

Today: 4.5, 4.6

L13



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L13

Newton's  
3<sup>rd</sup> law



Today: 4.5, 4.6

L13

Free guy  
body  
diagrams



Today: 4.5, 4.6

Friday: 5.1

L13

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L13

Using Newton's  
1<sup>st</sup> law: Particles  
in equilibrium

Today: 4.5, 4.6

L13

Friday: 5.1

NWS due Monday

Sept. 28<sup>th</sup>

# Newton's 3<sup>rd</sup> law

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In each of these cases, the force that you exert on the other object is in the opposite direction to the force that object exerts on you.

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Old  
School



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Force  
of object  
A onto  
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When two objects A & B exert forces on each other

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I will often write

$\vec{F}_{A \text{ on } B}$  as  $\vec{F}_{A \rightarrow B}$

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3MS

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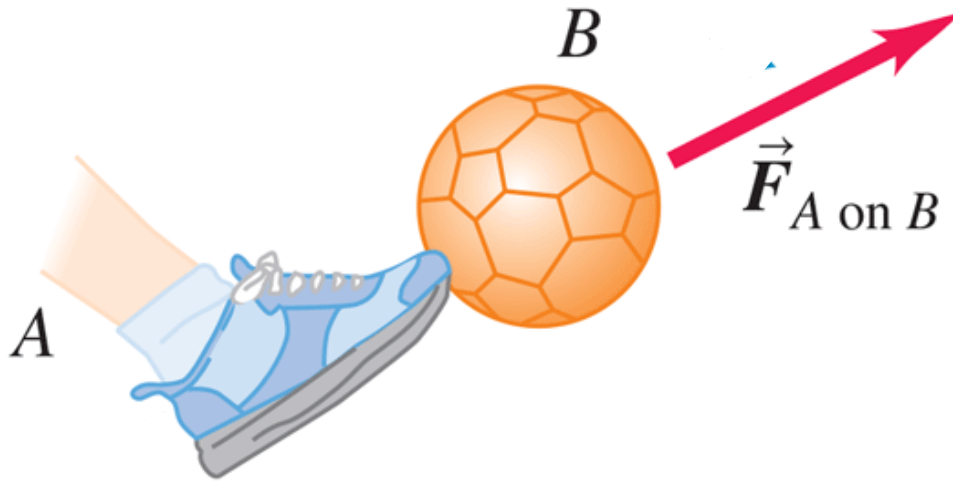
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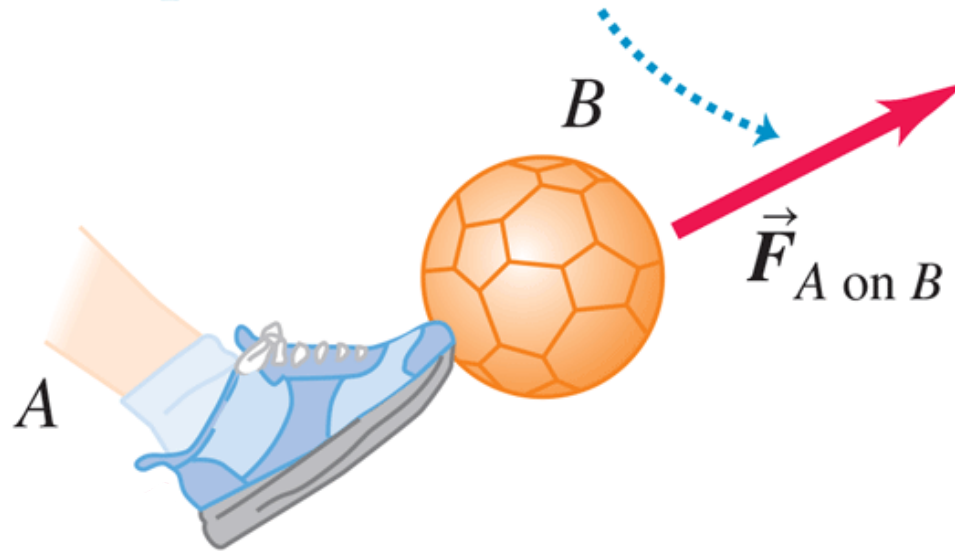
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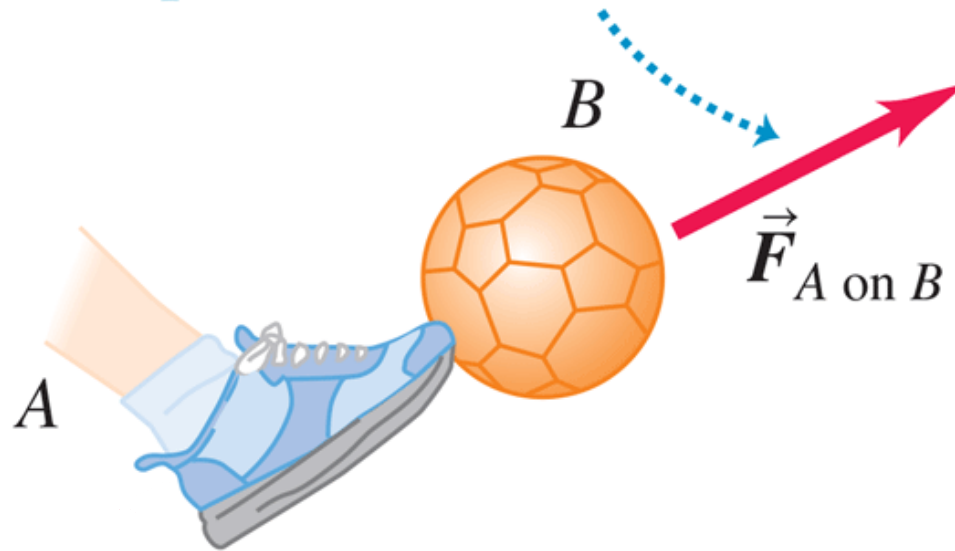
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If object  $A$  exerts force  $\vec{F}_{A \text{ on } B}$  on object  $B$   
(for example, a foot kicks a ball) ...

