Newton's 3rd Law

The Nature of Force

Forces – Dynamics

I. Laws of Motion: 1 & 2
- inertia, force, mass
- weight

II. Law 3
- **interaction & nature of force**
- **types of force: normal**, friction
- air resistance, terminal velocity

III. Applications/Problem Solving
- components, inclines

	The student will be able to:	HW:
1	State Newton's 1st and 2nd Laws of Motion and apply these laws to physical situations in order to determine what forces act on an object and to explain the object's resulting behavior.	✓ 1 – 5
2	Recognize and state the proper SI unit of force and give its equivalence in fundamental units and use the relation $\mathbf{F}_{net} = m\mathbf{a}$ to solve problems.	✓ 6 – 10
3	Recognize the difference between weight and mass and convert from one to the other.	✓ 11 – 18
4	State and utilize Newton's 3rd Law to solve related problems.	19 – 21
5	Understand and utilize the concept of the normal force to solve related problems.	22 – 25
6	Understand and utilize the relation between friction force, normal force, and coefficient of friction for both cases: static and kinetic.	26 – 32
7	State the factors that influence air resistance and describe qualitatively the effect of each factor on the magnitude of the frictional force. And explain what is meant by "terminal velocity".	33 – 35
8	Resolve forces into components using trigonometry and use the results to solve related force problems.	36 – 40
9	Apply the concept of force components to objects on an incline and solve related problems.	41 – 47

Newton's 3rd Law of Motion

Forces always occur in *pairs*. If object *A* exerts a force on object *B*, then object *B* exerts a force on object *A* that is equal in magnitude and opposite in direction.

Popularly known as: "equal and opposite action and reaction".

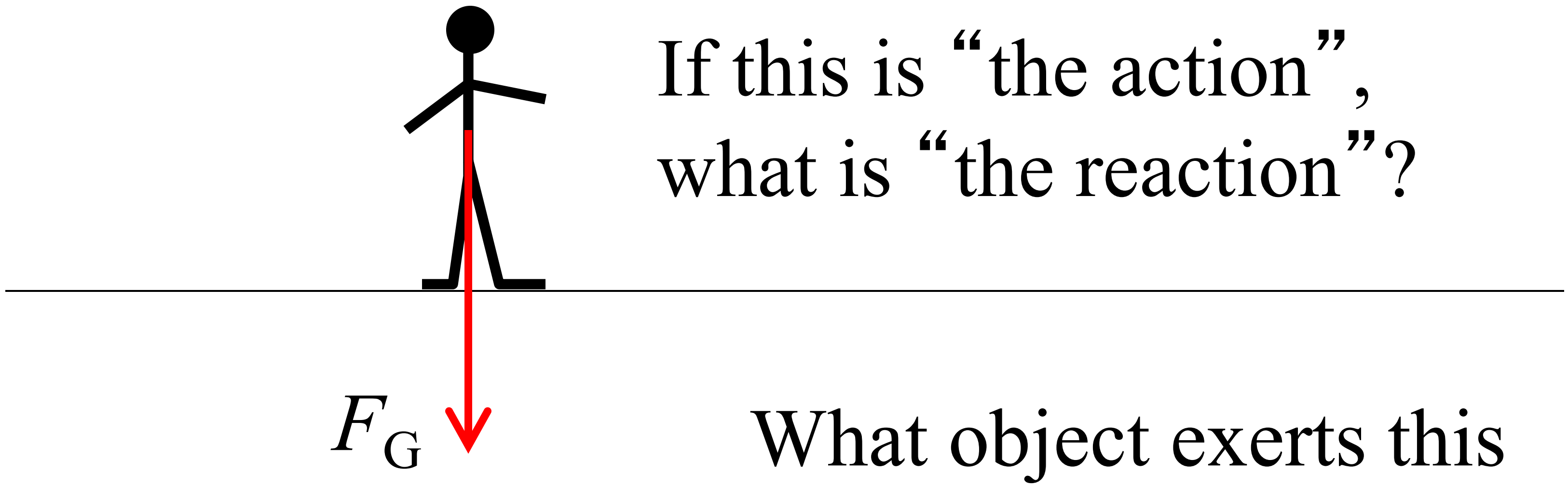
All forces arise in pairs as a result of an *interaction* of two objects. The equal and opposite forces (of each pair) act on two separate objects.

