

Reminder: Homework Assignment #1 is due Friday (09/08)

Homework Assignment #2 - due 09/15

Instructions

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Staple the cover sheet, with answers where indicated, in front of your solutions.

Computer problems

- Your best bet is to use *Mathematica*.
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Homework Assignment #2
due in class Friday, September 15

[6] Problem 1.35 *

[7] Problem 1.38 **

[8] Problem 1.39 *

[9] Problem 1.44 *

[10] Problem 1.51 *** [computer]

Use the cover sheet.

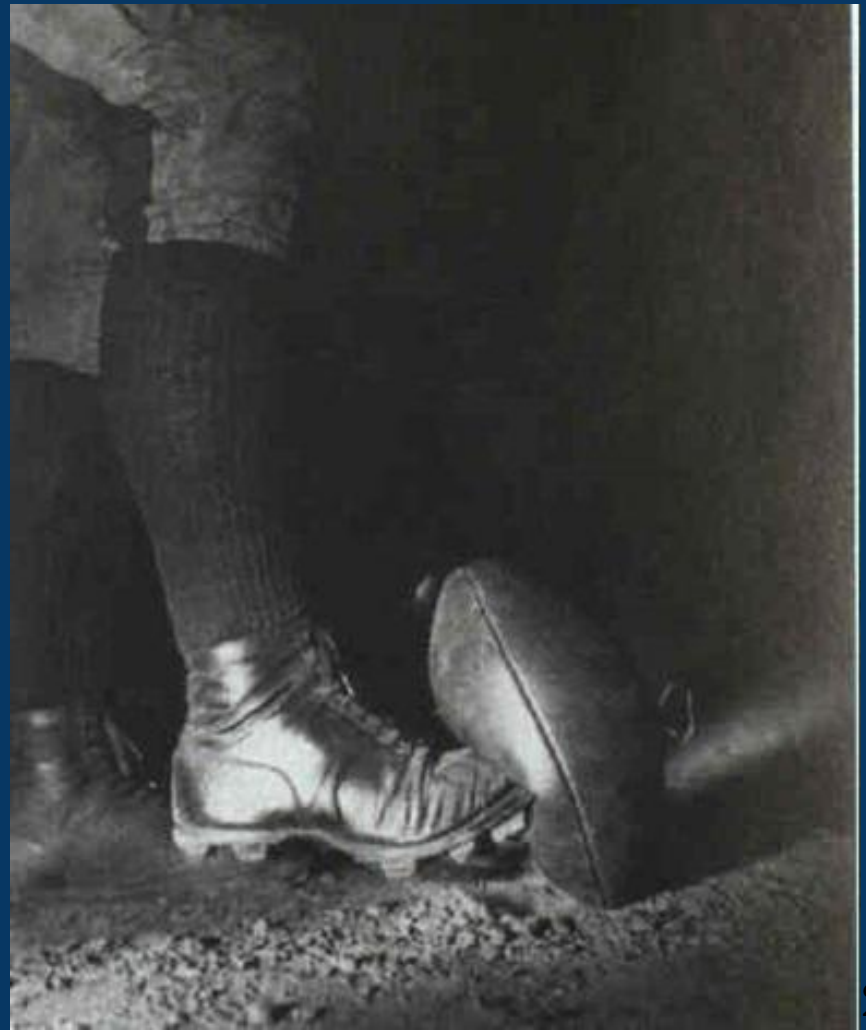
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1. Cover sheet for H.W. #2.
2. a *Mathematica* notebook to solve Taylor's Problem 1.50.

Newton's Third Law

Harold Edgerton, (an MIT professor who invented methods high-speed photography) took this picture, "Wes Fesler kicking a football".

What does the picture say about Newton's third law?



Section 1.5. Newton's Third Law

For every action there is an equal but opposite reaction.

That's how Newton expressed it, but his archaic language may create some confusion or misconceptions.

- What is meant by "action"?