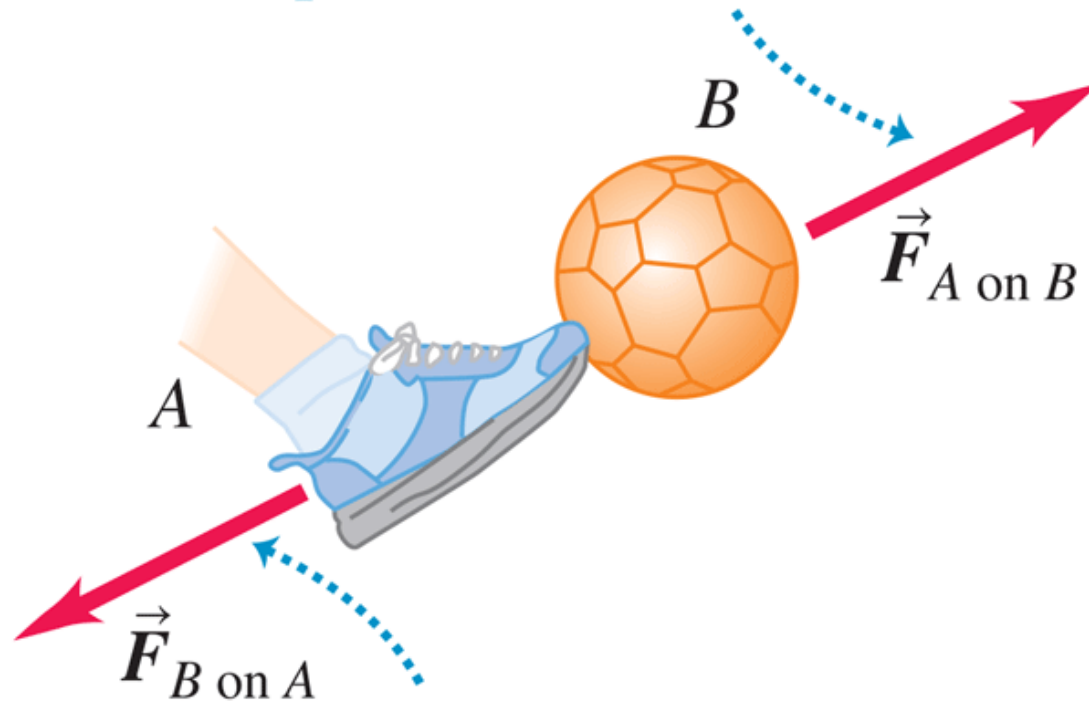


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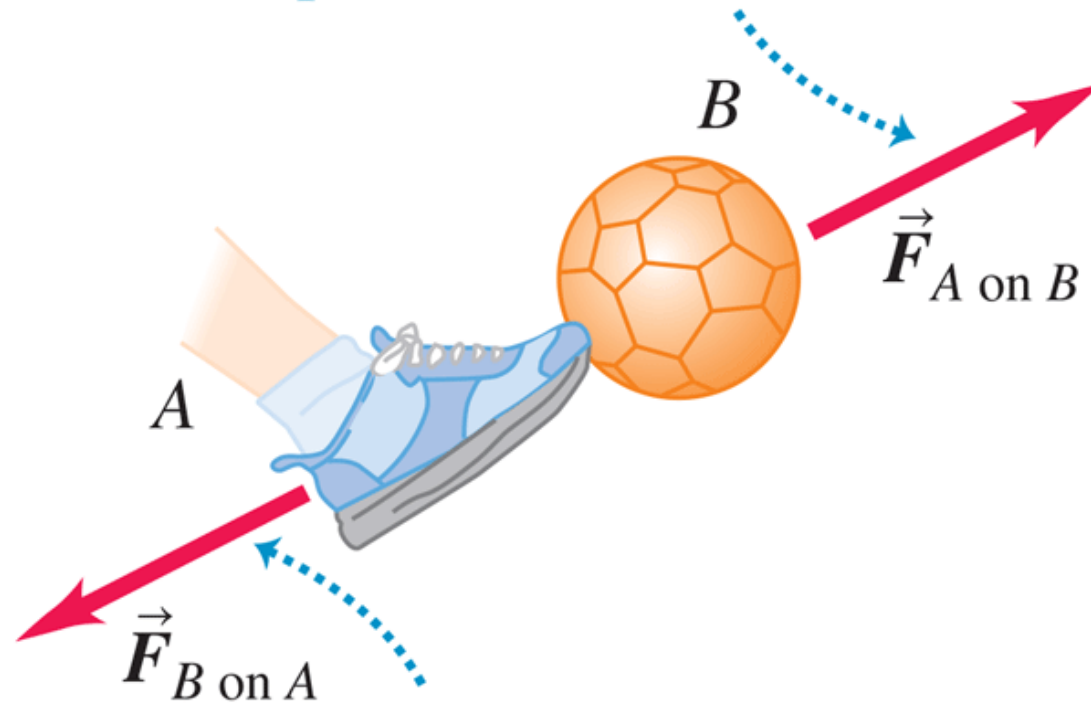
... then object  $B$  necessarily  
exerts force  $\vec{F}_{B \text{ on } A}$  on object  $A$   
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The two forces have the same magnitude  
but opposite directions:  $\vec{F}_{A \text{ on } B} = -\vec{F}_{B \text{ on } A}$ .

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Action-reaction pair

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$$\vec{F}_{A \rightarrow B}$$

Action

$$\& \vec{F}_{B \rightarrow A}$$

Reaction

# Newton's 3<sup>rd</sup> law

Action-reaction pair

$$\vec{F}_{A \rightarrow B}$$

Action

$$\vec{F}_{B \rightarrow A}$$

Reaction

OR

# Newton's 3<sup>rd</sup> law

Action-reaction pair

$$\vec{F}_{A \rightarrow B}$$

$$\& \vec{F}_{B \rightarrow A}$$

~~Action~~  
Reaction  
OR

~~Reaction~~  
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Action-reaction pair

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Does not matter which force is called action or reaction

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Action-reaction pair

$$\vec{F}_{A \rightarrow B} \quad \& \quad \vec{F}_{B \rightarrow A}$$

Does not matter which force is called action or reaction. Just need one of each. One force is the action force & the other is the reaction force.

# Newton's 3<sup>rd</sup> law

NOTE:

$F_{A \rightarrow B}$  is only acting on  
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!! DO NOT PUT THE  
FORCE ON WRONG  
OBJECT !!

# Blame Newton's Laws



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This car stopped because of Newton's second and third laws.



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This car stopped because of Newton's second and third laws. During the impact, the car exerted a force on the tree; in accordance with the third law, the tree exerted an equally strong force back on the car. In accordance with the second law, the force of the tree on the car gave the car an acceleration that changed its velocity to zero

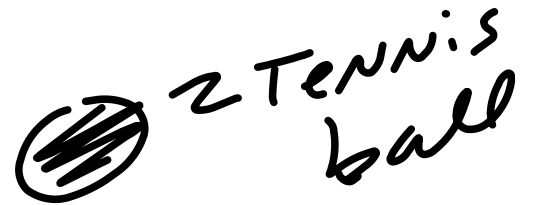


## Newton's 3<sup>rd</sup> law

The 3<sup>rd</sup> law also applies to long-range forces that do not require contact

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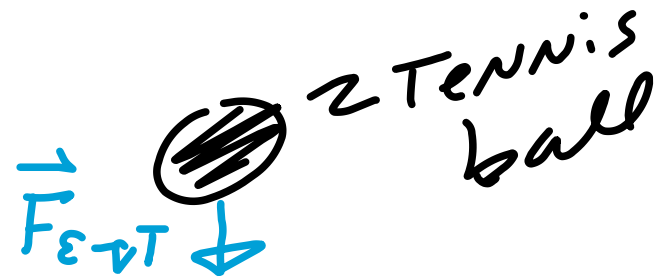
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EARTH

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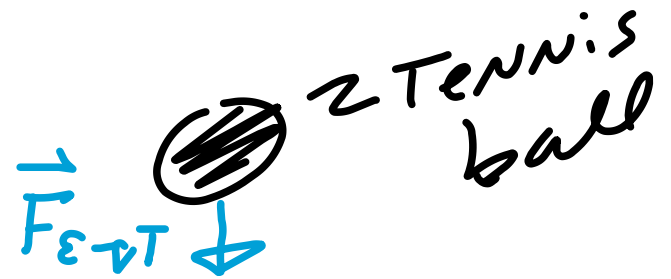


EARTH

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The 3<sup>rd</sup> law also applies to long-range forces that do not require contact

$$\text{Here } \vec{F}_{E \rightarrow T} = \vec{w}$$



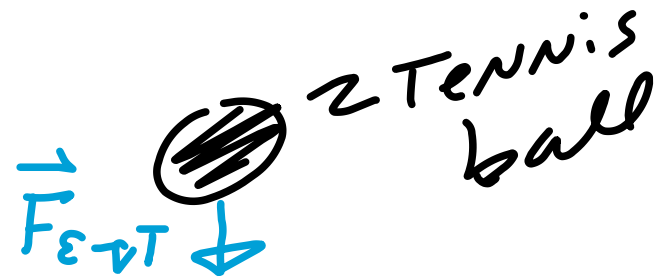
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EARTH

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$$\text{Here } \vec{F}_{E \rightarrow T} = \vec{w} = m\vec{g}$$



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EARTH

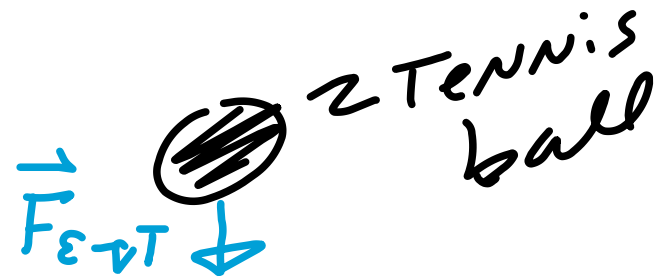
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$$\text{Here } \vec{F}_{\epsilon \rightarrow T} = \vec{w} = m\vec{g}$$

We know that the reaction force

$$\vec{F}_{T \rightarrow \epsilon} = -\vec{F}_{\epsilon \rightarrow T}$$



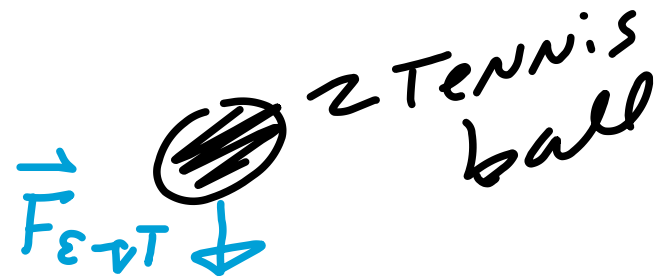
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EARTH

