PHYSICS 101, SPRING 2000, SOLUTIONS TO CHAP 7

We will constantly use two equations. The first is the work-energy theorem:

\[ KE_f + PE_f = KE_i + PE_i + W_{\text{other}}, \]  \hspace{1cm} (1)

where \( W_{\text{other}} \) is the work done by forces whose works are not already taken into account by the potential energy. Also the work done by a constant force is

\[ W = Fs \cos \theta_F s, \] \hspace{1cm} (2)

where \( \theta_F s \) is the angle between the force vector and the direction in which the object is moving.

- Remember that when \( \theta_F s = 90^\circ \), i.e. when the force and the displacement are perpendicular, the work done is zero.

7.17 Use Eq. (1). The forces acting on the wagon are a) gravity, b) the normal upward force exerted by the surface, and c) the applied force, \( \mathbf{F} \). The work done by gravity is zero (the initial and final potential energies are the same) and the work done by the normal force is zero also because, like gravity, this force is perpendicular to the displacement. So Eq. (1) is

\[ \frac{1}{2}mv_f^2 + mgh_f = \frac{1}{2}mv_i^2 + mgh_i + W_F, \] \hspace{1cm} (3)

where \( W_F \) is the work done by the force \( \mathbf{F} \). But Eq. (2) gives

\[ W_F = Fs \cos \theta_F s = (18)(4)(\cos 0^\circ) = 72 \text{ joules}. \] \hspace{1cm} (4)

So Eq. (3) is

\[ \frac{1}{2}(4.60)v_f^2 + mg(0) = \frac{1}{2}(4.60)(10)^2 + mg(0) + 72 \] \hspace{1cm} (5)

so that \( 2.3v_f^2 = 230 + 72 = 302 \text{ joules} \) and \( v_f = \sqrt{131.3} = 11.5 \text{ m/s} \).

b) \( a = F/m = 18/4.6 = 3.91 \text{m/s}^2 \). Then \( v_f^2 = v_i^2 + 2as \) is \( v_f^2 = (10)^2 + 2(3.91)(4) = 100 + 31.3 = 131.3(\text{m/s})^2 \), as before.

7.20 Use Eq. (1). The forces acting on the block are a) gravity, b) the upward force exerted by the table, and c) the radially inward force exerted by the string.
The work done by gravity and by the force exerted by the table is zero, because these forces are perpendicular to the direction of motion. So the only work done on the object is the work done by the person pulling on the string. Call that \( W_{St} \). Then Eq. (1) is

\[
\frac{1}{2}mv_f^2 = \frac{1}{2}mv_i^2 + W_{St},
\]

or

\[
\frac{1}{2}(0.05)(1.4)^2 = \frac{1}{2}(0.05)(0.7)^2 + W_{St}.
\]

So \( W_{St} = (0.025)(1.96 - 0.49) = 0.025(1.47) = 0.037 \text{ joules}. \)

**7.21** a) Use Eq. (1). The force of gravity and the normal upward force exerted by the road on the car are both perpendicular to the direction of motion. So these forces do zero work on the car. However, friction does work, \( W_f \), on the car, with

\[
W_f = F s \cos \theta_{FS} = (\mu_k N) s \cos(180^\circ) = -\mu_k mgs.
\]

Use Eq. (1):

\[
\frac{1}{2}mv_f^2 + mgh_f = \frac{1}{2}mv_i^2 + mgh_i + W_f.
\]

But \( h_f = h_i \) and \( v_f = 0 \), so that

\[
0 = \frac{1}{2}mv_i^2 - \mu_k mgs,
\]

and

\[
s = \frac{v_i^2}{2\mu_k g}.
\]

b) Repeat for \( v_i = 70 \text{ mph} \). Note that \( s \) is proportional to \( v_i^2 \). If we double \( v_i \) we multiply \( s \) by 4. So the stopping distance at 70 mph is \((4)(120) = 480 \text{ ft.}\)

**7.24** Use Eq. (1). Assume that no work is done on the bicycle other than by you and by gravity. This is reasonable because the normal force, being perpendicular
to the displacement, does zero work and the work done by gravity is accounted for in the potential energy. So the work you do, $W_Y$ satisfies

$$\frac{1}{2}mv_f^2 + mgh_f = \frac{1}{2}mv_i^2 + mgh_i + W_Y .$$

(12)

Using $g = 10$ m/s$^2$, we write this as

$$\frac{1}{2}(95)(1.5)^2 + (95)(10)(5.2) = \frac{1}{2}(95)(3.0)^2 + mg(0) + W_Y .$$

(13)

So

$$W_Y = (95)[\frac{1}{2}(1.5)^2 - \frac{1}{2}(3.0)^2 + (10)(5.2)]$$

$$= (95)[1.12 - 4.50 + 52] = (95)(58.6) = 4620 \text{ joules}. \quad (14)$$

(This is about one Kcalorie.)

7.27 Use Eq. (1). Note that the forces acting on the rock are a) gravity, whose work is taken into account in the potential energy, b) the normal force (which is always perpendicular to the direction of motion, and which hence does zero work), and c) friction, which tends to slow the rock down, and hence does NEGATIVE work on the rock. So Eq. (1) is

$$\frac{1}{2}mv_B^2 + mgh_B = \frac{1}{2}mv_A^2 + mgh_A + W_f .$$

(15)

This is

$$\frac{1}{2}(0.1)(1.8)^2 + mg(0) = \frac{1}{2}m(0)^2 + (0.1)(10)(0.6) + W_f ,$$

(16)

or

$$0.162 = 0.6 + W_f ,$$

(17)

so $W_f = -0.438$ joules. This is negative, as expected.