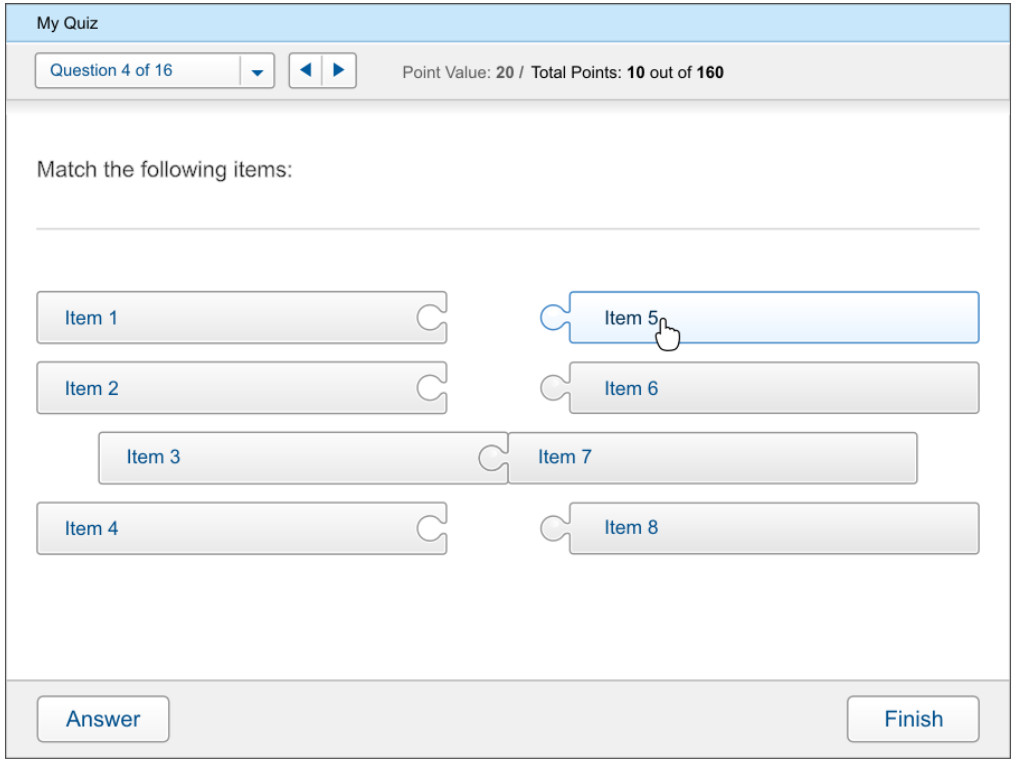
$$= F_1 \sin(-20) + F_2 \sin(60) = 5 \times -0.34 + 8 \times 0.87 = 5.2\,N$$

$$\therefore a_x = \frac{\sum F_x}{m} = \frac{8.7}{0.3} = 29\,m/s^2 \;,\; a_y = \frac{\sum F_y}{m} = \frac{5.2}{0.3} = 17\,m/s^2$$

$$\Rightarrow a = \sqrt{a_x{}^2 + a_y{}^2} = \sqrt{29^2 + 17^2} = 34\,m/s^2$$

$$\theta = \tan^{-1}\left(\frac{a_y}{a_x}\right) = \tan^{-1}\left(\frac{17}{29}\right) = 30^o$$

Quiz No. 5.2 and 5.3



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5.5 The Gravitational Force and Weight

- The attractive force exerted by the Earth on an object is called the gravitational force $\mathbf{F}_g$
- This force is directed toward the center of the Earth,3 and its magnitude is called the weight of the object.
- Using equation (5.2) with $\boldsymbol{a} = \boldsymbol{g}$ we have:

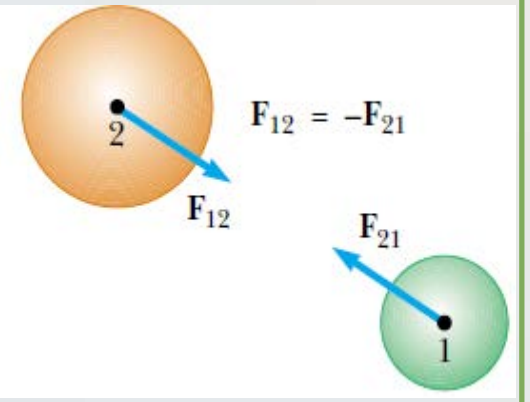
$$\boldsymbol{F_g} = m\,\boldsymbol{g} \qquad (5.6)$$

- Thus: the weight of an object = mg
- Kilogram is Not a Unit of Weight: You may have seen the "conversion" 1 kg = 2.2 lb. Despite popular statements of weights expressed in kilograms, the kilogram *is not a unit of weight*, it is a unit of mass. The conversion statement is not an equality; it is an equivalence that is only valid on the surface of the Earth.

