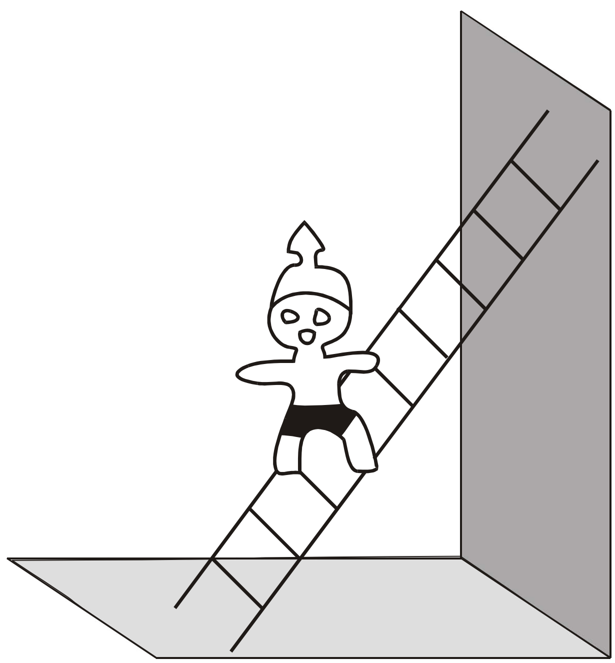
Force diagrams

Force diagrams

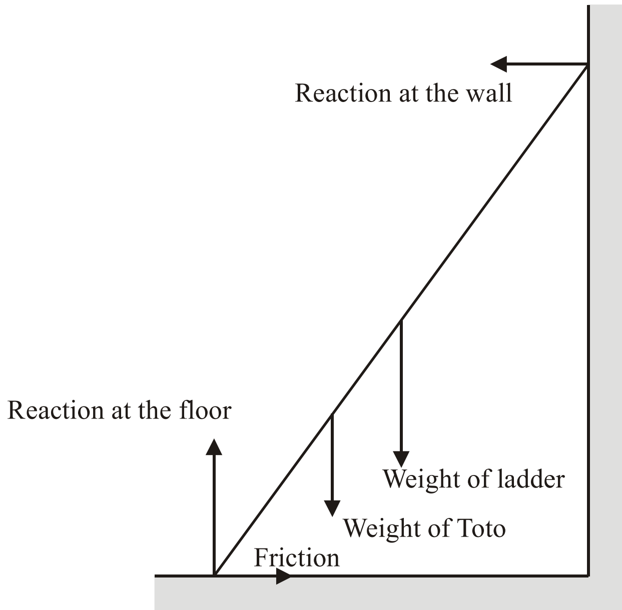
The student must learn to be able to visualise the effect of forces on objects. In order to do so, the student must be able to draw force diagrams. This is best illustrated by example.

Example (1)



My good friend Toto, who incidentally likes to collect Prussian helmets, decided to climb one third up a ladder. The wall itself was totally smooth but, fortunately for Toto, whose ladder might otherwise have slipped, the floor was rather rough. By representing Toto as a particle draw a schematic diagram showing the forces on the ladder and the forces acting on Toto.

Solution



The weight of the ladder acts at the centre of the mass of the ladder, which here is the mid-point of the ladder. Toto, standing one third up the ladder causes a downward thrust on the ladder, equal to his weight. The ladder presses against the wall, and this squeezes the wall slightly, so the wall responds by thrusting against the ladder – this is the reaction at the wall. The wall itself is smooth, which is "code" for "there is no friction" along the wall, so there is only a reaction at the wall which is perpendicular to the wall. At the foot of the ladder there are two forces acting on the ladder both due to the *contact* made between the ladder and the floor. Firstly, the ladder is pushing into the floor, so the floor responds by pushing back. This is the normal reaction at the floor. Also the ladder is not slipping. This is because the rough end of the ladder is catching the rough surface of the floor, so this rough surface is pushing back. This is the friction, which is shown as acting along the surface of the floor. This is also a contact force.

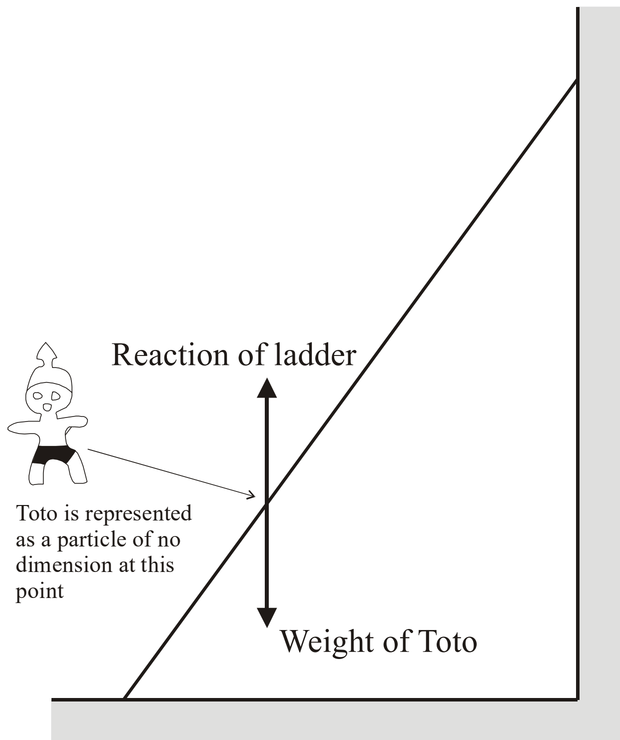
We call this whole arrangement of forces a "system". The entire system is not moving – we say it is in equilibrium. Therefore, we can say that