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We know that the reaction force

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EARTH

$$\vec{F}_{T \rightarrow \epsilon} = -\vec{F}_{\epsilon \rightarrow T} \quad \& \quad \vec{F}_{T \rightarrow \epsilon} \text{ acts on Earth}$$

# Newton's 3<sup>rd</sup> law

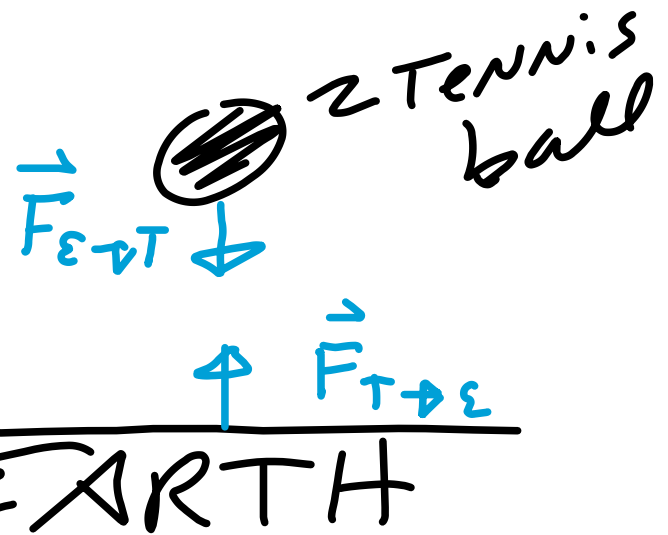
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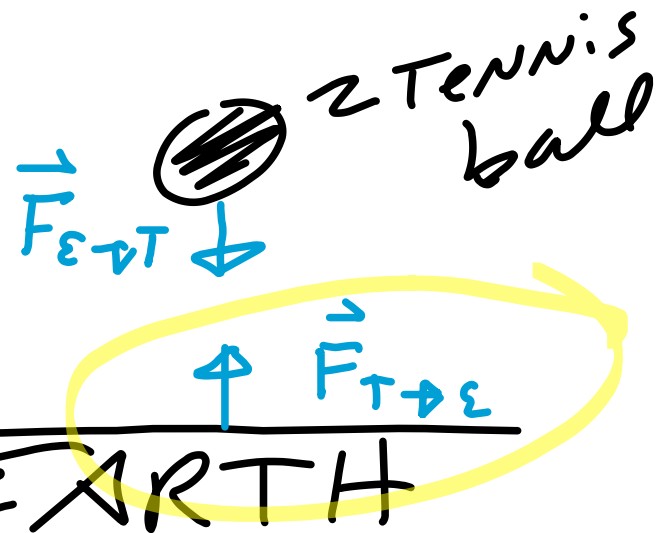
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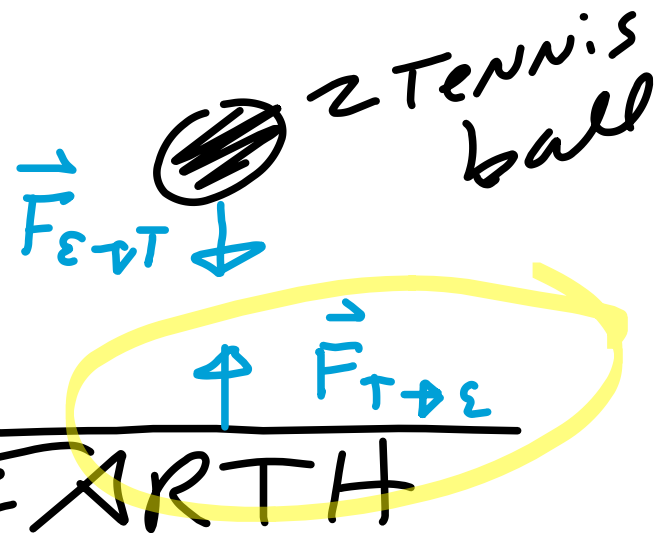
The 3<sup>rd</sup> law also applies to long-range forces that do not require contact

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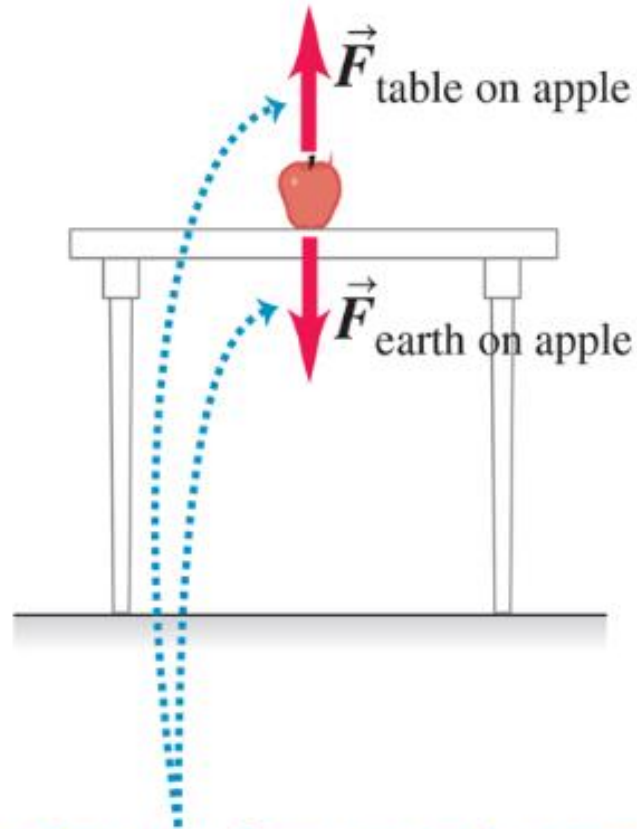
We know that the reaction force

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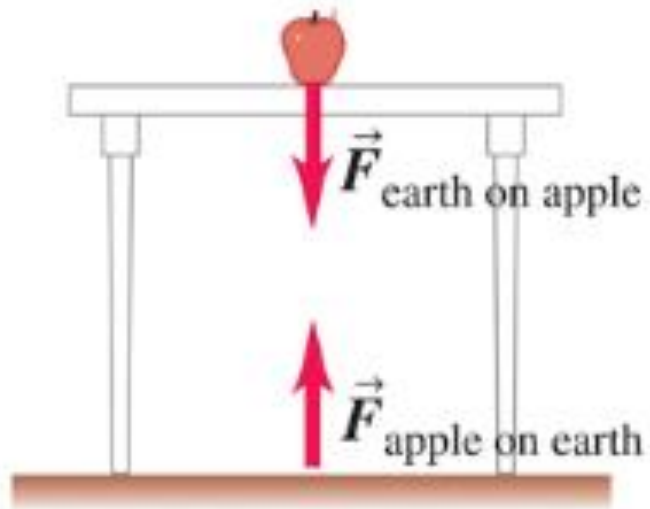


(a) The forces acting on the apple

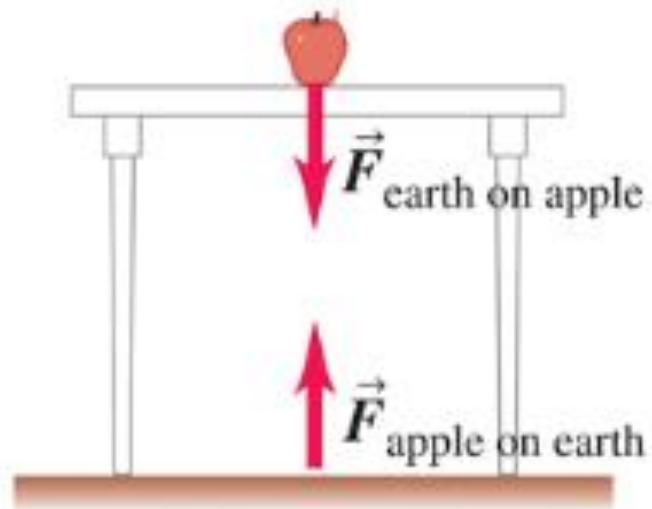


The two forces on the apple *cannot* be an action–reaction pair because they act on the same object.

