Free-Body Diagrams 3 (A and B) Name ____________________

In this section, you will draw free-body diagrams of *multiple objects at once*.
This will allow us to better understanding Newton's Third Law by creating action-reaction pairs.

Agent of a Force

Every force has an *agent*. The agent is the thing that is exerting the force.
The agent *must* be something that is physical and real. It must be something you can touch.

It is a good practice to always identify the agent of a force.

Examples:
If you punch somebody, the agent of that force is your fist.

Gravity is pulling you down, which is called the weight. The agent of this force is the earth.

When you are lying in bed, the normal force is holding you up. The agent of this force is your bed.

Newton's Third Law

If A exerts a force on B, then B exerts a force on A with equal magnitude and opposite direction.

These two forces are called an **action-reaction pair.**

How to identify action-reaction pairs:
- Action-Reaction pairs *always* appear on *different* free-body diagrams.

- Imagine that Phil punches Bob in the face and Bob's face exerts a reaction-force on Phil.
There is a force on Bob's free-body diagram whose *agent* is Phil
There is a force on Phil's free-body diagram whose *agent* is Bob.
These forces are an action-reaction pair.

- Action-reaction pairs always have equal magnitude and opposite direction.

- Also: EVERY force has a pair. Sometimes, the pair isn't a part of a problem because you haven't drawn every free-body diagram you can. In this section, were are going to identify an action-reaction pair for every force.

However, one of the things that makes understanding Newton's Third Law so difficult is that there are frequently *other pairs* of forces with equal magnitude and opposite direction that are *NOT* action-reaction pairs.

Being able to distinguish which pairs are action-reaction pairs and which are not is the key.

Pairs of Balanced Forces

In addition to action-reaction pairs, there are many other pairs of forces that *also* have equal magnitude and opposite direction, but are not action-reaction pairs.

Most of these are balanced forces.

How to identify balanced forces:

- Balanced forces appear on the *same* free-body diagram.

- Balanced forces are not action-reaction pairs.

- Balanced forces occur because an object has a net force of zero in the X or in the Y dimensions.

- Usually, one of the two balanced forces is a *constraint force*. A constraint force is a force that does not have a particular magnitude but adjusts its magnitude in order to match a particular situation. The most common constraint forces are the normal force and static friction.

Free-Body Diagrams 3 (A and B) Name ____________________

Problem 1A:
Draw a free-body diagram a person standing motionless on the floor (2 forces).
Also draw a free-body diagram of the floor, with one force only.
Also draw a free-body diagram of the earth, with one force only.

For each force in every free-body diagram, explicitly identify the agent of that force.

<table>
<tr><td colspan="3">Free-Body Diagram of the person:</td><td rowspan="4">The net force on acting on the person is zero. Why?</td></tr>
<tr><td>Name of Force</td><td>Direction</td><td>Agent</td></tr>
<tr><td></td><td></td><td></td></tr>
<tr><td></td><td></td><td></td></tr>
</table>

<table>
<tr><td colspan="3">Free-Body Diagram of the floor:</td><td rowspan="3">Note that many other forces not included here also act on the floor, and the net force acting on the floor is zero</td></tr>
<tr><td>Name of Force</td><td>Direction</td><td>Agent</td></tr>
<tr><td></td><td></td><td></td></tr>
</table>

<table>
<tr><td colspan="3">Free-Body Diagram of the earth:</td><td rowspan="3">Note that many other forces not included here also act on the earth.</td></tr>
<tr><td>Name of Force</td><td>Direction</td><td>Agent</td></tr>
<tr><td></td><td></td><td></td></tr>
</table>

Problem 1B: Identifying Action-Reaction Pairs
In the three free-body diagrams above, there are 4 forces included.

There are *two* action-reaction pairs. For each one
a) Identify the action-reaction pair
b) Explicitly state what body each force acts on, the agent of each force, and the direction of each force to make it abundantly clear that these forces comply with Newton's Third Law.

If every force is a member of an action-reaction pair, then state
"Every force is a member of an action-reaction pair, thus we are in full compliance with Newton's Third Law."

There is also one balanced force pair. These forces do have equal magnitude and opposite direction, but they are NOT an action-reaction pair because they act on the *same* free-body diagram.

a) Identify the balanced force pair,
b) explain why it is not an action-reaction pair,
c) identify which force is a constraint force,
d) and identify why the forces have equal magnitude and opposite direction.

Problem 2: Two boxes stacked on top of each other:

Two boxes are stacked on top of each other and are on the floor. None of the boxes is moving.
Draw a free-body diagram of each of these:
a) The top box (2 forces)
b) The bottom box (3 forces)
c) The floor (1 force included)
d) The earth (2 forces included)

For each force in every free-body diagram, explicitly identify the agent of that force.

