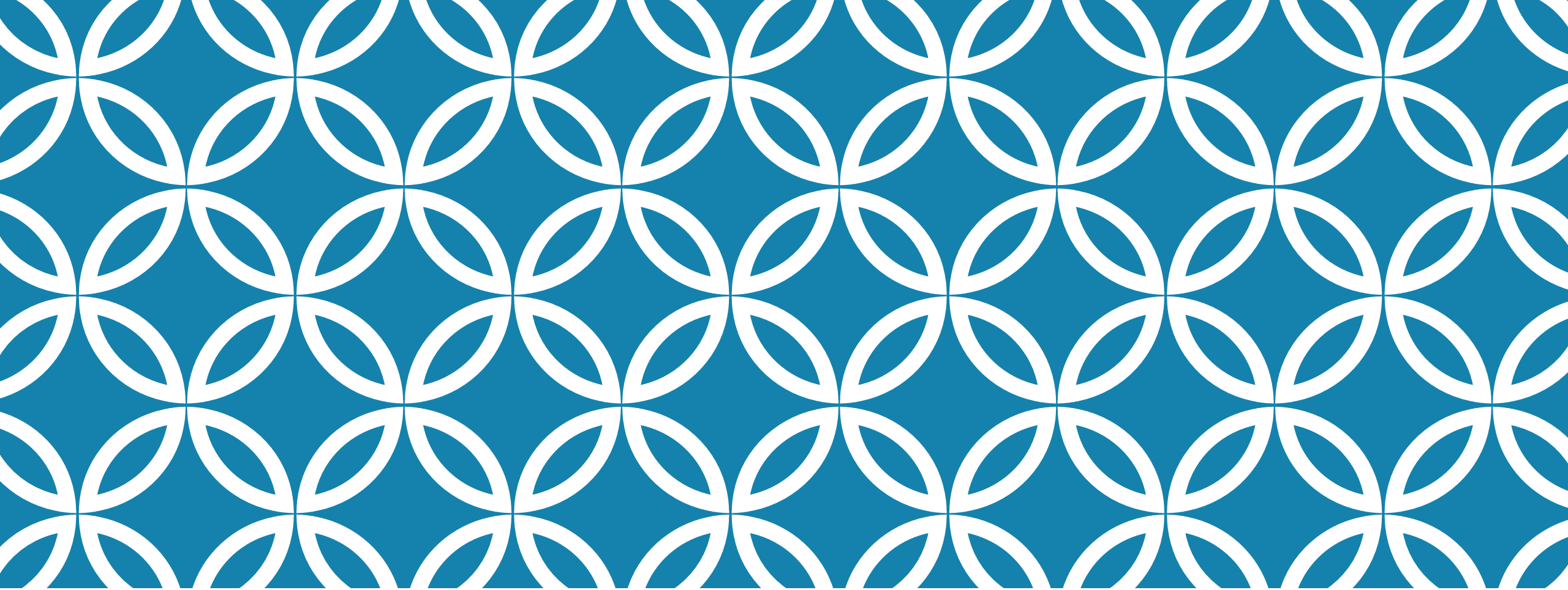


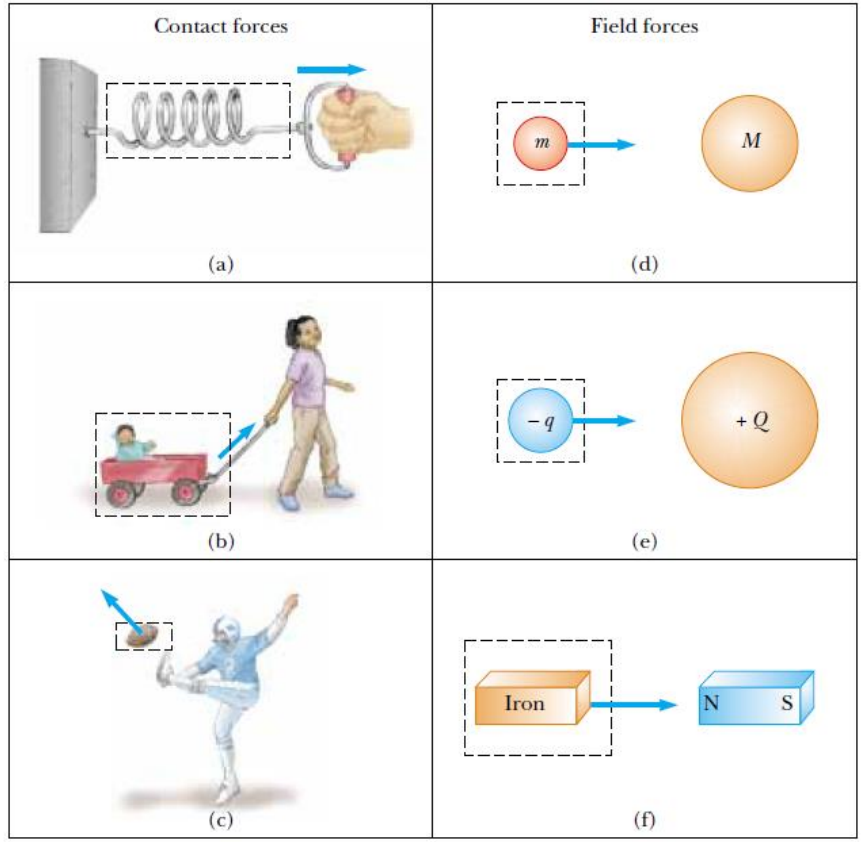
CHAPTER 4

Newton's laws of motion

CONTENTS

1. FORCE AND INTERACTIONS

- A force is a push or a pull. A better definition is that a force is an interaction between two bodies.
- The force can cause a change in an object's velocity.
- The force causes an object to accelerate.
- The SI unit of force is $\mathrm{N} = \mathrm{kg.\,m/s^2}$
- The force is a vector.
- The force can be either contact force or field force.
- The force requires an agent, something that acts or pushes or pulls.