Newton's 3rd Law of Motion

Forces always occur in *pairs*. If object *A* exerts a force on object *B*, then object *B* exerts a force on object *A* that is equal in magnitude and opposite in direction.

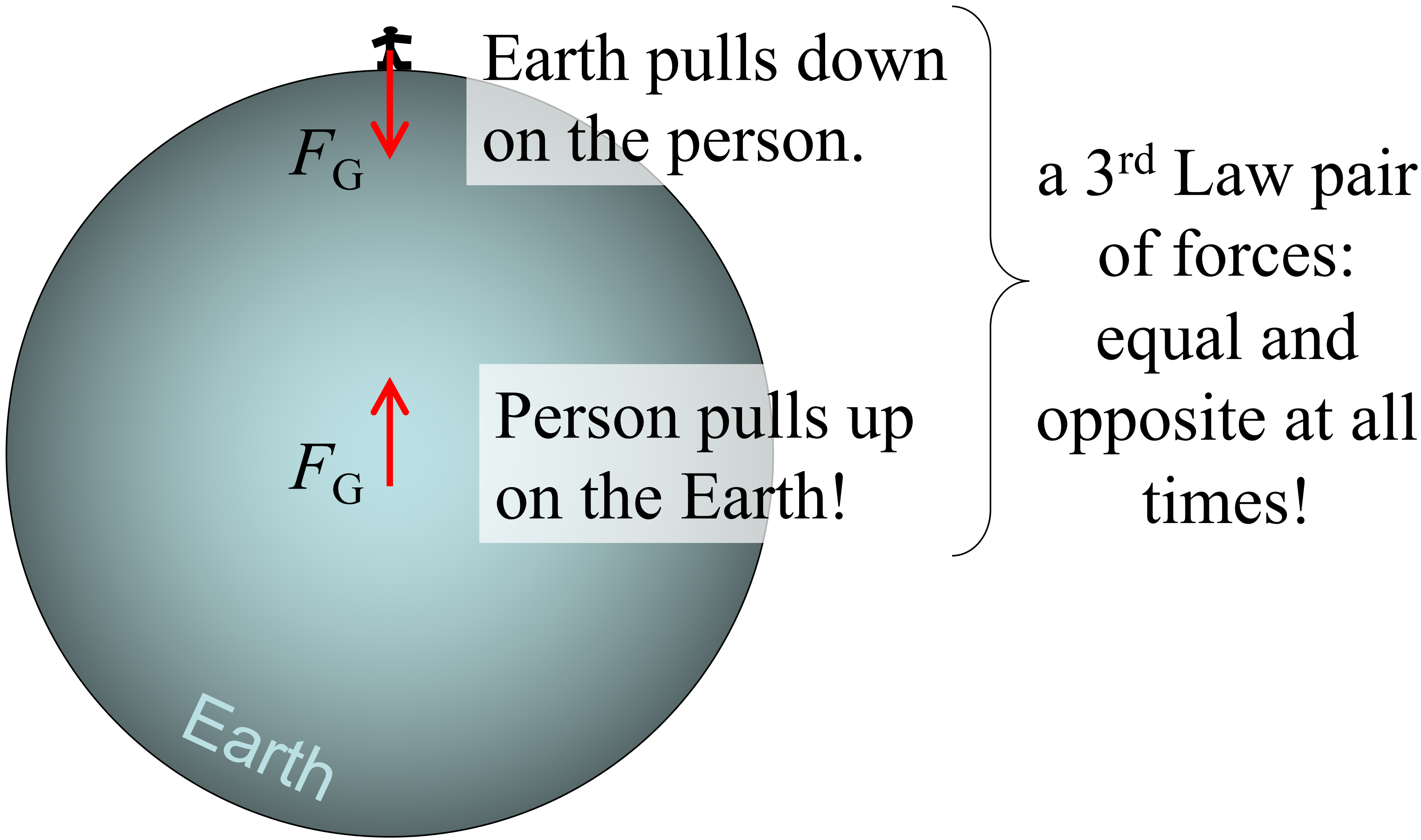
$$\vec{F}_{BA} = -\vec{F}_{AB}$$

What forces are there when a person stands at rest on the ground being pulled down by gravity?