Newton's word "action" is what we now call force.

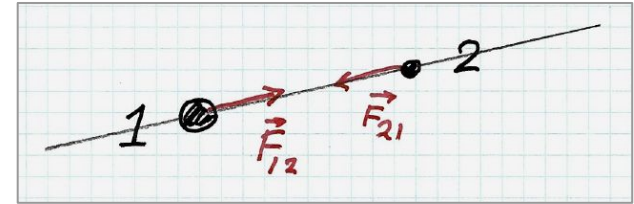
- When does the reaction occur?

The two forces (action and reaction) are perfectly simultaneous.

- If the two forces are simultaneous, then which one is the action and which one is the reaction?

You could call either force the action and the other one the reaction.

A modern statement of Newton's third law, trying to avoid these confusions, is:



"

If object 1 exerts a force F_{21} on object 2, then object 2 exerts a reaction force F_{12} on object 1 given by

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

"

(Taylor)

Figure 1.5

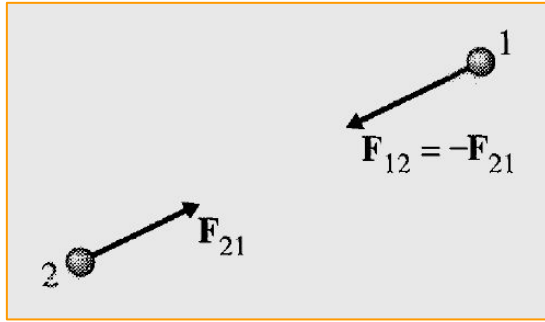
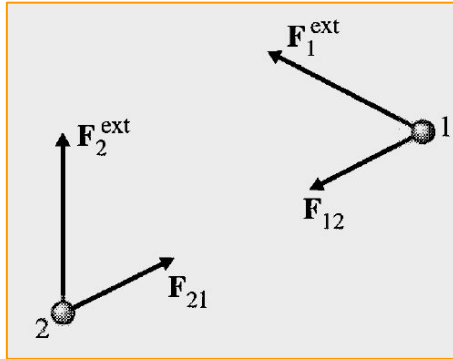


Figure 1.6



•The "external forces" do not need to be equal but opposite. •"Internal forces", i.e., action-reaction pairs, must be equal but opposite.

A famous puzzle:

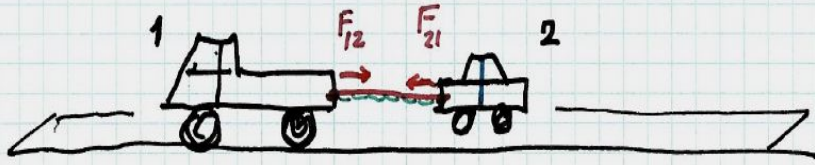
When the tow truck starts to accelerate and pull the car, which force in the figure below is stronger?



These two forces are equal but opposite.

Now, if the forces are equal but opposite, how can the vehicles begin to move and accelerate?

Let's think about this carefully...



The tow truck (object 1, mass = 3000 kg) pulls the car (object 2, mass = 1000 kg) with a tow rope.

When the truck accelerates to the left, the rope pulls the car to the left with a force F_{21} , and the rope pulls the truck to the right with a force F_{12} .

By Newton's third law, $F_{12} = -F_{21}$.

(= the "tension" in the rope)

The two forces are equal but opposite.

Now, if the forces are equal but opposite, how can the vehicles begin to move and accelerate?

There are other forces acting, e.g., friction between the tow truck tires and the road.

The truck tires are pushing the Earth backwards, and the Earth pushes the tires forward. Because the rubber is \approx inelastic, the truck accelerates forward.

What would happen if the truck were on a frictionless surface, like an icy road?

(If the truck tires are on frictionless surface -- the icy road -- then the tension in the rope must be 0; $F_{12} = -F_{21} = 0$.)