Free-Body Diagrams 3 (A and B)   Name ____________________

Free-Body Diagram of the top box:			The net force on acting on the person is zero. Why?
Name of Force	Direction	Agent	

Free-Body Diagram of the bottom box:			The net force on acting on the box is zero. Why?
Name of Force	Direction	Agent	

Free-Body Diagram of the floor:			Note that many other forces not included here also act on the floor, and the net force acting on the floor is zero
Name of Force	Direction	Agent	

Continues on the next page:

<table>
<tr><td colspan="3">Free-Body Diagram of the earth:</td><td rowspan="4">Note that many other forces not included here also act on the earth.</td></tr>
<tr><td>Name of Force</td><td>Direction</td><td>Agent</td></tr>
<tr><td></td><td></td><td></td></tr>
<tr><td></td><td></td><td></td></tr>
</table>

Problem 2B: Identifying force pairs:

There are 8 total forces in these free-body diagrams, which mean that there are 4 action-reaction pairs. Identify each action reaction pair.

Also, there is one balanced force pair. These are two forces of equal magnitude and opposite direction that are *not* an action-reaction pair because they act on the same free-body diagram.
a) Identify the balanced force pair,
b) explain why it is not an action-reaction pair,
c) identify which force is a constraint force,
d) and identify why the forces have equal magnitude and opposite direction.

Problem 3: Person Pushing a Big Box:

Problem 3A: Identifying forces and drawing free-body diagrams

A person is pushing a heavy box to the right across the floor. Assume he is pressing on the ground with his feet, but his feet are not slipping as he does.
The person and the box both move with a constant velocity.

Draw four free-body diagram
a) The person (with 4 forces)
b) The box (with 4 forces)
c) The floor (with 4 forces included)
d) The earth (with 2 forces included)

For each force in every free-body diagram, explicitly identify the agent of that force.

Note: One of the forces on the person pushing the box is static friction because, even though he is moving, his feet are not slipping.

<table>
<tr><td colspan="3">Free-Body Diagram of the person:</td><td rowspan="7">The net force on acting on the person is zero. Why?</td></tr>
<tr><td>Name of Force</td><td>Direction</td><td>Agent</td></tr>
<tr><td></td><td></td><td></td></tr>
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<tr><td></td><td></td><td></td></tr>
<tr><td></td><td></td><td></td></tr>
<tr><td></td><td></td><td></td></tr>
</table>

Free-Body Diagrams 3 (A and B) Name ____________________

Free-Body Diagram of the box:			The net force on acting on the box is zero. Why?
Name of Force	Direction	Agent	

Free-Body Diagram of the floor:			Note that many other forces not included here also act on the floor, and the net force acting on the floor is zero
Name of Force	Direction	Agent	

Free-Body Diagram of the earth:			Note that many other forces not included here also act on the earth.
Name of Force	Direction	Agent	

 Name ____________________

Problem 3B: Identifying Force Pairs:

There are 14 forces, which means there are a total of 7 action-reaction pairs.
Identify each action-reaction pair.

There are also 3 pairs of forces that are balanced forces. They have equal magnitude and opposite direction, but are not action-reaction pairs. For each of these pairs
a) Identify the balanced force pair,
b) explain why it is not an action-reaction pair,
c) identify which force is a constraint force,
d) and identify why the forces have equal magnitude and opposite direction.

Finally, do note that the three forces acting horizontally on the person must, in sum total, cancel each other out. Why?

Problem 4: Three boxes stacked on top of each other!

Problem 1A: Answers:

<table>
<tr><td colspan="3">Free-Body Diagram of the person:</td><td rowspan="4">The net force on acting on the person is zero. Why?</td></tr>
<tr><td>Name of Force</td><td>Direction</td><td>Agent</td></tr>
<tr><td>A. Gravity (weight)</td><td>Down (In)</td><td>Earth</td></tr>
<tr><td>B. Normal Force</td><td>Up</td><td>Floor</td></tr>
</table>

<table>
<tr><td colspan="3">Free-Body Diagram of the floor:</td><td rowspan="3">Note that many other forces not included here also act on the floor, and the net force acting on the floor is zero</td></tr>
<tr><td>Name of Force</td><td>Direction</td><td>Agent</td></tr>
<tr><td>C. Person Pressing Floor</td><td>Down</td><td>Person</td></tr>
</table>

<table>
<tr><td colspan="3">Free-Body Diagram of the earth:</td><td rowspan="3">Note that many other forces not included here also act on the earth.</td></tr>
<tr><td>Name of Force</td><td>Direction</td><td>Agent</td></tr>
<tr><td>D. Gravitational attraction of the person</td><td>Out</td><td>Person</td></tr>
</table>

Problem 1B: Answers:

Action-Reaction Pairs

The first action-reaction pair is Force A and Force D.
Force A acts on the person, its agent is the earth, and its direction is in.
Force B acts on the earth, its agent is the person, and its direction is out.

