Phys 103

Chapter 5

The Laws of Motion

By

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LECTURE OUTLINE

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5.2 Newton's First Law and Inertial Frames

5.3 Mass

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5.6 Newton's Third Law

5.7 Some Applications of Newton's Laws

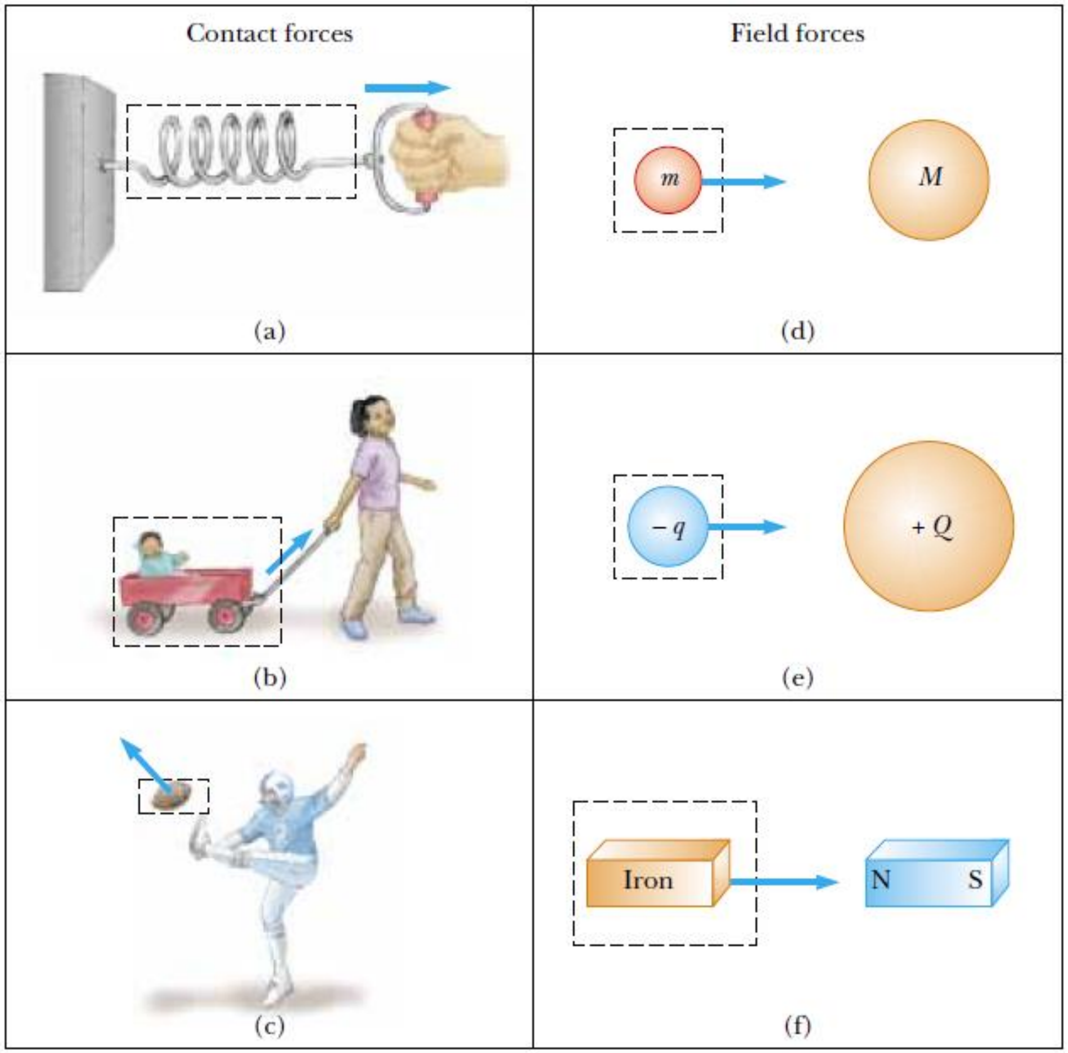
5.8 Forces of Friction

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 The Concept of Force

Examples of Contact and Field forces



5.2 Newton's First Law and Inertial Frames

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*.

5.3 Mass

Newton's First Law

- **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

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:

$$\sum \boldsymbol{F} = m\boldsymbol{a}$$

$$\sum F_x = ma_x \qquad \sum F_y = ma_y \qquad \sum F_z = ma_z$$

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	$lb = slug \cdot ft/s^2$

5.4 Newton's Second Law

Units

Units of Mass, Acceleration, and Force[a]

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SI	kg	m/s^2	$N = kg \cdot m/s^2$
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In the U.S. customary system, the unit of force is the **pound**, which is defined as the force that, when acting on a 1-slug mass,[2] produces an acceleration of 1 ft/s^2:

$$1\,lb \equiv 1\,slug \cdot ft/s^2 \tag{5.5}$$

A convenient approximation is that $1\,N \approx \frac{1}{4}\,lb$.