(b) The action–reaction pair for the interaction between the apple and the earth

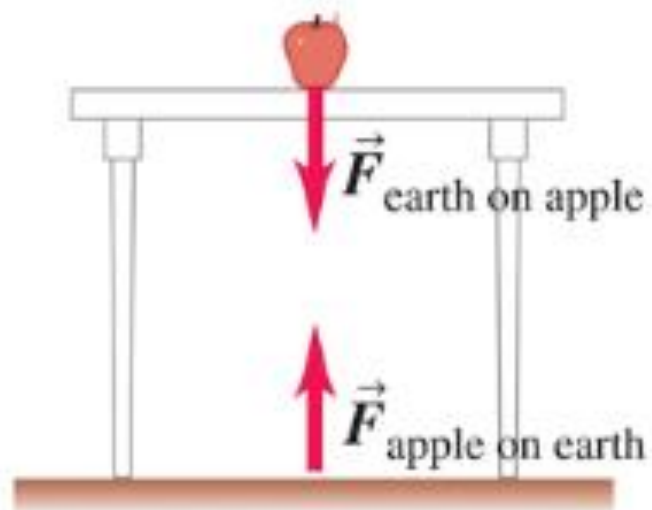


(b) The action–reaction pair for the interaction between the apple and the earth



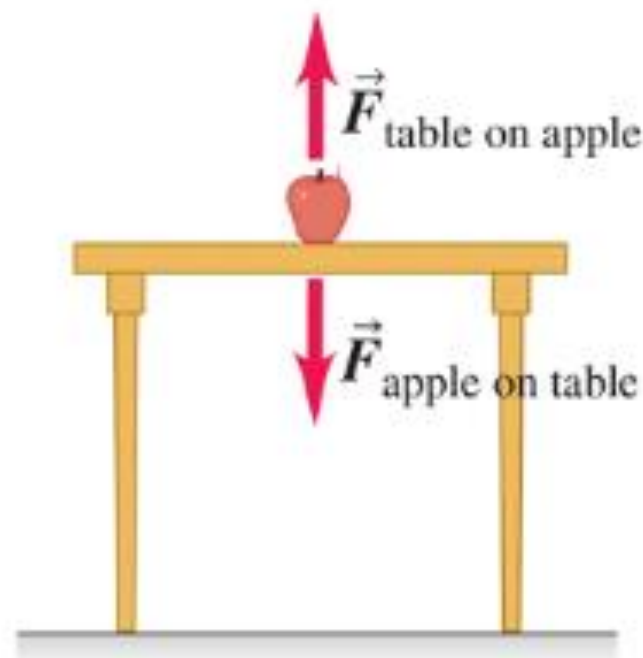
$$\vec{F}_{\text{apple on earth}} = -\vec{F}_{\text{earth on apple}}$$

(b) The action–reaction pair for the interaction between the apple and the earth



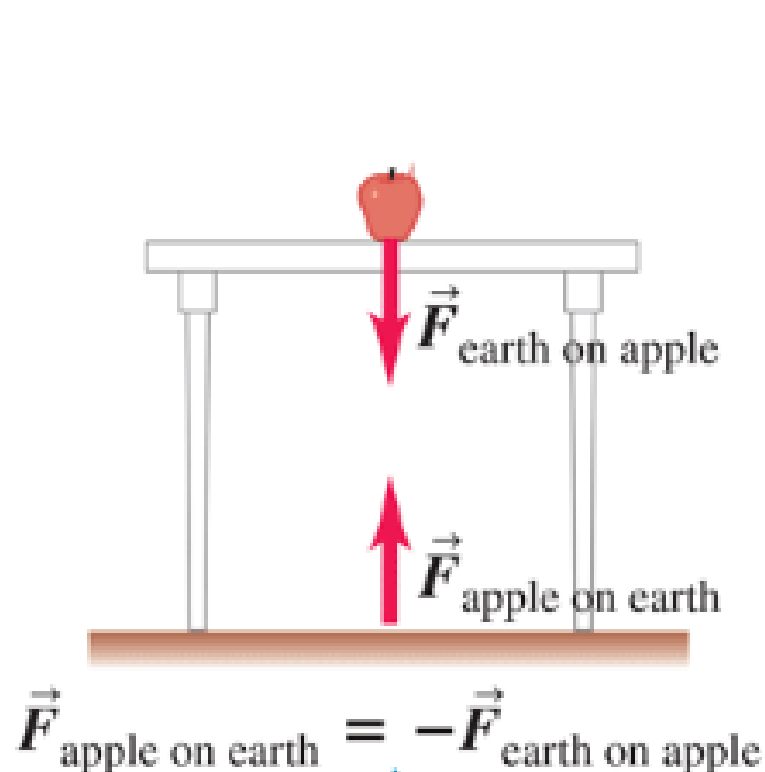
$$\vec{F}_{\text{apple on earth}} = -\vec{F}_{\text{earth on apple}}$$