2. NEWTON'S FIRST LAW

Newton's first law of motion:

An object acted on by no net force moves with constant velocity (which may be zero) and zero acceleration.

$$\sum \vec{F} = 0 \qquad \text{(the object in equilibrium)}$$

$$\sum \vec{F}_x = 0 \quad \text{and} \quad \sum \vec{F}_y = 0$$

There may be multiple forces on an object, but if their net force is zero, the object cannot accelerate.

* If the object at rest, it stays at rest

* If the object is moving, with constant velocity it continues to move with the same velocity (in a straight line)

3. NEWTON'S SECOND LAW

Newton's second law of motion:

If a net external force acts on an object, it accelerates.

The direction of acceleration is the same as the direction of the net force.

The mass of the an object times its acceleration equals the net force vector.

$$\sum \vec{F} = m\vec{a}$$ (Newton's second law of motion)

$$\sum \vec{F}_x = m\vec{a}_x \quad \text{and} \quad \sum \vec{F}_y = m\vec{a}_y$$

The greater the mass of an object, the less that object accelerates under the action of a given applied force.

$$a \propto \frac{1}{m}$$

Example 4.1: A constant force causes an object to accelerate at $4\ \mathrm{m/s^2}$. What is the acceleration of an object with twice the mass that experiences the same force?

Solution:

$$m_2 = 2m_1: \quad \text{if } m_1 = 1 \implies m_2 = 2 \times 1 = 2$$

$$F_1 = F_2$$

$$m_1 a_1 = m_2 a_2$$

$$1 \times 4 = 2 \times a_2$$

$$a_2 = \frac{4}{2} = 2\ \mathrm{m/s^2}$$

Remark: when the mass is doubled, the acceleration is halved.

4. NEWTON'S THIRD LAW

Newton's third law of motion:

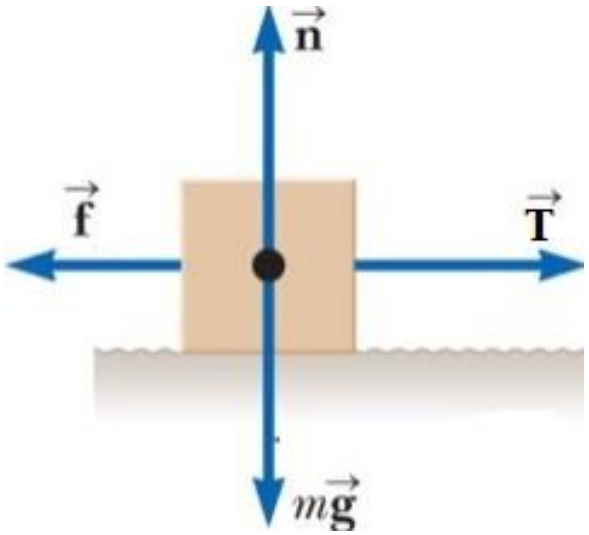
If an object A exerts a force on an object B (an "action"), then an object B exerts a force on an object A (a "reaction").

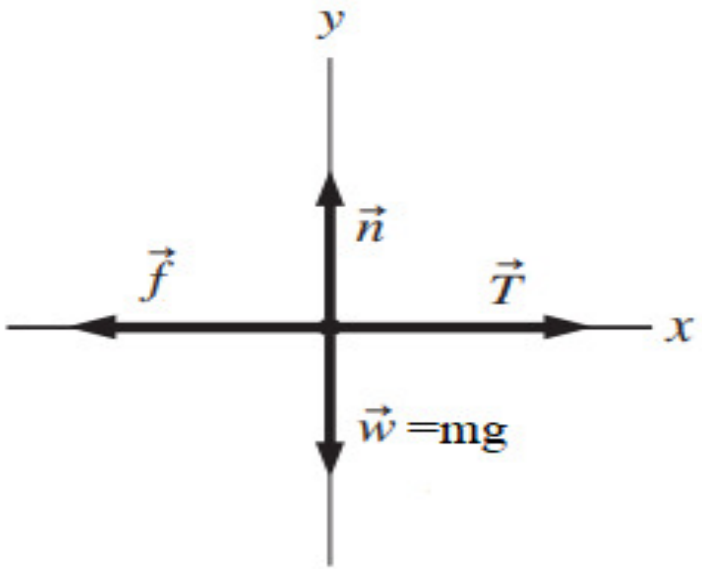
These two forces have the same magnitude but are opposite in direction.

These two forces act on different objects.

$$\vec{F}_{A\ on\ B} = -\vec{F}_{B\ on\ A}$$ (Newton's third law of motion)

5. FREE BODY DIAGRAMS





A free body diagram: is a force diagram that shows the relative magnitude and direction of all forces that acts on an object in a specific situation

A force is applied to the right to drag a box stationary on floor with a rightward acceleration.

A free-body diagram for this situation shown in figure