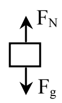
<u>Action & Reaction: Equal & Opposite</u> SOLUTIONS

Physics 1

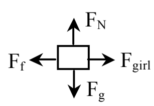
<u>**Forces and Interaction: Action-Reaction Pairs**</u>

In each case, draw a **free body diagram** of the object. For **every force** you draw, **identify the reaction** force.

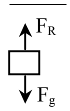
1. A book sitting at rest on a table.

<u>FBD</u>	<u>Action</u>	<u>Reaction</u>
	***Earth pulls down on Book*** ***Table pushes up on Book***	***Book pulls up on Earth*** ***Book pushes down on Table***

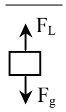
2. A girl pushing a book across a table.

<u>FBD</u>	<u>Action</u>	<u>Reaction</u>
	***Girl pushes Book forward*** ***Table pushes up on Book*** ***Table pulls back on Book*** ***Earth pulls down on Book***	***Book pushes back on Girl*** ***Book pushes down on Table*** ***Book pushes forward on Table*** ***Book pulls up on Earth***

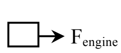
3. An apple falling from a tree. Include air resistance.

<u>FBD</u>	<u>Action</u>	<u>Reaction</u>
	***Earth pulls down on Apple*** ***Air pushes up on Apple***	***Apple pulls down on Earth*** ***Apple pushes down on Air***

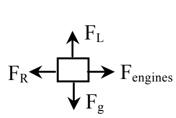
4. A helicopter hovering stationary in the air.

<u>FBD</u>	<u>Action</u>	<u>Reaction</u>
	***Earth pulls down on Helicopter*** ***Air pushes up on Helicopter***	***Helicopter pulls up on Earth*** ***Helicopter pushes down on Air***

5. A rocket flying through space.

<u>FBD</u>	<u>Action</u>	<u>Reaction</u>
	***Gas pushes Rocket forward***	***Rocket pushes Gas backward***

6. An airplane flying in a straight line through the air.

<u>FBD</u>	<u>Action</u>	<u>Reaction</u>
	***Earth pulls down on Plane*** ***Air pushes Plane forward*** ***Air pushes Plane upward*** ***Air pushes back on Plane***	***Plane pulls up on Earth*** ***Plane pushes Air backward*** ***Plane pushes Air downward*** ***Plane pushes Air forward***

Equal Force ≠ Equal Acceleration

7. A father (80 kg) and his young son (25 kg) are standing on ice. The son pushes his father backward with a force of 15 N. What will the father's acceleration be? What will the son's acceleration be?

$a_F = F_{SF} / m_F = (15\ N) / (80\ kg) = 0.1875\ m/s^2$ F_{SF} = ___15 N___ , a_F = ___0.188 m/s^2___

$a_S = F_{FS} / m_S = (15\ N) / (25\ kg) = 0.6\ m/s^2$ F_{FS} = ___15 N___ , a_S = ___0.6 m/s^2___

8. A person firing a rifle (80 kg) fires a bullet (mass = 0.030 kg). The bullet is fired forward with an acceleration of 10,000 m/s^2. How much backwards acceleration does the person experience?

$F_{PB} = m_B{*}a_B = (0.030\ kg){*}(10{,}000\ m/s^2) = 300\ N$ F_{PB} = ___300 N___ , a_B = ___10,000 m/s^2___

$a_P = F_{BP} / m_P = (300\ N) / (80\ kg) = 3.75\ m/s^2$ F_{PB} = ___300 N___ , a_P = ___3.75 m/s^2___

9. A person (70 kg) takes a step forward on an airplane (300,000 kg) with an acceleration of 3 m/s^2. How much backwards acceleration does the airplane experience as a result of the person stepping forward?

$F_{AP} = m_P{*}a_P = (70\ kg){*}(3\ m/s^2) = 210\ N$ F_{AP} = ___210 N___ , a_P = ___3 m/s^2___

$a_A = F_{PA} / m_A = (210\ N) / (300{,}000\ kg) = 0.0007\ m/s^2$ F_{PA} = ___210 N___ , a_A = ___0.0007 m/s^2___

10. What is all 200 people on the airplane took a step forward at the same time? What would the resulting force and acceleration on the airplane be then?
$F_{PA} = 200{*}(210\ N) = 42{,}000\ N \rightarrow a_A = F_{PA} / m_A = (42{,}000\ N) / (300{,}000\ kg) = 0.14\ m/s^2$

F_{PA} = ___42,000 N___ , a_A = ___0.14 m/s^2___

11. A person (70 kg) jumps off of a building and falls with an acceleration of 9.8 m/s^2. How fast does the Earth (6×10^{24} kg) accelerate upwards towards him?

$F_{EP} = m_P{*}g = (70\ kg){*}(9.8\ m/s^2) = 686\ N$ F_{EP} = ___686 N___ , a_P = ___9.8 m/s^2___

$a_E = F_{PE} / m_E = (686\ N) / (6 \times 10^{24}\ kg) = 1.14 \times 10^{-22}\ m/s^2$ F_{PE} = ___686 N___ , a_E = ___$1.14\text{x}10^{-22}\ m/s^2$___

12. How far does the person fall towards the Earth in 1 second? How far does the Earth move towards the person in 1 second?

$d_P = ½\, a_P\, t^2 = ½\, (9.8\ m/s^2)(1\ s)^2 = 4.9\ m$ d_P = ___4.9 m___

$d_E = ½\, a_E\, t^2 = ½\, (1.14\text{x}10^{-22}\ m/s^2)(1\ s)^2 = 5.7 \times 10^{-23}\ m$ d_E = ___$5.7\text{x}10^{-23}$ m___
(this is about <u>ten trillion times smaller</u> than the width of an atom!)

13. What if all 6 billion (6×10^9) people on Earth jumped of a building at the same time on the same side of the Earth. What would be the acceleration then?
$F_{PE} = (6{,}000{,}000{,}000){*}(686\ N) = 4.11 \times 10^{12}\ N$ F_{PE} = ___$4.11\text{x}10^{12}$ N___
$\rightarrow a_E = F_{PE} / m_E = (4.11\text{x}10^{12}\ N) / (6\text{x}10^{24}\ kg) = 6.86 \times 10^{-13}\ m/s^2$ a_E = ___$6.86\text{x}10^{-13}\ m/s^2$___

14. How far would the Earth move in 1 second as a result of everyone jumping at once?

$d_E = ½\, a_E\, t^2 = ½\, (6.86\text{x}10^{-13}\ m/s^2)(1\ s)^2 = 3.43 \times 10^{-13}\ m$ d_E = ___$3.43\text{x}10^{-13}$ m___
(this is STILL about <u>one thousand times smaller</u> than the width of an atom!!!)