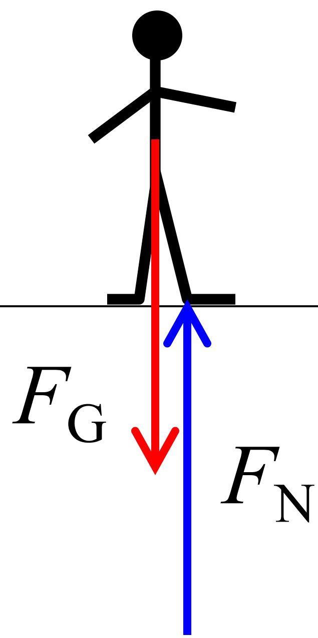


If this is "the action", what is "the reaction"?

What object exerts this force on the person?

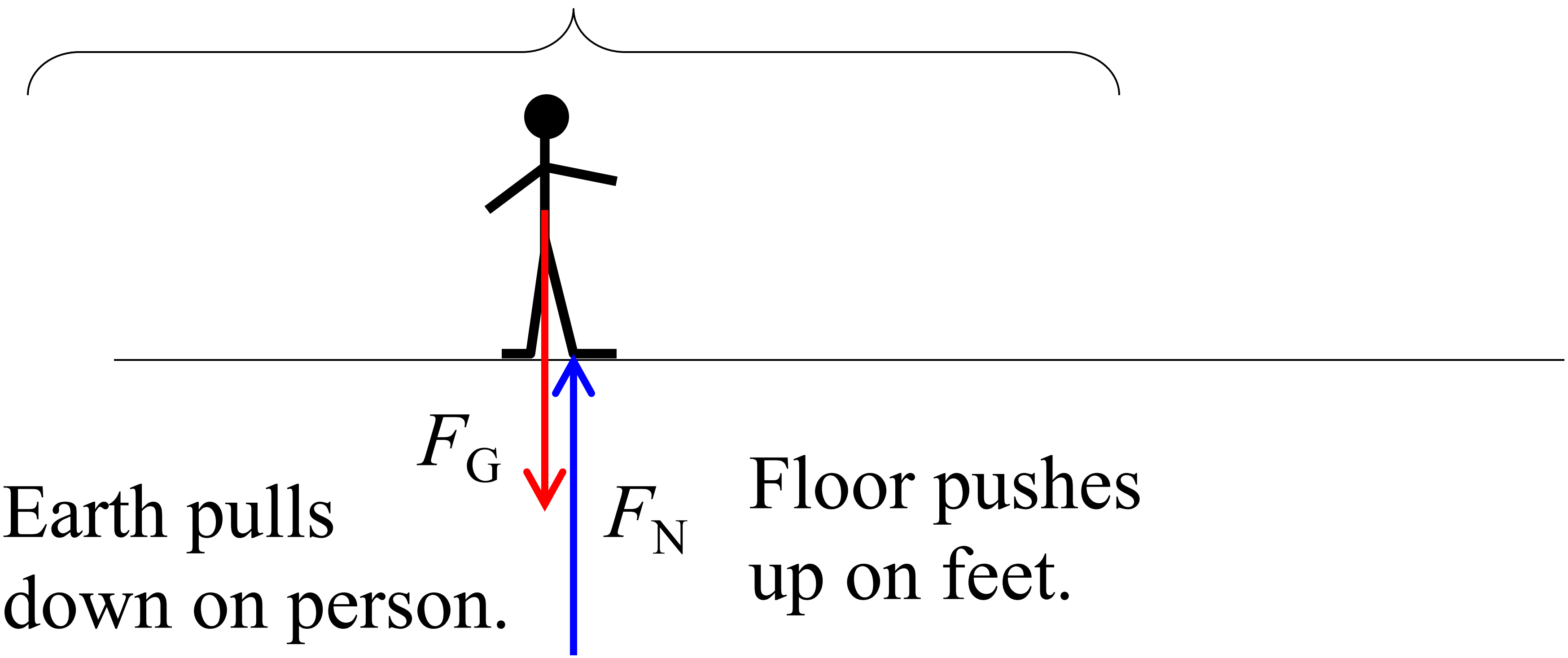

Earth pulls down on the person.
F_G
F_G
Person pulls up on the Earth!
a 3rd Law pair of forces: equal and opposite at all times!
Earth

If there is a downward force, how does the person remain at rest?