5.6 Newton's Third Law

- *If two objects interact, the force F_{12} exerted by object 1 on object 2 is equal in magnitude and opposite in direction to the force F_{21} exerted by object 2 on object 1:*

$$\boldsymbol{F_{12} = -F_{21}} \qquad (5.7)$$



- where $\mathbf{F}_{ab}$ means "the force exerted by a on b."
- The third law, which is illustrated in the figure is equivalent to stating that forces always occur in pairs, or that a single isolated force cannot exist. The force that object 1 exerts on object 2 may be called the *action* force and the force of object 2 on object 1 the *reaction* force.
- The action force is equal in magnitude to the reaction force and opposite in direction.

Problem Solving Hints

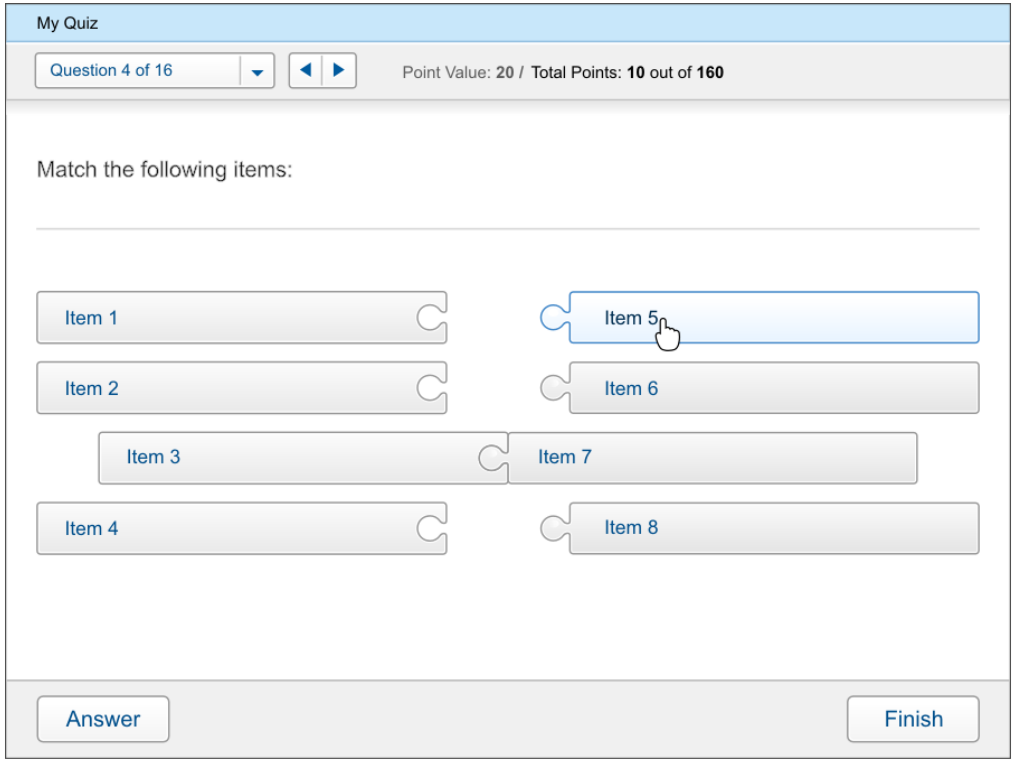
PROBLEM-SOLVING HINTS

Applying Newton's Laws

The following procedure is recommended when dealing with problems involving Newton's laws:

- Draw a simple, neat diagram of the system to help *conceptualize* the problem.
- *Categorize* the problem: if any acceleration component is zero, the particle is in equilibrium in this direction and $\Sigma F = 0$. If not, the particle is undergoing an acceleration, the problem is one of nonequilibrium in this direction, and $\Sigma F = ma$.
- *Analyze* the problem by isolating the object whose motion is being analyzed. Draw a free-body diagram for this object. For systems containing more than one object, draw *separate* free-body diagrams for each object. *Do not* include in the free-body diagram forces exerted by the object on its surroundings.
- Establish convenient coordinate axes for each object and find the components of the forces along these axes. Apply Newton's second law, $\Sigma \mathbf{F} = m\mathbf{a}$, in component form. Check your dimensions to make sure that all terms have units of force.
- Solve the component equations for the unknowns. Remember that you must have as many independent equations as you have unknowns to obtain a complete solution.
- *Finalize* by making sure your results are consistent with the free-body diagram. Also check the predictions of your solutions for extreme values of the variables. By doing so, you can often detect errors in your results.