(c) The action–reaction pair for the interaction between the apple and the table

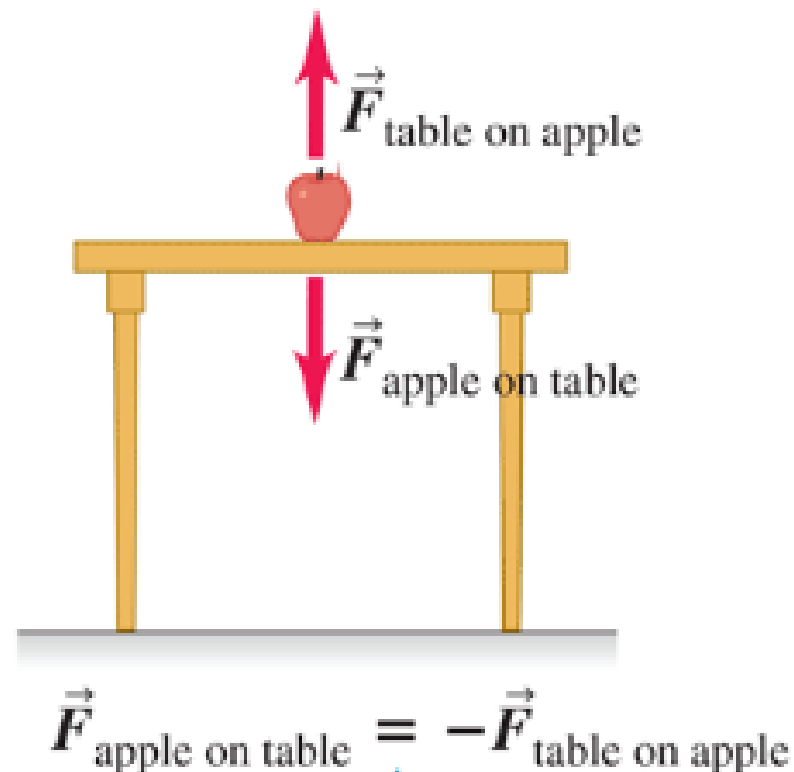


$$\vec{F}_{\text{apple on table}} = -\vec{F}_{\text{table on apple}}$$

(b) The action–reaction pair for the interaction between the apple and the earth

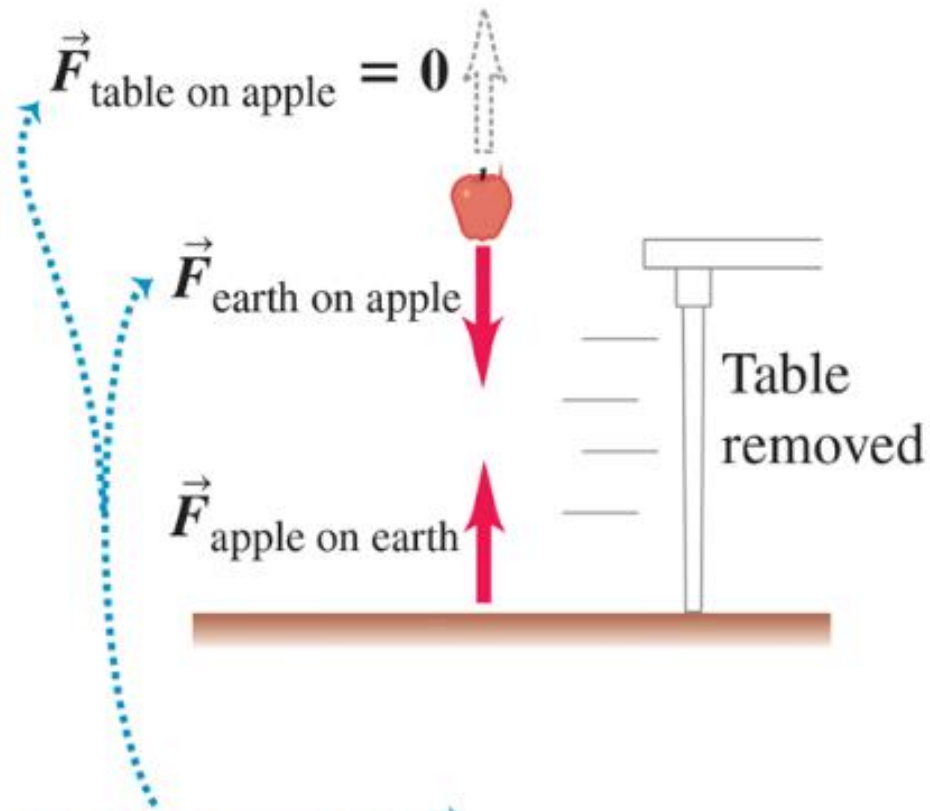


(c) The action–reaction pair for the interaction between the apple and the table



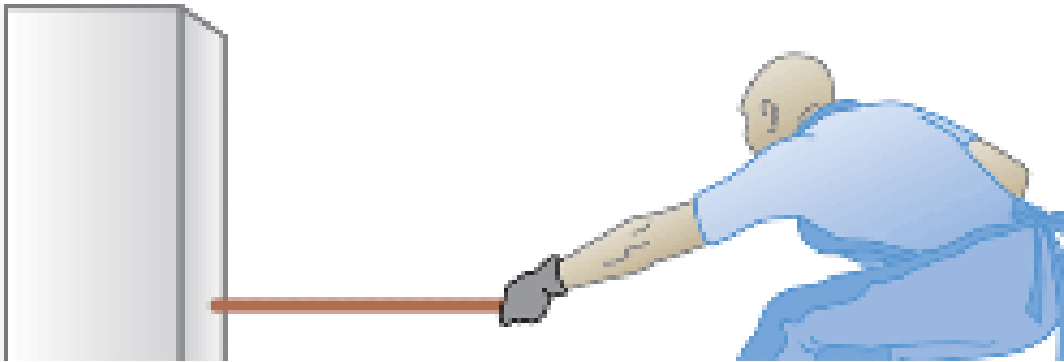
An action–reaction pair is a mutual interaction between two objects. The two forces act on two *different* objects.

(d) We eliminate the force of the table on the apple.

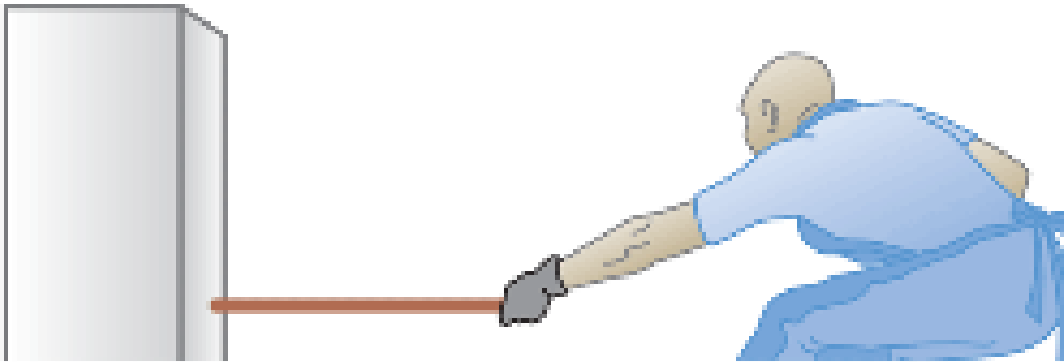


When we remove the table,  $\vec{F}_{\text{table on apple}}$  becomes zero but  $\vec{F}_{\text{earth on apple}}$  is unchanged. Hence these forces (which act on the same object) *cannot* be an action–reaction pair.

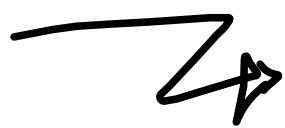
## (b) The action–reaction pairs



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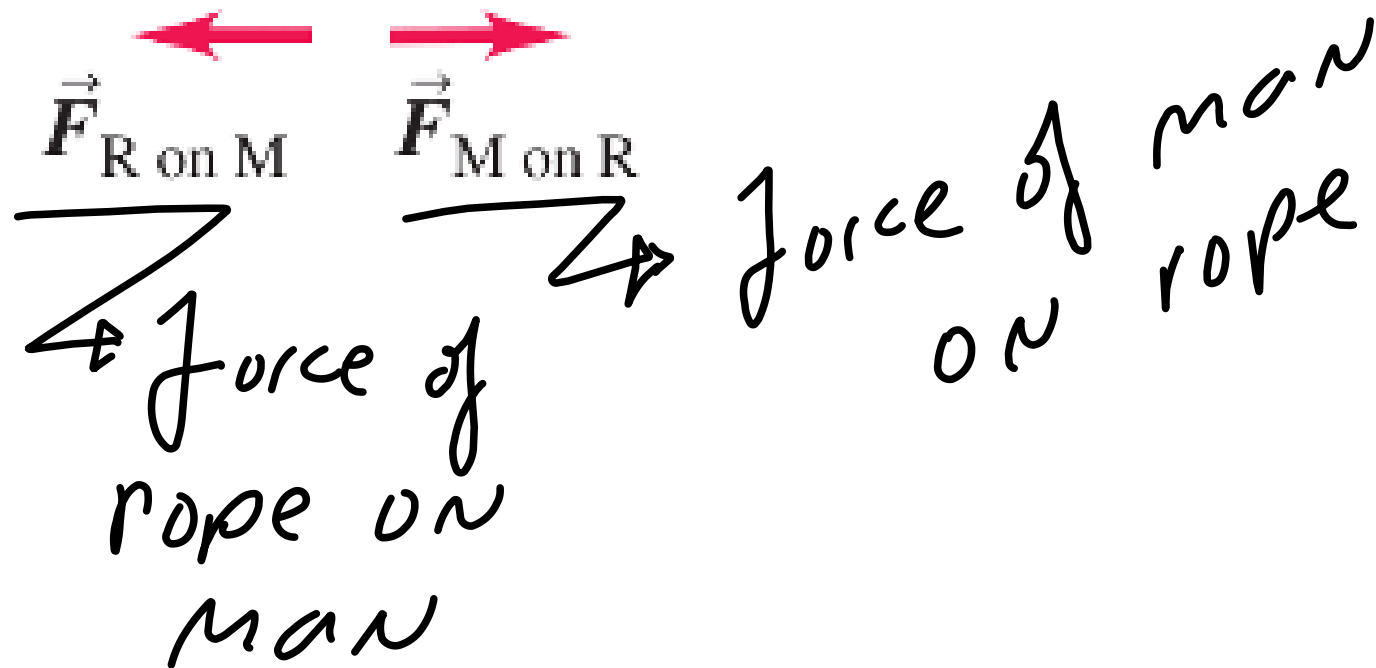
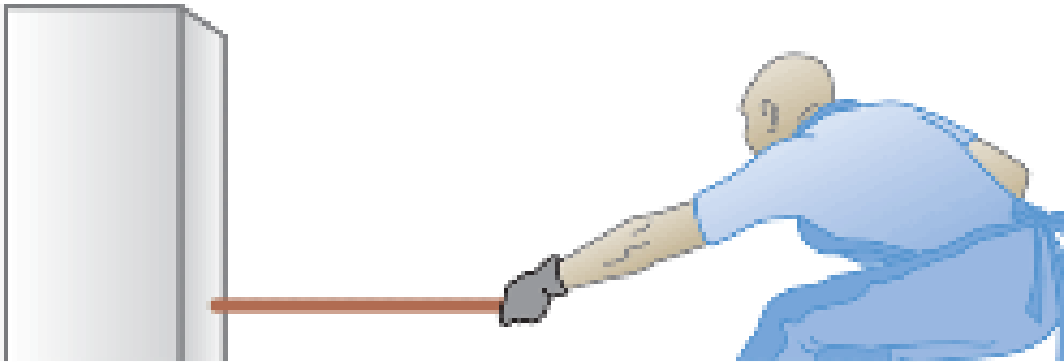


