Introduction to Mechanics
Dynamics
Forces
Newton's Laws

Lana Sheridan

De Anza College

Feb 27, 2020

Last time

- Newton's second law
- mass and weight
- Newton's second law and kinematics
- vector addition with forces

Overview

- Newton's third law
- action-reaction pairs of forces
- types of forces: gravitation

Newton's Third Law

Newton III

If two objects (1 and 2) interact the force that object 1 exerts on object 2 is equal in magnitude and opposite in direction to the force that object 2 exerts on object 1.

$$\vec{\mathsf{F}}_{1\rightarrow 2} = -\vec{\mathsf{F}}_{2\rightarrow 1}$$

Newton's Third Law

Main idea: you cannot push on something, without having it push back on you.

If object 1 pushes on (or interacts with) object 2, then the force that object 1 exerts on object 2, and the force that object 2 exerts on object 1 form an **action reaction pair**.

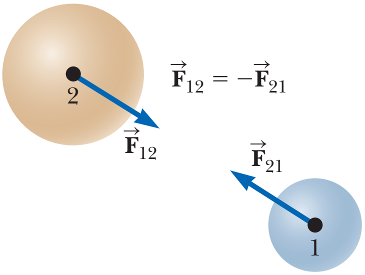
Newton's Third Law

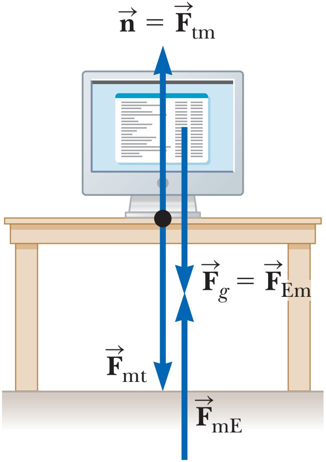
Main idea: you cannot push on something, without having it push back on you.

If object 1 pushes on (or interacts with) object 2, then the force that object 1 exerts on object 2, and the force that object 2 exerts on object 1 form an **action reaction pair**.

Notice: **two** objects are interacting here!

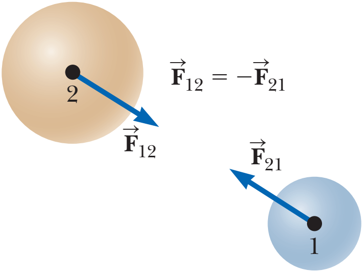
Newton's Third Law: Action Reaction Pairs





Defining a System

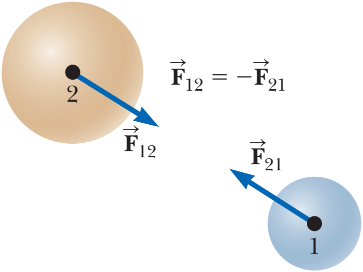
Consider these particles which exert a force on each other:



They are attracted. Each will accelerate toward the other.

Defining a System

Consider these particles which exert a force on each other:



They are attracted. Each will accelerate toward the other.

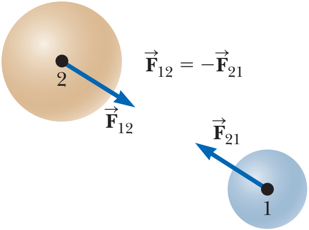
But wait: do the forces cancel?

$$\vec{\mathbf{F}}_{1\to 2} = -\vec{\mathbf{F}}_{2\to 1} \;\Rightarrow\; \vec{\mathbf{F}}_{1\to 2} + \vec{\mathbf{F}}_{2\to 1} = 0$$

Is the net force zero? How can they each accelerate?

Defining a System

Consider these particles which exert a force on each other:



Is the net force zero?

No! The forces act on different objects. To find if particle 1 accelerates, we find the net force **on particle 1**. We do not consider forces on particle 2.

The only force on particle 1 is $\vec{F}_{2\to1}$, so the net force is not zero: it accelerates.

Action and Reaction

Why when we fire a cannon does the cannon ball move much faster forward than the cannon does backwards?

Why when we drop an object does it race downwards much faster than the Earth comes up to meet it?

Action and Reaction

Why when we fire a cannon does the cannon ball move much faster forward than the cannon does backwards?