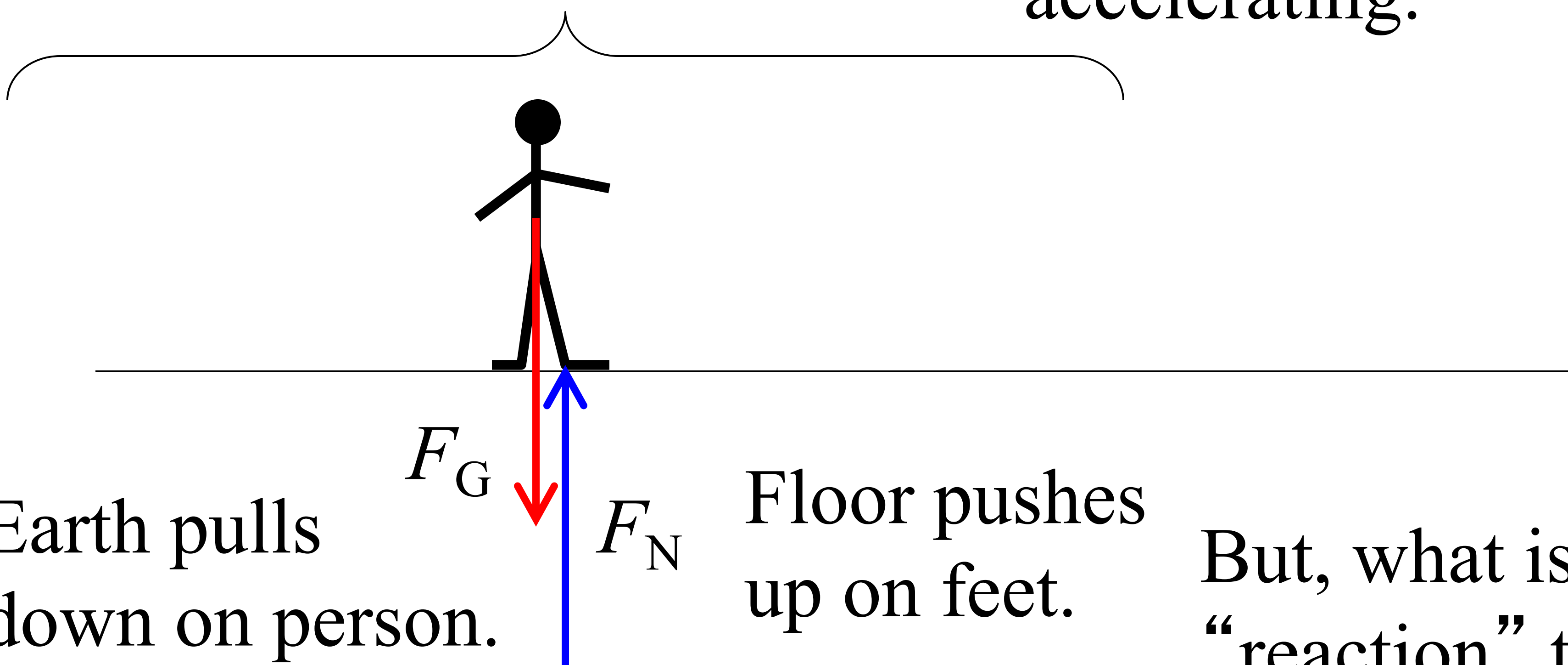
The floor pushes up on the person's feet!

Is this a 3rd Law pair of forces?



No! Not *every* pair of equal and opposite forces is a *3rd Law pair*!