The units of mass, acceleration, and force are summarized in Table 5.1.

5.5 The Gravitational Force and Weight

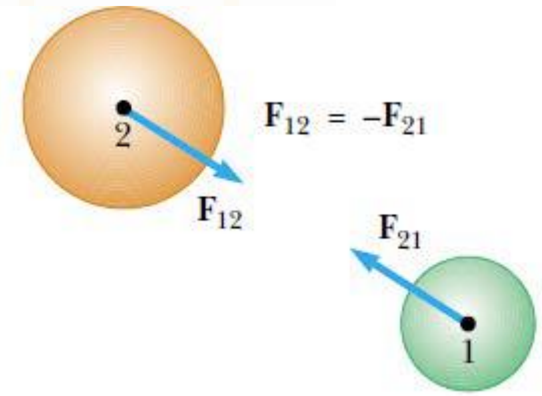
- The attractive force exerted by the Earth on an object is called the gravitational force $\mathbf{F}_g$
- This force is directed toward the center of the Earth,3 and its magnitude is called the weight of the object.
- Using equation (5.2) with ***a*= *g*** we have:

- 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 F21exerted by object 2 on object 1:*

$$F_{12}=-F_{21}$$



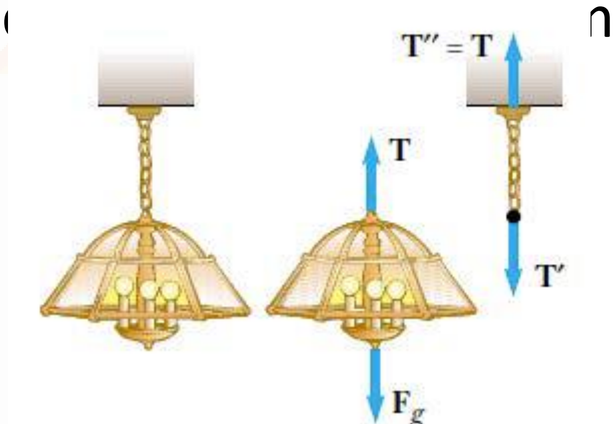
- where $\mathbf{F}_{ab}$ means "the force exerted by a on b."
- The third law, which is illustrated in the figure
- is equivalent to stating that forces always occur
- in pairs, or that a single isolated force cannot exist.
- The force that object 1 exerts on object 2 may be called
- the *action* force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

5.7 Some Applications of Newton's Laws

- ***when we apply Newton's laws to an object, we are interested only in external forces that act on the object***
- **Objects in Equilibrium:**
- If the acceleration of an object is zero, the particle is in **equilibrium**

$$\sum F_x = 0 \qquad \sum F_y = 0 \qquad \sum F_z = 0$$

- For example: a lamp hang by a robe from the … n because:



$$\sum F_y = T - mg = 0$$

$$ma = 0 \; so \; a = 0$$

A lamp suspended from a ceiling by a chain of negligible mass balanced Under the effect of two forces **T** and **F**g.

5.8 Forces of Friction

- When an object is in motion either on a surface or in a viscous medium such as air or water, there is resistance to the motion because the object interacts with its surroundings. We call such resistance a ***force of friction***
- There are two types of frictional forces:Static: f_s and kinetic: f_k

$$f_s = \mu_s n$$

$$f_k = \mu_k n$$

- We define these two types as:
- μ_s is called coefficient of static friction, and $\mu_k$is called coefficient of kentic friction. $\mu_s > \mu_k$, $(0 \leq \mu \leq 1)$
- The direction of the friction force on an object is parallel to the surface with which the object is in contact and ***opposite*** to the actual motion.

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: $\Sigma\mathbf{F} = ma$. 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.

Lecture Summary

- **Newton's first law**: defined earliar.
- **Newton's second law**: $\sum \boldsymbol{F} = m\boldsymbol{a}$.
- **The gravitational force**: weight of an object = mg.
- **Newton's third law**: $\boldsymbol{F_{12}}=-\boldsymbol{F_{21}}$.
- **The maximum force of static friction** f_s, max between an object and a surface is proportional to the normal force acting on the object.
- In general, $f_s \leq \mu_s n$, where μ_s is the **coefficient of static friction** and n is the magnitude of the normal force.
- When an object slides over a surface, the direction of the force of kinetic friction f_k is **opposite**the direction of motion of the object relative to the surface and is also proportional to the magnitude of the normal force. The magnitude of this force is given by $f_k \leq \mu_k n$, where μ_k is the **coefficient of kinetic friction**.

Thank You

ACKNOWLEDGEMENTS