The important consequence of Newton's third law

Theorem: In an interaction between two isolated particles, the total momentum is constant.

Proof:

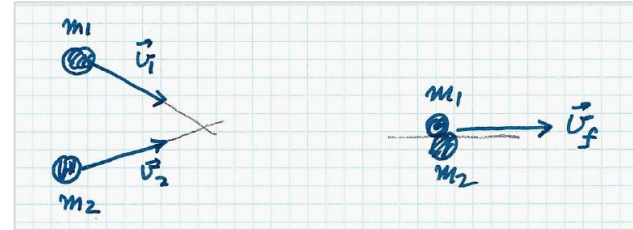
Recall from PHY 183,

$$\mathbf{p}_1 = m_1 \mathbf{v}_1 \quad \text{and} \quad \mathbf{p}_2 = m_2 \mathbf{v}_2.$$

The total momentum is $\mathbf{P} = \mathbf{p}_1 + \mathbf{p}_2$.

$$\begin{aligned} \frac{d\mathbf{P}}{dt} &= m_1 \frac{d\vec{v}_1}{dt} + m_2 \frac{d\vec{v}_2}{dt} \\ &= \vec{F}_1 + \vec{F}_2 \\ &= \vec{F}_{12} + \vec{F}_{21} \quad (\text{isolated system}) \\ &= 0 \quad (\text{Newton's 3rd law}) \end{aligned}$$

Example: *a perfectly inelastic collision*
See the figure. The two objects stick together after the collision.



Calculate the final velocity.

Principle: Momentum is conserved.

$$\begin{aligned} m_1 \vec{v}_1 + m_2 \vec{v}_2 &= (m_1 + m_2) \vec{v}_f \\ \vec{v}_f &= \frac{m_1}{m_1 + m_2} \vec{v}_1 + \frac{m_2}{m_1 + m_2} \vec{v}_2 \end{aligned}$$

We'll study a lot more about conservation of momentum in Chapter 3.

The validity of Newton's third law

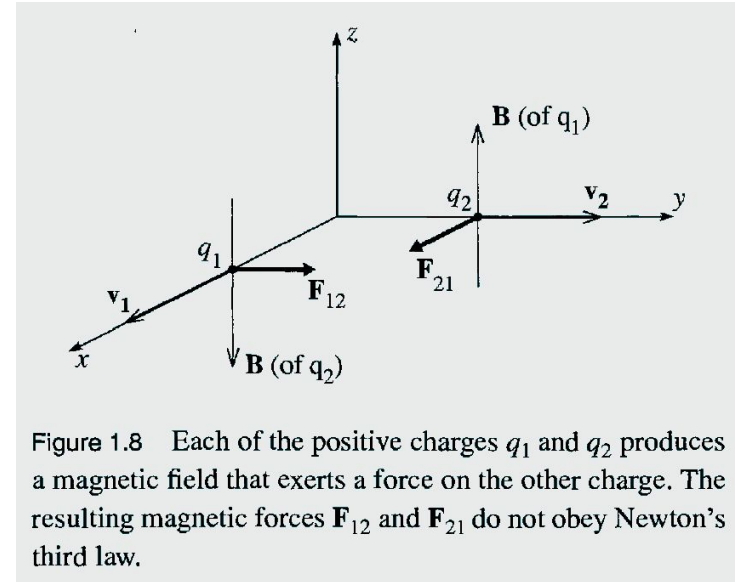
We know from many experiments that momentum is conserved for an isolated system.

So Newton's third law *[equal but opposite forces]* must be valid.

But it can't always be valid!

Read Taylor: " **The third law cannot be valid once relativity becomes important.**" (page 21)

Figure 1.8. The magnetic force between two moving charges does not obey Newton's third law.



In fact, momentum is conserved, *but we must include the momentum of the E.M. radiation fields.* Read Page 21.

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Quiz

"Wes Fesler kicking a football"

What does Newton's third law say about the forces?

