

# The Concept of Force

**V. G. Jadhao**

*Regional Institute of Education, Bhopal, India*

**B. K. Parida**

*Regional Institute of Education, Bhubaneswar, India*

The concept of Force is the most fundamental yet the most misunderstood concept in physics especially by the students up to higher secondary level. Learning materials in print form, which discuss the *formation* of these concepts, technically known as *cognition* or in Piagetian terminology, *schemata*, are rarely available to a practicing teacher or to learners. Here we present what special and technical meaning the concept of force has in the realm of pre-relativistic classical physics and review the existence of various alternative conceptions of the learners reported in some research studies. In particular we have presented the studies on school and college students spanning from the period 1983 to 1998. From these studies following alternative conceptions are culled out for the purpose of discussion in this presentation.

1. Force is associated with the body till it is in motion.
2. When a body is at rest the force acting on it is zero.
3. Force is always in the same direction as the velocity of the body.
4. If the velocity is changing then the force is also changing.
5. Centripetal force and centrifugal force both act on the body moving uniformly in a circle.
6. The action-reaction forces act on the same body.
7. The product of mass and acceleration is a force.
8. Only animate things like people and animals exert forces; passive ones like tables, floors do not exert forces.
9. A force applied by, say a hand, still acts on the object even after the object leaves the hand.

We present Osborne's (1985) thought experiment as a teaching episode to find out alternative conceptions of students at higher secondary level regarding the concept of force. The episode in brief is as follows.:

Consider an elastic ball. If we just drop the ball, it will

go down. On its journey downward if it meets a perfectly elastic horizontal floor, it will return to the same spot from where we dropped it. This process would continue for ever. State the direction of the force acting on the ball when it passes through a midway point B as it travels

- i) upwards
- ii) downwards

This episode is used to create the cognitive conflict in terms of opposite responses regarding the direction of force acting on the ball during its to and fro journey. The students are also asked to justify each of their responses.

This gives a large repertoire of alternative conceptions about force. It is stated that the correct response can be arrived at by two different routes. One shorter and the other longer one. The shorter route asks the student just a simple question what applies the force. Because the earth applies the force so it is always downwards hence the force is always downwards. The longer route is to find the direction of the acceleration or change of momentum. This is also always downwards.

The other alternative conceptions about force are then taken one by one. Possible causes for formation of the alternative conceptions are discussed at length. These are as follows.

a) The familiarity with the use of the term force in our everyday language creates some alternative conceptions. For example we say:

1. Water is coming out of the tap with great force.
2. Force within the earth pulls the stone down.
3. The police forced the door open
4. In spite of applying so much force the lid of the tin is not opening
5. The earth keeps us tied down to itself by gravitational force.

b) The other reason for alternative conceptions about force is the Aristotelian idea about the state of rest

being the preferred state.

c) Lastly it is our faulty way of teaching the concept of force from primary to secondary level, which gives rise to alternative conceptions. The alternative conceptions about force are also related with the alternative concepts about velocity and acceleration.

Some exemplar teaching and testing strategies are also illustrated in this presentation. For example, it is stated that “force” is an abstract concept and that there does not exist a definition of force independent of Newton’s laws of motion. In particular the first law gives a criterion to find out whether an unbalanced force acts on the body or not. The second law, while giving us the unit of force also gives the quantitative measure of the unbalanced force. But still they both do not tell us anything about the physical cause of the force. The third law tells us that the force is a result of interaction. All the three laws define the concept of force. Many alternative conceptions particularly about third law of motion widely held by public in general are also commented upon. Identification of correct pair of action reaction forces is also explained carefully. The concept of centrifugal force is explained as pseudo force to make the Newton’s laws valid even in non-inertial frame of reference. Any given problem can be analyzed both in an inertial and non-inertial frame. A modified definition of weight is suggested to explain the weight measured in an accelerated frame. Operationally, weight of a body is what the balance measures. It turns out that, weight should be defined as the opposite of the reaction that the floor or support applies on the body. In this connection it is stated that the concept of friction, tension, reaction and pressure are self-adjusting forces.

Sufficient number of problems, simple but illustrating the various aspects of the concept of force are also listed. Concept of force is used as an illustration to train the learners to talk and think aloud about force and other related concepts and events. Detailed mathematical analysis has been deliberately left out which can be easily found in any textbook. The presentation is expected to encourage the learners to think about and sometimes question the way we think and interpret events without being judgmental about ourselves. Lastly the two important aspects of scientific method, the logical thinking and curiosity to experiment are also illustrated taking concept of force as one example.

The teachers as well as self-learners can profitably use this in their attempts to develop correct concept about force.

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