The second action-reaction pair is Force B and Force C.

Force B acts on the person, its agent is the floor, and its direction is down.
Force C acts on the floor, its agent is the person, and tis direction is up.

Every force is a member of an action reaction pair, thus we are in full compliance with Newton's Third Law.

Balanced Force Pairs:

a) Forces A and B are a balanced force pair.
b) They have equal magnitude and opposite direction, but they are NOT an action-reaction pair because they both act on the same free-body diagram (the person).
c) The normal force is a constraint force
d) They have equal magnitude and opposite direction because the net force acting on the person is zero. The normal force adjusts to the same magnitude as gravity in order for the vertical net force acting on the person to be zero.

Problem 2A Answers:

<table>
<tr><td colspan="3">Free-Body Diagram of the top box:</td><td rowspan="4">The net force on acting on the person is zero. Why?</td></tr>
<tr><td>Name of Force</td><td>Direction</td><td>Agent</td></tr>
<tr><td>A. Gravity (weight)</td><td>Down (In)</td><td>Earth</td></tr>
<tr><td>B. Normal Force</td><td>Up</td><td>The bottom box</td></tr>
</table>

Free-Body Diagrams 3 (A and B)   Name ____________________

Free-Body Diagram of the bottom box:			The net force on acting on the box is zero. Why?
Name of Force	Direction	Agent	
C. Gravity (weight)	Down (In)	Earth	
D. Normal Force	Up	The floor	
E. The top box pressing down	Down	The top box	

Free-Body Diagram of the floor:			Note that many other forces not included here also act on the floor, and the net force acting on the floor is zero
Name of Force	Direction	Agent	
F. The boxes on top pressing down	Down	The bottom box	

Free-Body Diagram of the earth:			Note that many other forces not included here also act on the earth.
Name of Force	Direction	Agent	
G. Gravitational Pull of the top box	Out	Top Box	
H. Gravitational pull of the bottom box	Out	Bottom Box	

Problem 2B Answers:

The action reaction pairs are:
A. and G.
B. and E.
C. and G.
D. and F.

a) The balanced force pair is A and B.
b) These forces have equal magnitude and opposite direction, but they are not an action reaction pair because they both act on the same free-body diagram, the top box.
c) The normal force (force B) is a constraint force
d) They have an equal magnitude and opposite direction because they are not moving, thus the net force acting on the top box must be zero.

Free-Body Diagrams 3 (A and B) Name ____________________

Problem 3A Answers:

Free-Body Diagram of the person:			The net force on acting on the person is zero. Why? Why does static and not kinetic friction act on the person?
Name of Force	Direction	Agent	
A. Gravity (weight)	Down (In)	The earth	
B. Normal Force	Up	The floor	
C. Static Friction	Right	The floor	
D. Box pushing back	Left	The box	

Free-Body Diagram of the box:			The net force on acting on the box is zero. Why?
Name of Force	Direction	Agent	
E. Gravity (weight)	Down (in)	The earth	
F. Normal Force	Up	The floor	
G. Applied Force	Right	Person	
H. Kinetic Friction	Left	Floor	

Free-Body Diagrams 3 (A and B) Name ____________________

Free-Body Diagram of the floor:			Note that many other forces not included here also act on the floor, and the net force acting on the floor is zero
Name of Force	Direction	Agent	
I. Person pushing down	Down	Person	
J. Box pushing down	Down	Box	
K. Static Friction of Person	Left	Person	
L. Kinetic Friction of Box	Right	Box	

Free-Body Diagram of the earth:			Note that many other forces not included here also act on the earth.
Name of Force	Direction	Agent	
M. Gravitational attraction of person	Out	Person	
N. Gravitational Attraction of Box	Out	Box	

Problem 3B Answers:

Action-Reaction Pairs:
A and M
B and I
C and K
D and G
E and N
F and J
H and L

Balanced Force Pairs:
A and B: They are not an action-reaction pair because they both act on the person, the normal force is a constraint force and is equal to gravity because the vertical net force on the person is zero.
C and D: They are not an action-reaction pair because they both act on the person, static friction is a constraint force and is equal to the box force because the person has a horizontal net force of zero (because they are moving at a constant velocity).
E and F: They are not an action-reaction pair because they both act on the box, normal force is a constraint force and is equal to gravity because the vertical net force acting on the box is zero.
G and H: They are not an action-reaction pair because thy both act on the box, the applied force is a constant force here because the person adjusts his push in order for the box to move at a constant velocity; the applied force is equal to the kinetic friction because the horizontal net force acting on the box is zero.