These two forces are *not always* equal and opposite – only if the person is not accelerating.

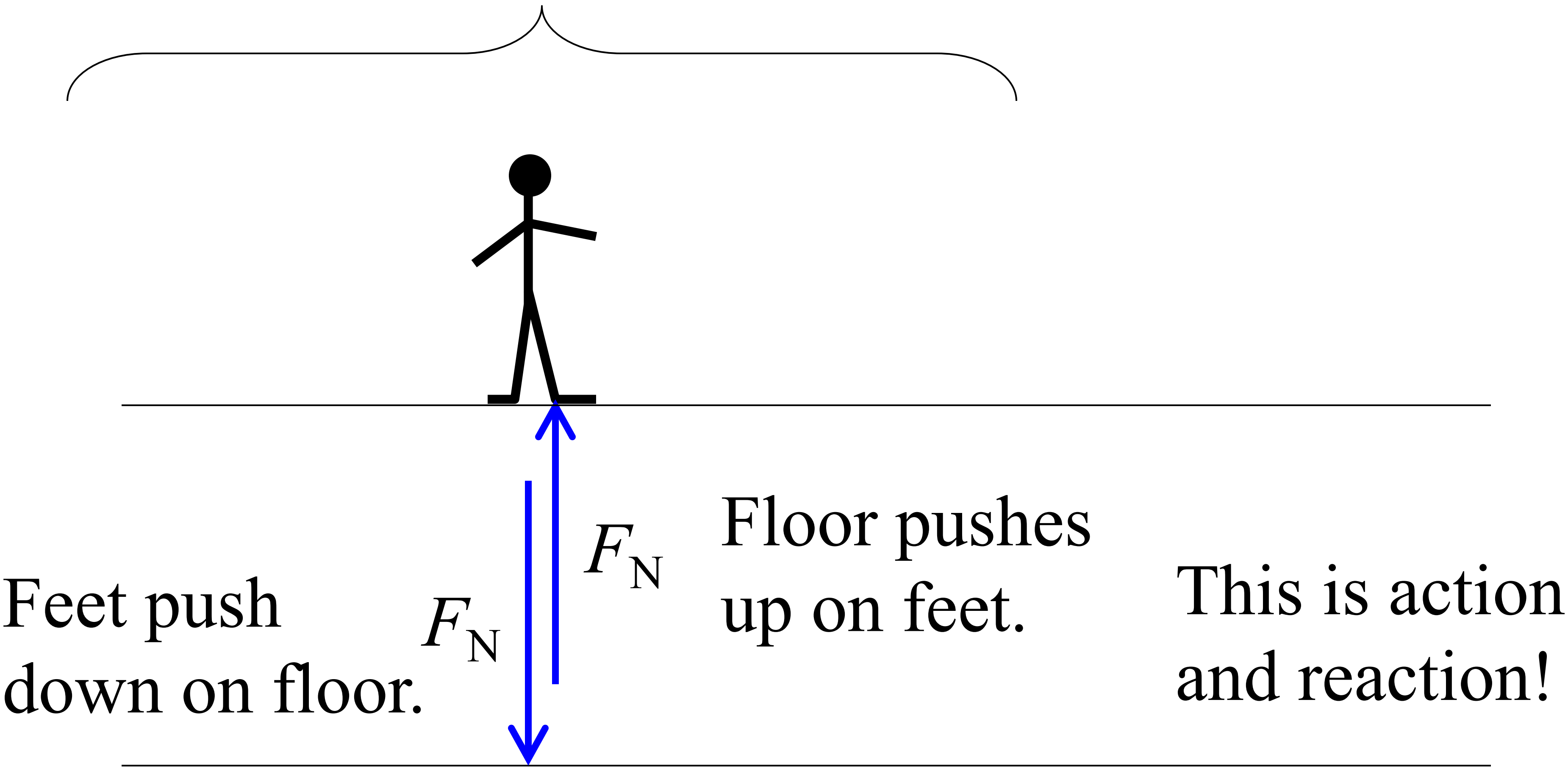


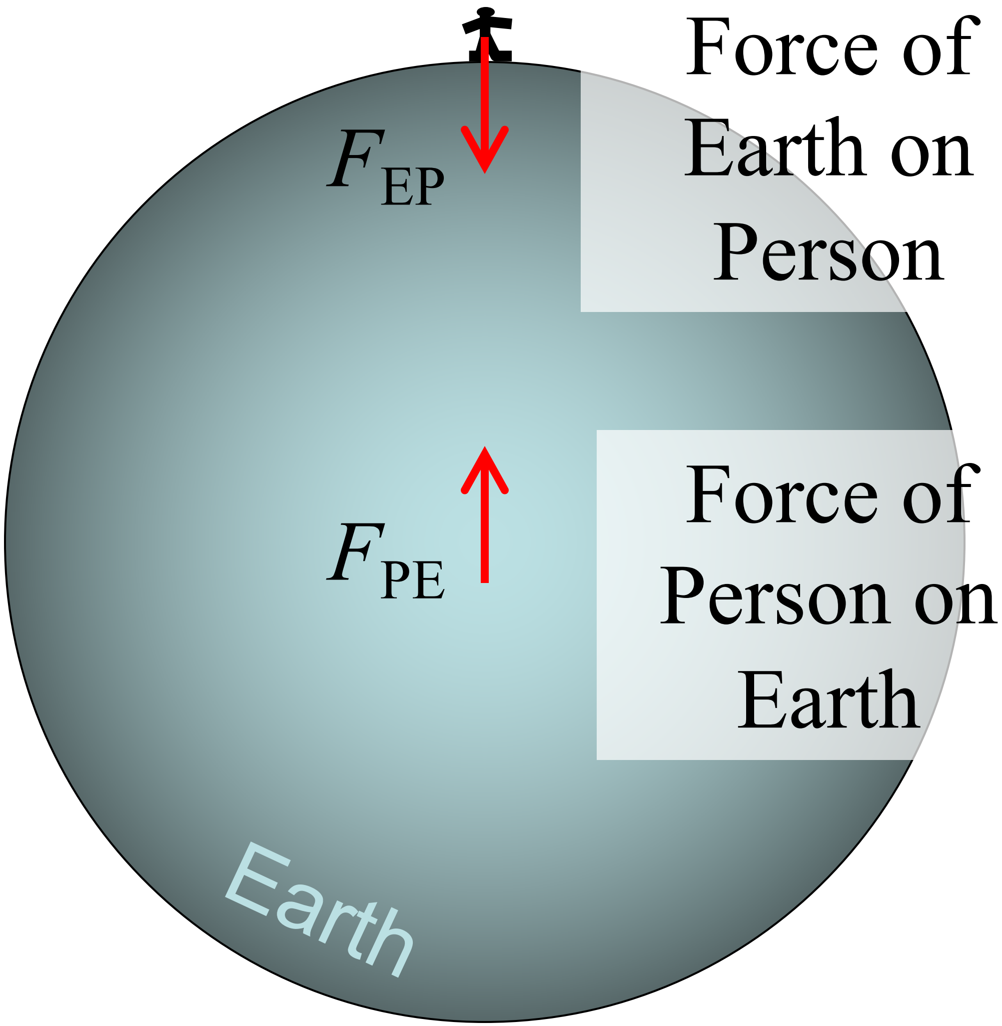
Earth pulls down on person.

Floor pushes up on feet.

But, what is the "reaction" to this F_N force?

This *is* a 3rd Law pair of forces: equal and opposite at all times!





$$\vec{F}_{PE} = -\vec{F}_{EP}$$

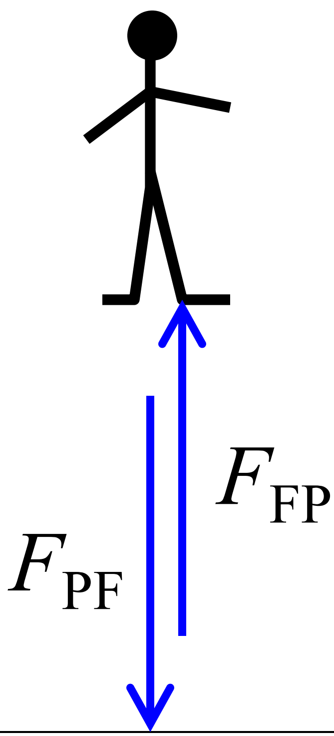
a 3rd Law pair of forces!