$\vec{F}_{M \text{ on } R}$

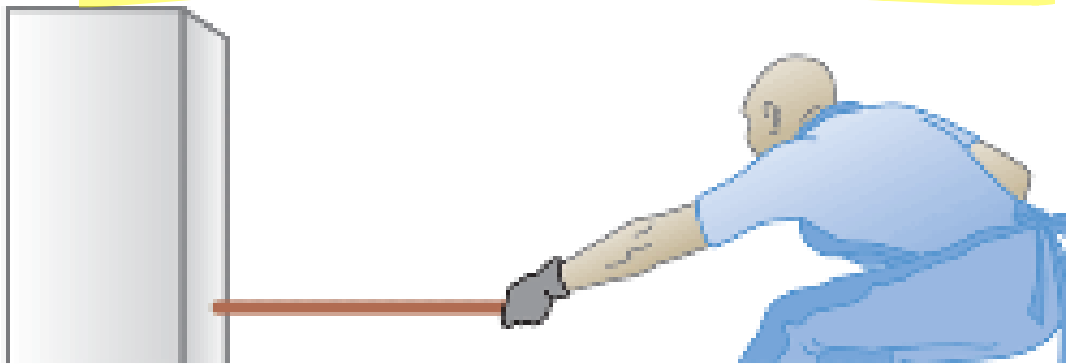


force of man  
on rope

## (b) The action–reaction pairs

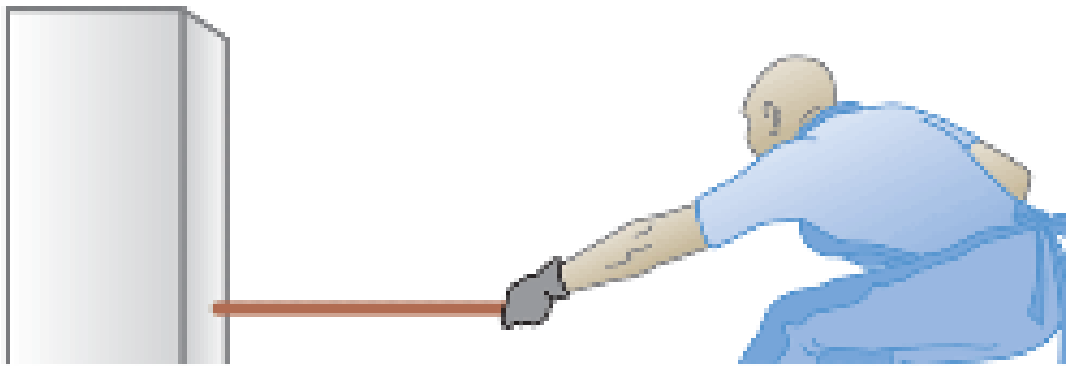


## (b) The action–reaction pairs

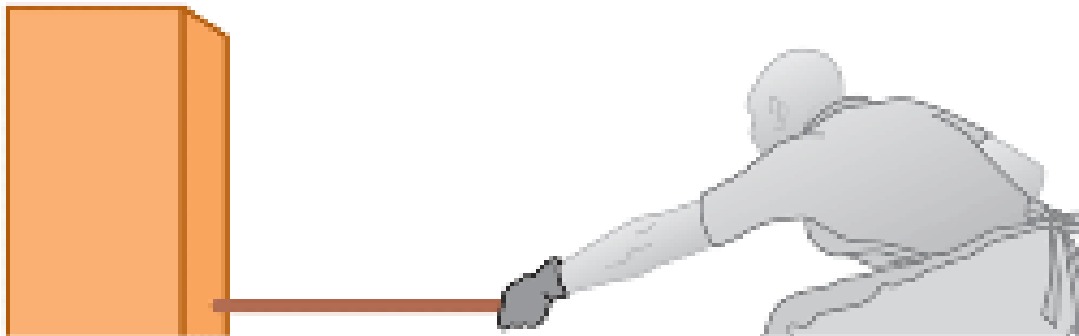


$\vec{F}_{R \text{ on } M}$        $\vec{F}_{M \text{ on } R}$

## (b) The action–reaction pairs



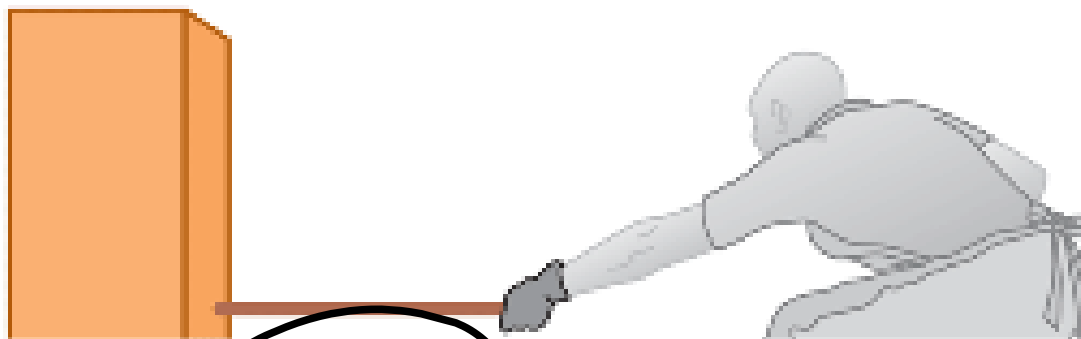
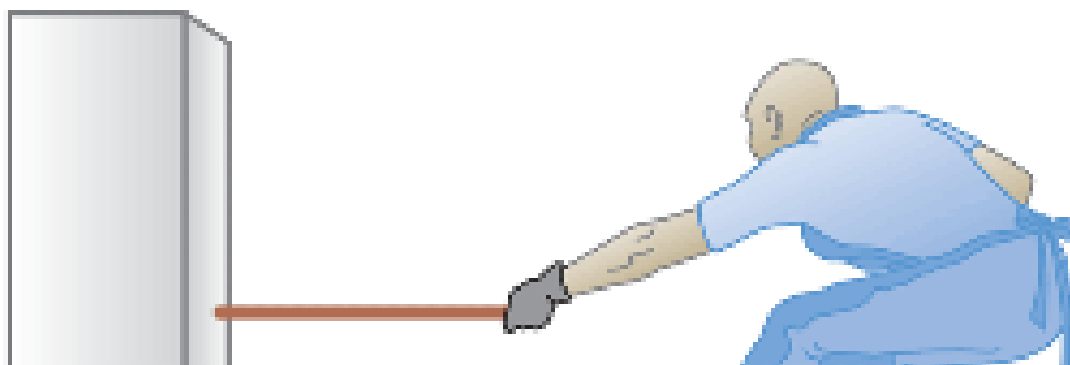
$\vec{F}_{R \text{ on } M}$        $\vec{F}_{M \text{ on } R}$