Why when we drop an object does it race downwards much faster than the Earth comes up to meet it?

The masses of each object are very different!

From Newton's second law

$$a = \frac{F_{\text{net}}}{m}$$

If m is smaller, a is bigger. If m is very, very big (like the Earth), the acceleration is incredibly small.

Action and Reaction

Question. Do the two forces shown in the diagram that act on the monitor form an action-reaction pair under Newton's third law?

(A) Yes.

(B) No.

Action and Reaction

Question. Do the two forces shown in the diagram that act on the monitor form an action-reaction pair under Newton's third law?

(A) Yes.

(B) No. ←

Some types of forces

Gravitation

The force that massive objects exert on one another.

Newton's Law of Universal Gravitation

$$F_G = \frac{Gm_1 m_2}{r^2}$$

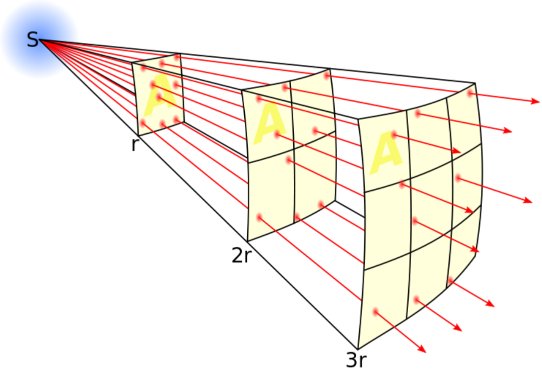
for two objects, masses m_1 and m_2 at a distance r.

$G = 6.67 \times 10^{-11}$ Nm^2 kg^{-2}.
(Challenge: check the units of G.)

Form of Newton's Law of Gravitation

$$F = G\,\frac{m_1 m_2}{r^2}$$

This kind of law is called an **inverse square law**.



[1]Figure from Wikipedia.

Some types of forces: Gravitation

For the moment, we will care about this force in that it gives objects weight, written F_g or W.[1]

$$F_g = W = mg$$

and

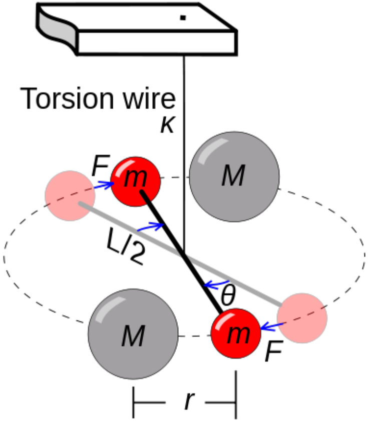
$$g = \frac{GM_{\text{Earth}}}{R^2_{\text{Earth}}}$$

The force $\vec{\mathbf{F}}_g$ or $\vec{\mathbf{W}}$, acts downwards towards the center of the Earth.

[1] The textbook uses W for weight.

Gravitation: Measurement of G

G was first measured by Henry Cavendish using a torsion balance.



[1]Diagram from Wikipedia by Chris Burks.

Gravitation: Mass of the Earth

Determining G allowed for a the mass of the Earth M_E to be calculated.

Christopher Columbus notwithstanding, the radius of the Earth was known fairly accurately from ancient times:

$$R_E = 6.37 \times 10^6 \text{ m}$$

$$F_G = \frac{G m_1 m_2}{r^2}$$

$G = 6.67 \times 10^{-11} \text{ Nm}^2 \text{ kg}^{-2}$.

Figure out the mass of the Earth, M_E.

Gravitation: Mass of the Earth

The weight of an object is the force on the object due to gravity, when the distance is the radius of the Earth.

$$
\begin{aligned}
F = G\,\frac{mM_E}{r^2} &= mg \\
G\,\frac{M_E}{R_E^2} &= g \\
M_E &= \frac{gR_E^2}{G} \\
M_E &= 6 \times 10^{24}\ \text{kg}
\end{aligned}
$$

Summary

- Newton's 3rd law
- action-reaction pairs
- gravity

Quiz Monday, start of class.

Homework

Walker Physics:

- Ch 5, onward from page 138. Questions: 11; Problems: 16 & 17, 19 (Newton's 3rd law)