always equal and opposite!

a 3rd Law pair of forces!

$$\vec{F}_{PF} = -\vec{F}_{FP}$$

Force of Person on Floor



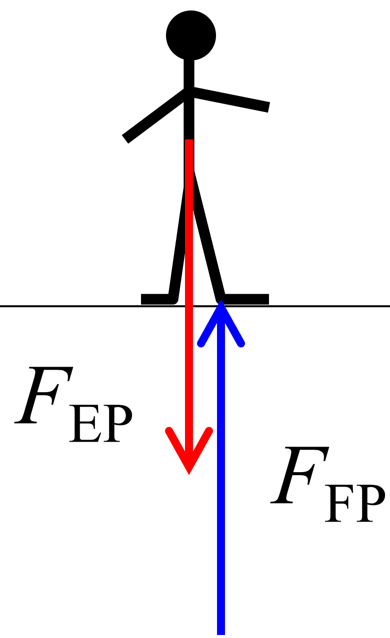
Force of Floor on Person

always equal and opposite!

Not a 3rd Law pair of forces!

$$\vec{F}_{EP} \overset{?}{=} -\vec{F}_{FP}$$

maybe…
…maybe not



Force of Earth on Person

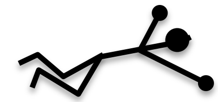
Force of Floor on Person

Not *always* equal and opposite!

Laws of Motion for Systems

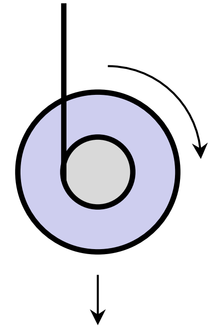
- A "system" is any collection of particles or masses. Examples: a car, a human body, the solar system.
- *Internal* forces are irrelevant – being equal and opposite, there is no net effect on the system as a whole.
- The *center of mass* will stay at rest or move with constant velocity if net *external* force is zero.
- The acceleration of the center of mass equals net external force divided by total mass.
- The center of mass is the "balancing point" for the system.

Example System: Person in Freefall



System	all the parts that make up a person
External Forces	gravity acting on each part of the body
Internal Forces	muscles moving body parts and tissues connecting the parts of the body
2nd Law	$a = F_{net}/m = 9.80\ \text{m/s}^2$
Result	The center of mass of the person accelerates downward at 9.80 m/s^2 regardless of how he/she moves arms or legs! Push your arms down, your arms push you up, equal and opposite.

Example System: Descending Yo-Yo



$T = 0.65$ N
$m = 0.10$ kg

System	all the parts that make up the yo-yo
External Forces	gravity down and tension of string up
Internal Forces	bonds between atoms and molecules that keep the yo-yo solid and prevent it breaking apart as it spins
2nd Law	$a = F_{net}/m = (0.98 - 0.65)/0.1 = 3.3\ \text{m/s}^2$
Result	The center of the yo-yo accelerates downward at 3.3 m/s^2 in spite of its spinning. Different parts of the yo-yo have different accelerations!

Objects in Contact
(when worlds collide …)

- Whenever two objects touch there will be an interaction and forces will occur.
- There are two *aspects* of contact: frictional force and normal force.

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Normal Force

- The word "normal" in this context means *perpendicular to the surface* of an object.
- By definition, "normal force" is the amount of force perpendicular to the surface at a point of contact between two objects.
- The magnitude of the normal force depends on how much the two objects are pressed together and results from an interaction of atoms in the objects.

Normal Force

- Normal forces occur whenever two objects touch and thus are all around us!
- Standing on a floor your feet and the floor experience normal force: feet push down on floor and floor pushes up on feet (the 3rd Law pair mentioned above).
- Problem solving: in diagrams draw a normal force perpendicular to the surface at any point of contact. The size of this force can vary greatly depending on various factors, such as other forces present and acceleration of the object(s) involved…