In this section of Resonance, we invite readers to pose questions likely to be raised in a classroom situation. We may suggest strategies for dealing with them, or invite responses, or both. “Classroom” is equally a forum for raising broader issues and sharing personal experiences and viewpoints on matters related to teaching and learning science.

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What is Rolling Friction?

While discussing friction, often after describing static and sliding friction, a third type called rolling friction is mentioned. The static friction acting on a rolling body can be either in the direction of motion or opposite to it depending upon the forces acting on the body. But the direction of rolling friction is generally not mentioned. By analyzing the process of rolling in the absence of any push or pull we come to the conclusion that the energy loss in rolling motion is due to the continuous collision of the rolling body with the body on whose surface it rolls.

We know that when a cylindrical or spherical body rolls on a horizontal surface free of any push or pull, both the translational as well as the rotational velocities of the body decrease continuously. This decrease is often described as due to ‘rolling friction’. However, it does not help in identifying the direction of the so-called rolling friction.

To decrease the translational velocity, a force directed opposite to it is necessary. To decrease the angular velocity, a torque directed opposite to it is necessary. If we assume that the force of rolling friction is in the plane of the surface on which the body
Rolling, then the direction of the force of friction necessary to reduce linear velocity is just the opposite to that needed for reducing angular velocity of the rolling body. How can the force of friction act in opposite directions simultaneously at the same point?

Obviously, the assumptions on which the reasoning is based need re-examination.

One of the assumptions is that the surface is perfectly rigid and the body rolls about a line just below its centre of gravity. But real bodies get deformed under the action of forces. When a body is rolling, it has some linear momentum. So the rolling motion is equivalent to the continuous collisions between the rolling body and the other body on whose surface it rolls. Due to its weight it should deform the plane surface below it into a mould in which its lowest part fits.

When the body is rolling, the net reaction of the concave surface below it must be acting at a point slightly ahead of the foot of the vertical line through the centre of gravity of the body. When we resolve this net reaction $N$ into horizontal and vertical components, we see that the horizontal component is responsible for the decrease of the translational velocity whereas the vertical component balances the weight. Due to the shift of the point of
application of the net force exerted by the surface on the body, the weight of the body produces a torque, which is directed opposite to the angular velocity of the rolling body. Both the translational as well as the rotational speed of the body decrease under the action of the force $N$ exerted by the curved surface. But still we have not made any statement regarding the direction of the force of rolling friction. The component of the force $N$, which is anti-parallel to the direction of motion, is responsible for the loss of translational kinetic energy whereas the component perpendicular to the direction is responsible for the loss of rotational kinetic energy. If we want to assign the total loss of kinetic energy of the rolling body to rolling friction then we have to say that rolling friction consists of two mutually perpendicular components: the component anti-parallel to the translational velocity retards the velocity and the component perpendicular to the velocity retards the angular velocity of the rolling body. Or, in other words, the direction of rolling friction is along $N$.

When the deformation of the surface under the rolling body is large, the angle $\theta$ is large and both the retarding force as well as the retarding torque will be large. This means larger loss of kinetic energy. This is equivalent to larger rolling friction. The observation that a rolling body loses more energy on a softer bed than on a harder one supports this inference.

While discussing the motion of bodies in contact with other bodies, we consider the bodies to be rigid and use the concept of frictional force to obtain the net force on the body. From the analysis given above the conclusion is that for an ideal rigid body rolling on an ideal rigid surface there cannot be any rolling friction.