# Newton's laws of motion

How to construct a system of dynamics:

1. Begin with a steel cube which weighs about 2.2lbs and declare the mass of this steel cube to be exactly 1kilogram (1kg).

2. Get an air hockey table that the cube can slide freely on and a compressible spring. Use the spring to push the cube across the table with an acceleration of $1.0 m/s^2$ and carefully mark how far the spring is compressed during this motion. Declare that when the spring is compressed this amount, it applies a force of 1Newton (1N).

3. Make many more steel blocks, each of 1kg. This is easy to do. Simply push a block with the 1N spring and add or subtract steel until the push achieves an acceleration of $1 m/s^2$.

4. Likewise, make many more 1N springs by marking the compression whenever it makes a 1kg cube move with an acceleration of $1 m/s^2$.

5. Now you can push on a single cube with two springs and see what happens. You will find an acceleration of $2 m/s^2$. Push with three springs and you will get $3 m/s^2$, etc.

6. Also, try pushing two stacked cubes with a single spring and you will find an acceleration of $0.5 m/s^2$. Three stacked cubes will accelerate with $0.33 m/s^2$, etc.

7. All of these results and relationships can now be written as the equation $F = m \cdot a$, where $F$ is the net force (or sum of all forces) applied to an object, $m$ is the inertial mass of the object (conceptually, this is how much an object resists acceleration), and $a$ is the acceleration that results from the applied net force.

8. You can experiment with various forces speeding up and slowing down bocks and you will find the equation works at all velocities.

9. You can also see if the equation works in two or three dimensions. For example, use one spring to push the block east along the table and one spring to push the block north along the table. You will find the resulting acceleration is ($1.414 m/s^2$, 45º) as predicted by the Pythagorean Theorem and inverse tangent. Various other combinations of forces can convince you the equation holds true as a vector equation, $\mathbf{F} = m \cdot \mathbf{a}$. This is Newton's second law of motion.

| Answer Webassign Question 1 |
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| Answer Webassign Question 2 |
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Suppose you are riding a train and holding a marble in your palm. If the train hits the brakes and slows quickly, the marble will roll off of your hand. In your frame of reference, there was an acceleration of the marble without any discernable force causing it, invalidating the equation F = ma.

Further similar experiments will show that F = ma only holds true in frames of reference which are not accelerating (called inertial frames of reference). It does not hold true in accelerating frames of reference (called non-inertial frames of reference). This is the essence of Newton's first law of motion.

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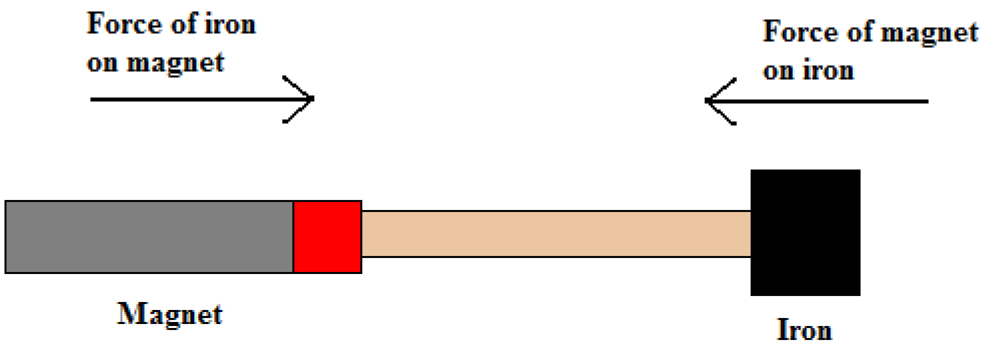
Take a magnet and a piece of iron and glue them on opposite ends of a popsicle stick. Then place the system on the air hockey table. The magnet is going to pull on the iron and apply a force to it, so the iron should accelerate in the direction of the magnet, taking the popsicle stick and magnet to which it is attached along for the ride. But this doesn't happen; the system just sits there. Well, if it just sits there, then the net force must be zero, so there must be a second force equal in magnitude and opposite direction acting somehow on the system. This is from the iron pulling the magnet.




Likewise, whenever you find object A applying a force to object B and make all relevant measurements, you will find object B is simultaneously applying a force on object A of the same magnitude, but in the opposite direction. This is Newton's third law of motion.

Conceptually, it is best to think of forces as *interactions* between two objects. For example, put the iron piece next to the magnet on the air hockey table and they will pull themselves together by their common attraction. This is one single interaction, not a separate *action* and *reaction*.

| Answer Webassign Question 3 |
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Suppose you have a stone with a mass of 2kg falling to the ground. What can we determine using Newton's second law of motion?

Well, $F = m \cdot a$ and we know for falling objects, $a = -9.8 m/s^2$ or $-g$

If the force of gravity is the only force acting on the stone, then it is also the net force, F

So $F = F_{gravity} = (m)(-g)$ or $F_G = -m \cdot g$

The force of gravity on an object is the mass of the object times the negative acceleration due to gravity. The weight of an object is simply the magnitude of this force of gravity.

If the stone then lands on the ground and sits there, the Earth doesn't know whether it is falling or not, so it still pulls with a force $F_G = -m \cdot g$.

Yet now the stone has no acceleration. Its velocity is zero and it remains zero. Therefore, by $F = m \cdot a$, the net force is zero.

So there must be some second force so that $0 = -m \cdot g + F_{something\ else}$

This other force is from the ground pushing up on the stone with a force of $+m \cdot g$. This force between the surface of the Earth and the surface of the stone is an example of what is called a "normal force", a force between two surfaces that exists perpendicular to their interface.

| Answer Webassign Question 4 |
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| Answer Webassign Question 5 |
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