Weight of ladder + Weight of Toto = Normal reaction at the floor

Also

Reaction at the wall = Friction along the surface of the floor

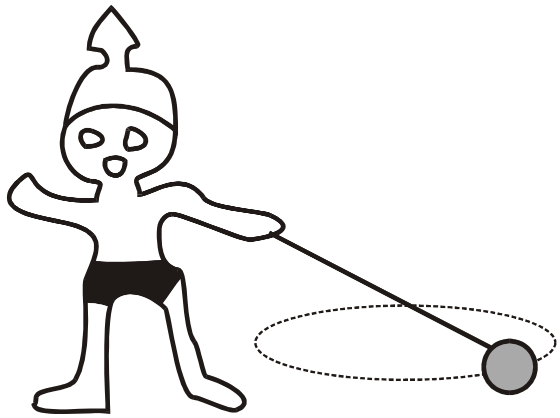
The second part of the question is easier. If we look at the system from the point-of-view of Toto, there are just two forces acting on Toto.



Firstly, there is Toto's weight, acting downwards; secondly, since Toto is standing on the ladder and pressing down on it, the ladder is responding with a reaction. This reaction is equal and opposite to Toto's weight, since Toto is not moving, and he is in equilibrium.

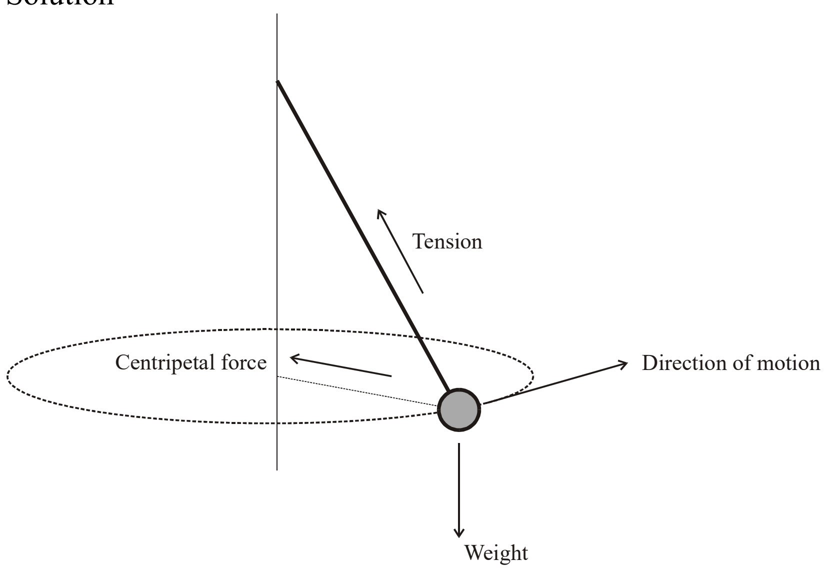
Note that the force diagrams depend on the point-of-view. The force diagram from the point-of-view of the ladder is *not* the same as the force diagram from the point-of-view of Toto. The force diagram for the system as a whole, that is, if we included the wall, would have no forces marked on it at all. This is because the system as a whole is not moving (we will ignore for the moment the motion of the Earth). All the forces inside this system cancel out.

Example (2)



My friend, Toto, decided whirl a ball on a string in the air. Explain in terms of forces why the ball continues moving in a circle.

Solution



Once Toto has got the ball moving the ball would naturally want to move in a straight line, indicated in the diagram by the direction of motion. What keeps in moving in a circle is the tension in the string. This tension does two things: firstly, it holds the ball up. The ball has a weight and would fall but for the tension in the string. Secondly, the tension in the string supplies a centripetal force that pulls the ball towards the centre of the circle.

Actually, there is another force acting on the ball. This is air resistance. The effect of the air resistance would be to gradually slow the ball down, and hence cause the ball to spiral in towards the centre. To overcome this, Toto keeps jerking the string, which sends an impulse along the string and imparts a boost of energy to the ball. Thus, the ball keeps moving in a circle for as long as Toto keeps jerking the string.