$\vec{F}_{B \text{ on } R}$

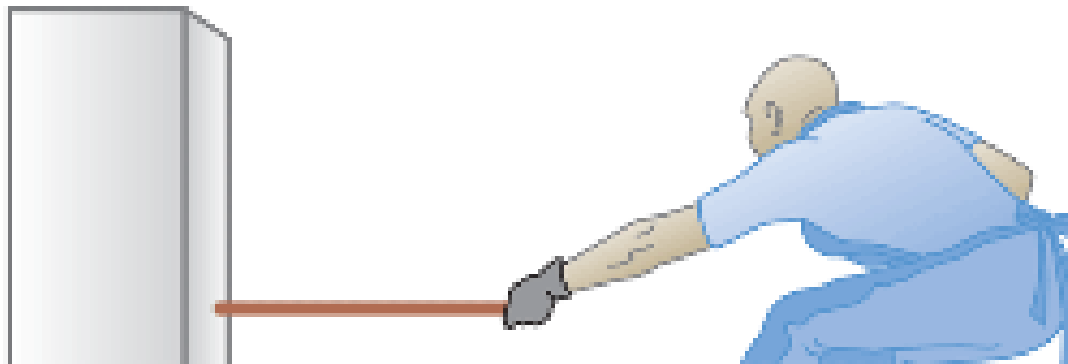
*Force of block on rope*

(b) The action–reaction pairs

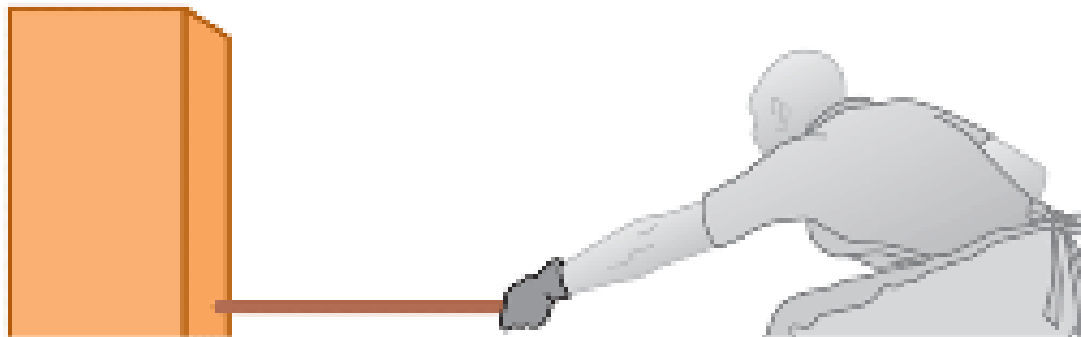


Force of rope on block<sup>79</sup>

## (b) The action–reaction pairs

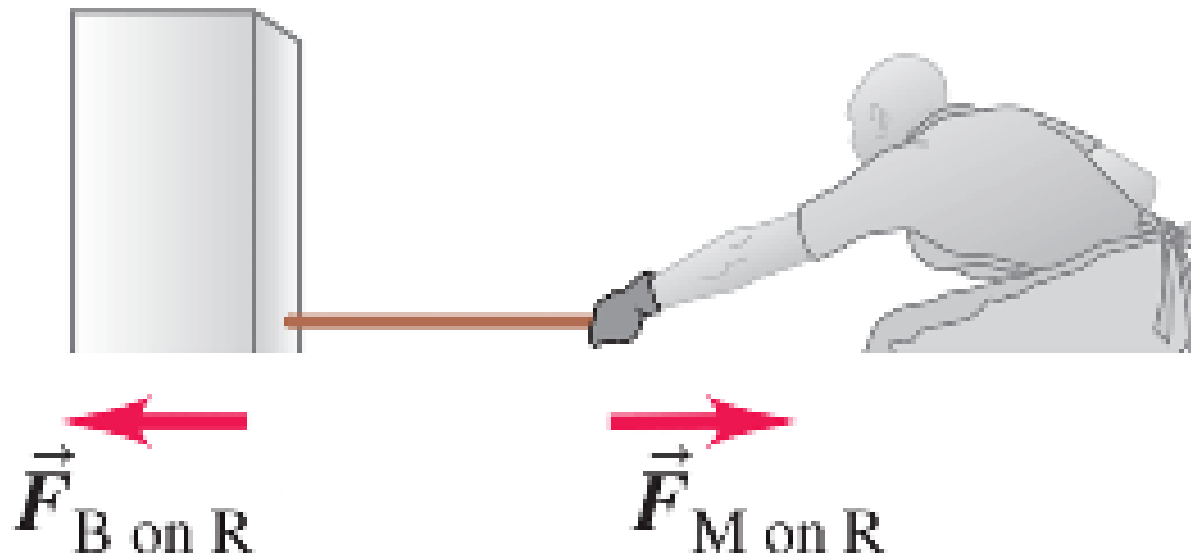


$\vec{F}_{R \text{ on } M}$        $\vec{F}_{M \text{ on } R}$

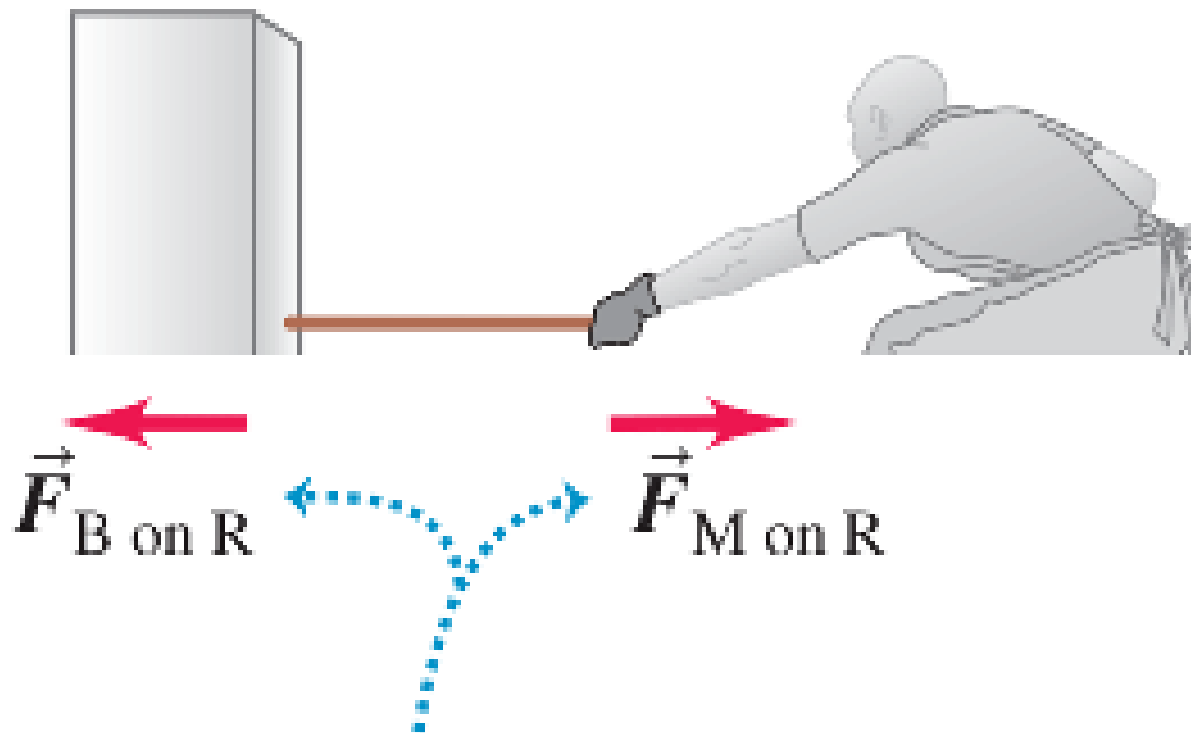


$\vec{F}_{B \text{ on } R}$        $\vec{F}_{R \text{ on } B}$

(c) *Not* an action–reaction pair

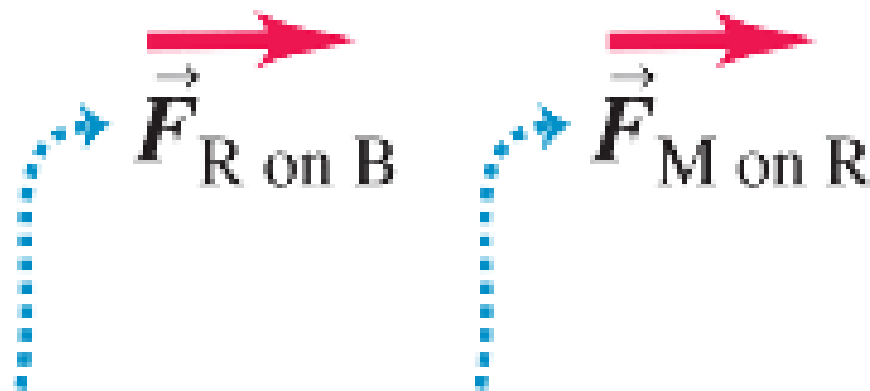
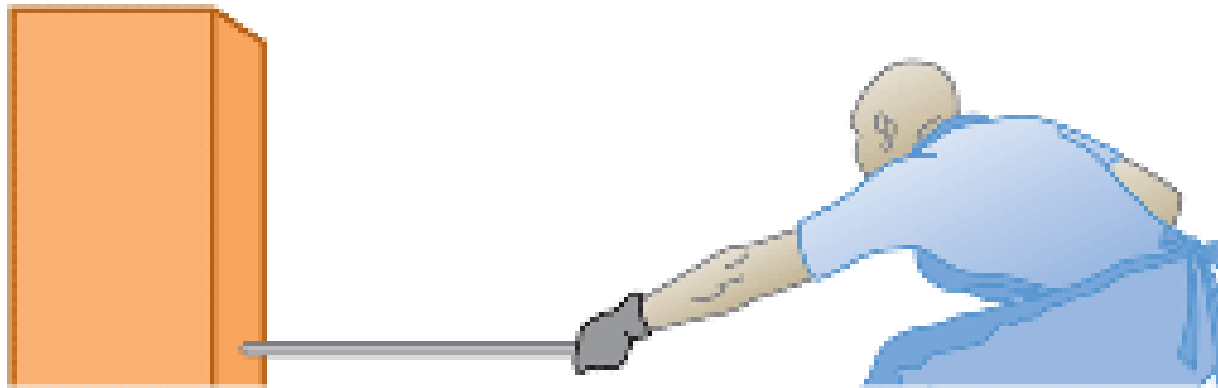


(c) *Not* an action–reaction pair



These forces cannot be an action–reaction pair because they act on the same object (the rope).

