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2. A block of mass $0.500\,\mathrm{kg}$ slides on a flat smooth surface with a speed of $2.80\,\frac{\mathrm{m}}{\mathrm{s}}$. It then slides over a rough surface with μ_{k} and slows to a halt. While the block is slowing, (a) what is the frictional force on the block? (b) What is the magnitude of the block's acceleration? (c) How far does the block slide on the rough part before it comes to a halt?

The problem is illustrated in Fig. 5.6. As indicated in Fig. 5.6 the block slides a distance x in coming to a halt on the rough surface.

First, find the forces which act on the block... draw the damn picture, as we do in Fig. 5.7. The forces are gravity (mg, downward) the normal force from the surface (F_N, upward) and the force of kinetic friction (f_{k}, backward i.e. opposite the direction of motion).

Now, the motion only takes place along a horizontal line, so the vertical acceleration is zero. So the net vertical force on the mass is zero, giving:

$$F_N - mg = 0 \qquad \Longrightarrow \qquad F_N = mg = (0.500\,\mathrm{kg})(9.80\,\tfrac{\mathrm{m}}{\mathrm{s}^2}) = 4.90\,\mathrm{N}$$

Now that we have the normal force of the surface, Eq. 5.2 gives us the magnitude of the (kinetic) friction force:

$$f_{\mathrm{k}} = \mu_{\mathrm{k}} F_N = (0.300)(4.90\,\mathrm{N}) = 1.47\,\mathrm{N}$$

(b) The net force on the block *is* the friction force so that the magnitude of the block's acceleration is

$$a = \frac{F_{\mathrm{net}}}{m} = \frac{(1.47\,\mathrm{N})}{(0.500\,\mathrm{kg})} = 2.94\,\tfrac{\mathrm{m}}{\mathrm{s}^2}$$

We should note that the direction of the acceleration *opposes* the diretion of motion, so if the velocity is along the $+x$ direction, the acceleration of the block is

$$a_x = -2.94\,\tfrac{\mathrm{m}}{\mathrm{s}^2}$$

Actually, by plugging the numbers into the formulae we've missed an important point. Going back to part (a), we had $F_N = mg$, so that

$$f_{\mathrm{k}} = \mu_{\mathrm{k}} F_N = \mu_{\mathrm{k}} mg$$

and the magnitude of the acceleration is

$$a = \frac{F_{\mathrm{net}}}{m} = \frac{\mu_{\mathrm{k}} mg}{m} = \mu_{\mathrm{k}} g\ ,$$

that is, the acceleration of the mass does not depend on the value of m, just on μ_{k} and g.

(c) The distance travelled by the mass before it comes to a halt: We have the initial velocity v_0 of the mass, the final velocity ($v = 0$) and the acceleration. We can use Eq. 2.8 to solve for x:

$$v^2 = v_0^2 + 2ax \qquad \Longrightarrow \qquad 0^2 = (2.80\,\tfrac{\mathrm{m}}{\mathrm{s}})^2 + 2(-2.94\,\tfrac{\mathrm{m}}{\mathrm{s}^2})x$$

Solve for x:

$$x = \frac{(2.80\,\frac{\mathrm{m}}{\mathrm{s}})^2}{2(2.94\,\frac{\mathrm{m}}{\mathrm{s}^2})} = 1.33\,\mathrm{m}$$