Quiz



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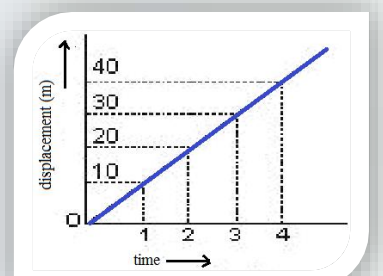
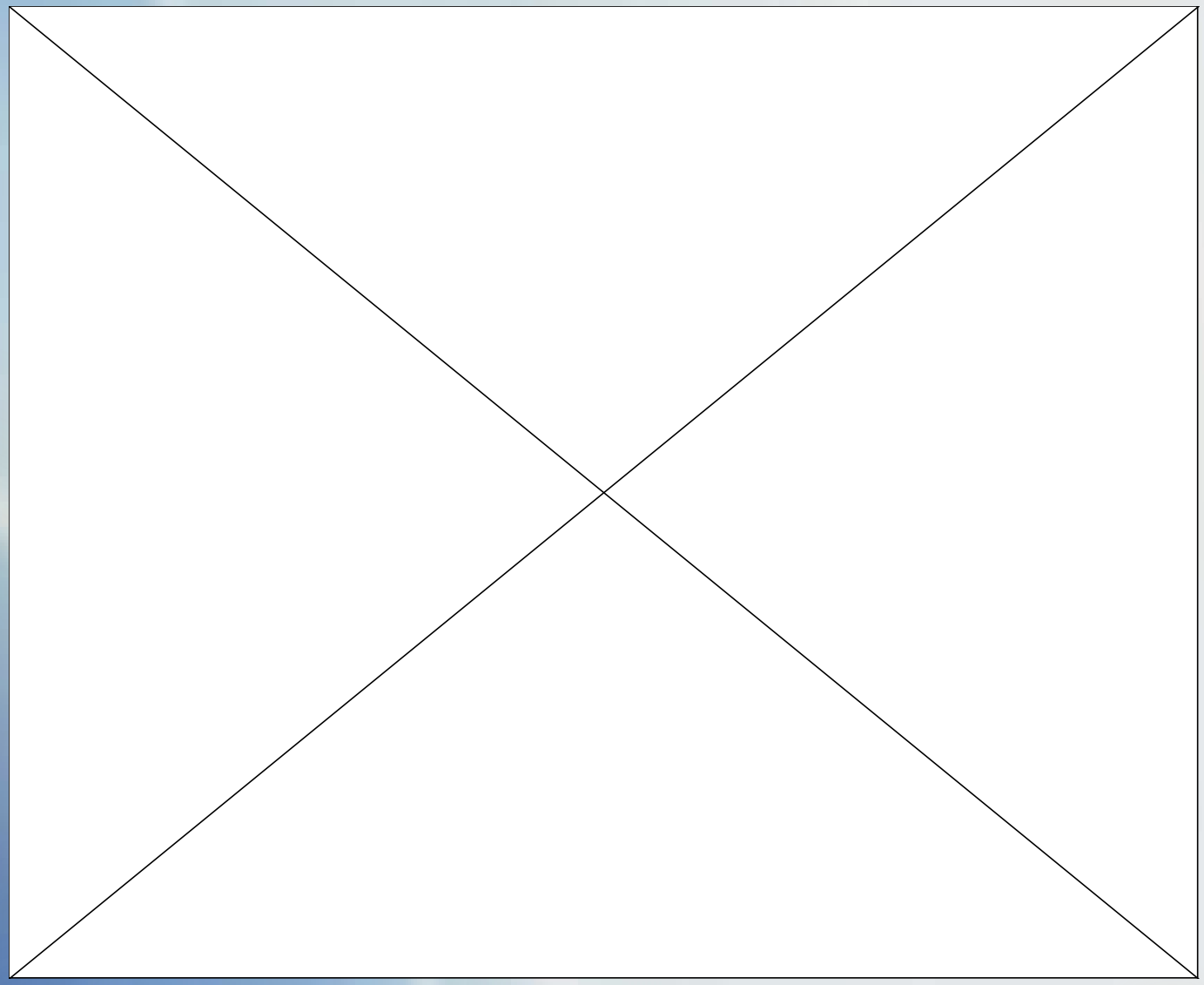
Lecture Summary

- **Newton's first law** states that it is possible to find such a frame, or, equivalently, in the absence of an external force, when viewed from an inertial frame, an object at rest remains at rest and an object in uniform motion in a straight line maintains that motion.
- **Newton's second law** states that the acceleration of an object is directly proportional to the net force acting on it and inversely proportional to its mass. The net force acting on an object equals the product of its mass and its acceleration: $\Sigma \mathbf{F} = m\mathbf{a}$. If the object is either stationary or moving with constant velocity, then the object is in equilibrium and the force vectors must cancel each other.
- **The gravitational force** exerted on an object is equal to the product of its mass (a scalar quantity) and the free-fall acceleration: $\mathbf{F}_g = mg$. The weight of an object is the magnitude of the gravitational force acting on the object.
- **Newton's third law** states that if two objects interact, the force exerted by object 1 on object 2 is equal in magnitude and opposite in direction to the force exerted by object 2 on object 1. Thus, an isolated force cannot exist in nature.



Please watch this Video

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