(d) Not necessarily equal



These forces are equal only if the rope is in equilibrium (or can be treated as massless).

Force on rope

ROPE

# Force on rope



# Force on rope



# Force on rope



$$\sum \vec{F} = m\vec{a} \Rightarrow \vec{F}_{B \to R} + \vec{F}_{M \to R} = m\vec{a}$$

# Force on rope



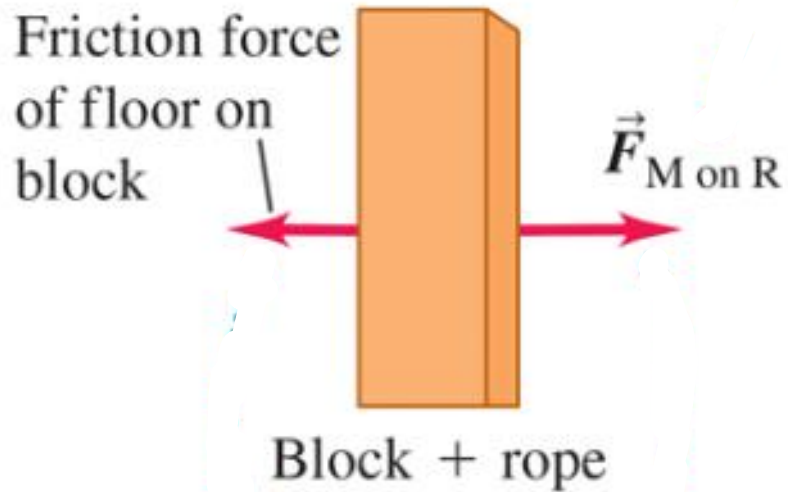
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$$\Rightarrow \vec{a}_{\text{rope}} = \frac{\vec{F}_{B \to R} + \vec{F}_{M \to R}}{M_{\text{rope}}}$$

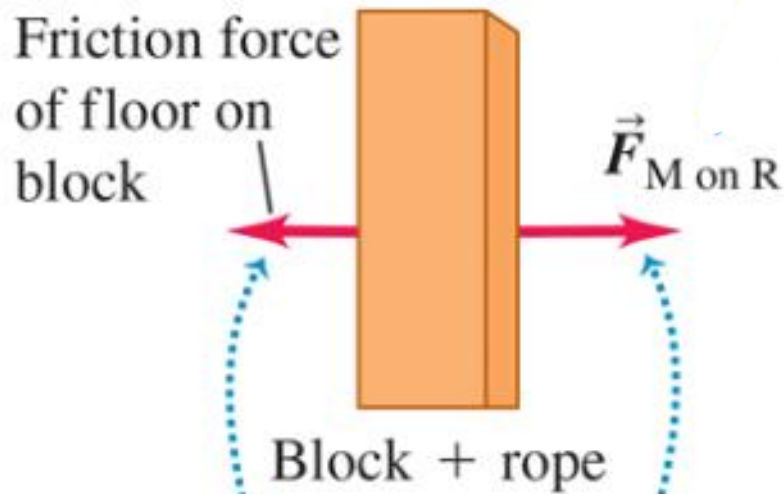
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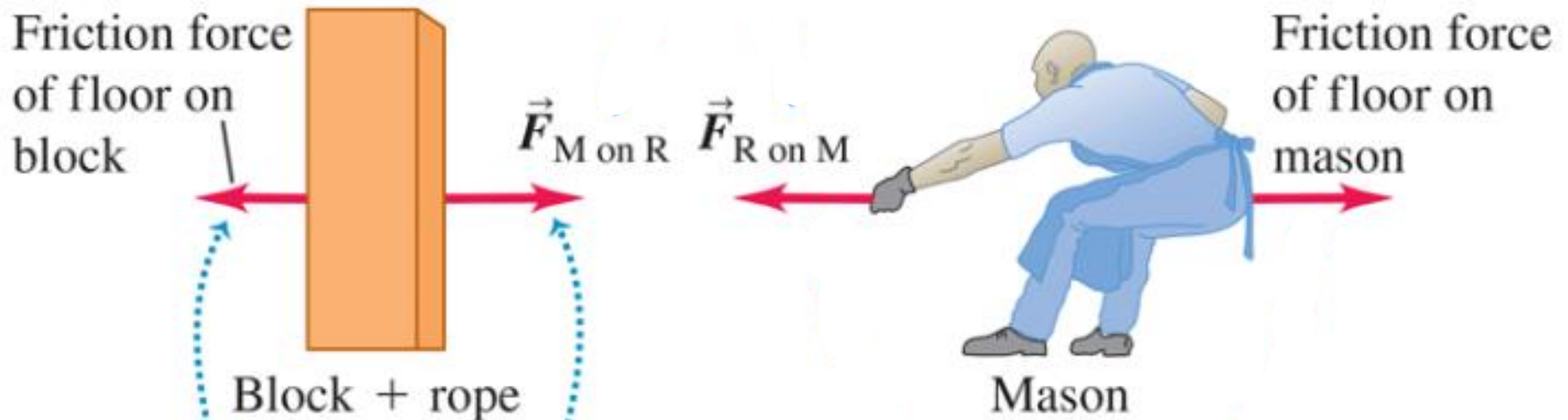


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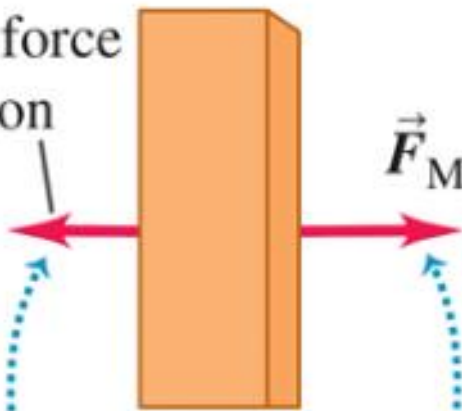
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Block + rope

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$\vec{F}_{R \text{ on } M}$



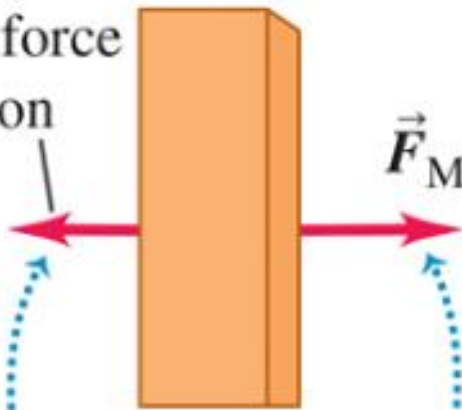
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The mason remains at rest if  $\vec{F}_{R \text{ on } M}$  is balanced by the friction force on the mason.

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These forces are an action–reaction pair. They have the same magnitude but act on different objects.

Friction force  
of floor on  
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Block + rope

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$\vec{F}_{M \text{ on } R}$   $\vec{F}_{R \text{ on } M}$



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## Newton's 3<sup>rd</sup> law

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An object that has pulling at each end is said to be in tension. Tension is that force

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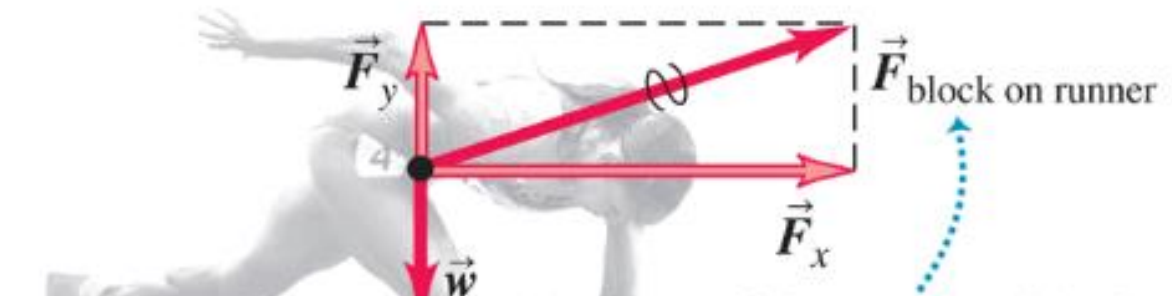


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The force of the starting block on the runner has a vertical component that counteracts her weight and a large horizontal component that accelerates her.









