An easy way to Physics: 04 Force and Gravitation

Force

If we hold a ball and release it, it falls down, because it is attracted by the earth. There is a force at work, the gravitation. When this ball falls down, its velocity increases. If we throw the ball upward, it becomes slower and slower. If we throw the ball horizontally, it is driven away from the straight path downwards. In all these 3 cases the force causes an acceleration in downward direction. The velocity of the fall is simply $v = - a \cdot t$. The minus sign indicates here, that the movement goes downward. If we throw the ball upward, we start with the velocity v_{Start} upwards and the gravity accelerates downwards: $v = v_{Start} - a \cdot t$. The ball climbs, until $v_{Start} = a \cdot t$. Then it stops, and the ball begins to fall again. If we throw the ball horizontally, the horizontal movement has simply a constant velocity v_{Start}. The movement downward is the movement of the falling ball $v = - a \cdot t$.
In each case the force in downward direction creates an acceleration in the same direction. For all masses m the force creates the same acceleration a. In physics, therefore the force $F = m \cdot a$.
the unit of the force is 1 N [Newton] = 1 kg · m/s². This force increases the velocity of a mass of 1 kg by 1 m/s at each second.

If no force acts upon a body, that body moves straight on with a constant velocity or it doesn't move at all. If we want to change the velocity of a body or the direction of the velocity we need a force. If you sit in a car, that moves with 50 km / h, you move with 50 km / h, too. If the car suddenly stops because it hits another car, you continue to move with 50 km / h until you hit the windscreen.

If a velocity changes very quickly, there is a very big acceleration and a very big force. If something falls on a hard floor, it breaks more easily.

A force can deform an object. This can result in an irreversible change (plastic deformation) or in a reversible deformation (elastic deformation). In an elastic deformation you need a stronger force to deform more, and the deformed body acts against the deformation with a force directly opposite to the deforming force. When we stand on the ground, we are attracted towards the earth, but the earth is a bit deformed and opposes us with a force in the upward direction. The deformation of the earth is so strong, that this opposing force is exactly as strong as the attraction of the earth. Both forces cancel each other, that means, that the sum of both forces is 0 N and produces, therefore, no acceleration.

For a force we need to know, where it acts, how strong it is and in what direction it acts. 2 forces of 1 N acting both from North to South, give an effect of 2 N. If both forces act in opposite directions, that means one acting from North to South and the other one from South to North, they give an effect of 0 N. 1 N from North to South and 1 N from West to East give together a force of 1.412 N in the direction from North West to South East.

A force F is needed to change the velocity of a mass. If I change the velocity of a mass by 1 m/s within 1 second, I need the force of 1 N [Newton]. The change of a velocity is called acceleration a. I need a force to make a mass faster, to make a mass slower or to turn away a mass from a straight movement. If no force is applied, a mass maintains the the amount and the direction of its velocity. If the mass m is constant, we need a double force to achieve a double acceleration a or a 3-fold force to achieve a 3-fold acceleration. If the acceleration is constant, but the mass m is doubled, we need the double force, and if we have the 3-fold mass, we need the 3-fold force. That behavior is written down by the formula $F = m \cdot a$. For the unit therefore is 1 N = 1 kg·m/s²

If we put together 2 masses, the mass of the sum of both masses is always the sum of both masses. Example: Mass $m_1 = 2$ kg and mass $m_2 = 3$ kg. The sum of both masses together is always $m_1 + m_2 = 5$ kg. When we add two forces, the effect of both forces combined doesn't depend on the strength of the forces alone, but also on their directions: If we have 2 equal forces and both forces pull a mass in the same direction, the forces add up. If they act in opposite directions, the forces cancel out and have no net effect. If one of these forces draws towards North and the other draws to West, the total force draws towards North West and is about 1,4 times stronger than each of the original forces.

Forces can be added like arrows, arrow 1 and arrow 2. We get the sum of two arrows, if we put the end of arrow 2 at the tip of arrow 1. The new arrow goes from the start of arrow 1 to the tip of arrow 2. Quantities, that are added like arrows are called vectors. A vector F therefore is often denoted by bold typeface **F**, by underlining $\underline{F}$ or by a little arrow above the letter $\overline{F}$.

Friction

If we hit a mass and let slide it on a table, we can see, that the mass becomes slower. The force producing this slow down is called friction. If we want that the mass on the table slides with a constant velocity, we need to pull it with a force that is as strong as the friction force. The friction increases with the velocity. If we want to get a higher velocity, we need, therefore, a stronger force. Bodies falling through the air experience a friction with the air. During the fall their velocity increases so much that finally the friction is as strong as the attraction of the earth. Then both forces add up to 0 N and there isn't anymore an acceleration, and the body has always the same velocity.

Gravitation

All masses attract each other. This attraction is very small, but it works over very big distances:
If the distance is doubled, the force is ¼ = ½ · ½.
If the distance is 3 times, the force is 1/9 = 1/3 · 1/3.
If the distance is 10 times, the force is 1/100 = 1/10 · 1/10.
If the distance is 100 times, the force is 1/10000 = 1/100 · 1/100.

The attraction F between Mass m_1 and mass m_2, that have a distance r, can therefore be described by the formula $F = \gamma \cdot m_1 \cdot m_2 / r^2$. γ is called the gravitational constant. $\gamma = 6{,}672 \cdot 10^{-11}\ N \cdot m^2/kg^2$.

Every mass in the world is attracted by all other masses in the cosmos.

If masses form a (radial symmetric) sphere, then the sum of the forces of all of these masses is the same as the force of a very tiny sphere with the same center and the same mass. The center of the earth is below us, about 6370 km distant from us. If we go up to an altitude of 6370 km above ground, the attraction is ¼ only of the present attraction. If we, however, lift a mass by some meters only, the attraction towards the center of the earth doesn't change.

At the surface of the earth a mass of 1 kg is attracted to the center of the earth with a force of about 9,81 N.≈ 10 N. This force is called weight. It is dependent on the place on earth and its height above ground.