3.2.1 In Class or Homework Exercise

1. A rope is used to pull a metal box 15.0 *m* across the floor. The rope is held at an angle of 46.0° with the floor and a force of 628 *N* is used. How much work does the force on the rope do?

$\Delta d = 15.0m$

$\theta = 46.0°$

$F = 628N$

$W = ?$

$$W = F\Delta d\cos\theta$$
$$= (628)(15.0)\cos 46.0°$$
$$= \boxed{6540J}$$

2. An 845 *N* sled is pulled a distance of 185 *m*. The task requires 1.20×10^4 *J* of work and is done by pulling on a rope with a force of 125 *N*. At what angle is the rope held?

$F_g = 845N$

$\Delta d = 185m$

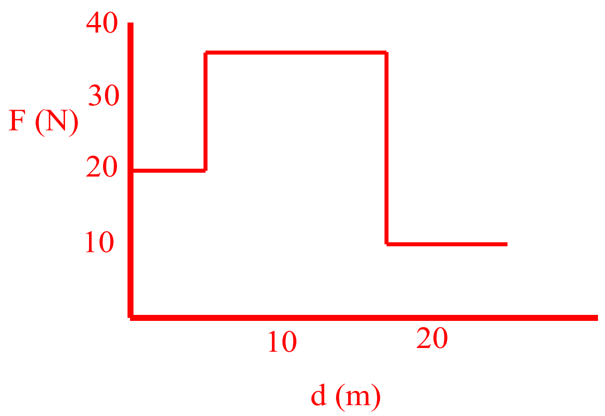
$W = 1.20\times10^4 J$

$F = 125N$

$\theta = ?$

$$W = F\Delta d\cos\theta$$
$$1.20\times10^4 = (125)(185)\cos\theta$$
$$\theta = \boxed{58.7°}$$

3. John pushes a crate across a floor with a horizontal force. The roughness of the floor changes and John must exert a force of 20. *N* for 5.0 *m*, then 35 *N* for 12 *m*, then 10. *N* for 8.0 *m*. Draw a graph of force as a function of distance. How much work did John do?



Since the force and the displacement are in the same direction, we simply have to multiply the two together to calculate the work done.

$F_1 = 20.N$

$F_2 = 35N$

$F_3 = 10.N$

$\Delta d_1 = 5.0m$

$\Delta d_2 = 12m$

$\Delta d_3 = 8.0m$

$$W_1 = F_1\Delta d_1 = (20.)(5.0) = 1\bar{0}0J$$

$$W_2 = F_2\Delta d_2 = (35)(12) = 420J$$

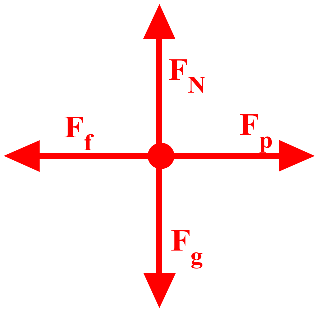
$$W_3 = F_3\Delta d_3 = (10.)(8.0) = 80.J$$

$$W_t = 1\bar{0}0J + 420J + 80J$$
$$= \boxed{6\bar{0}0J}$$

Notice that when calculating the work for each one of the parts, you were actually calculating the area on the graph. When given a force vs displacement graph, the area under the graph gives the work done.

4. How much work did a horse do that dragged an 80.0 *kg* teacher along the ground 70.0 *m*

   a. without acceleration if the coefficient of friction was 0.160?

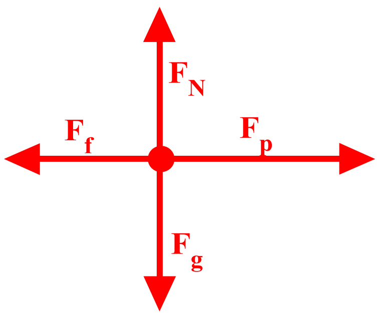


$$m = 80.0kg \qquad F_f = \mu F_N$$
$$\mu = 0.160 \qquad = \mu mg$$
$$\Delta d = 70.0m \qquad = (0.160)(80.0)(9.80)$$
$$W_h = ? \qquad = 125N$$

Since we are looking for the work done by the horse, we need to know the force exerted by the horse. It can be seen in the free body diagram that this force must be equal to the force of friction:

$$W_h = F_h \Delta d \cos\theta$$
$$= (125)(70.0)\cos 0°$$
$$= \boxed{8750J}$$

   b. with an acceleration of 2.20 m/s^2 with the same coefficient of friction?



$m = 80.0kg$

$F_f = 125N$

$\vec{a} = 2.20m/s^2$

$W_h = ?$

Since we are looking for the work done by the horse again, we again need to know the force exerted by the horse.

$$m\vec{a} = \sum \vec{F}$$
$$m\vec{a} = \vec{F}_h + \vec{F}_f$$
$$80.0(2.20) = F_h - 125$$
$$F_h = 301N$$

$$W_h = F_h \Delta d \cos\theta$$
$$= (301)(70.0)\cos 0°$$
$$= \boxed{21100J}$$

c. How much work is done by friction in (a) and (b)?

In both (a) and (b), the force of friction and the distance travelled are the same, so the work done by friction in each will be the same.

$F_f = 125N$

$\Delta d = 70.0m$

$W_f = ?$

$$W_f = F_f \Delta d \cos\theta$$
$$= (125)(70.0)\cos 180°$$
$$= \boxed{-8750J}$$

5. A student librarian picks up a 2.0 *kg* book from the floor to a height of 1.25 *m*. He carries the book 8.0 *m* to the stacks and places the book on a shelf that is 0.35 *m* above the floor. How much work does he do on the book?

Break the problem up into 3 parts:

Part 1 – Lifting the book

$m = 2.0kg$

$\Delta d = 1.25m$

$W_1 = ?$

$$F_g = mg$$
$$= (2.0)(9.80)$$
$$= 19.6N$$

$$W_1 = F_1 \Delta d_1 \cos\theta_1$$
$$= (19.6)(1.25)\cos 0°$$
$$= 24.5J$$

Part 2 – carrying the book 8.0 m

Since the student is still exerting an upward force, but the motion is horizontal, the angle is $90°$ and the work done is zero

$W_2 = 0$

Part 3 – Lowering the book

$F_g = 19.6N$

$\Delta d = 1.25 - 0.35 = 0.90m$

$W_3 = ?$

Since the force is upward and it is moving down, the angle is $180°$

$$\begin{aligned} W_3 &= F_3 \Delta d_3 \cos\theta_3 \\ &= (19.6)(0.90)\cos 180° \\ &= -17.6J \end{aligned}$$

$$\begin{aligned} W_t &= W_1 + W_2 + W_3 \\ &= 24.5 + 0 + (-17.6) \\ &= \boxed{6.9J} \end{aligned}$$

6. Calculate the work done for the following.
   a. A person pushes a 5.0 *kg* box with a force of 40.0 *N* for 2.0 *m*.

      $m = 5.0kg$

      $\Delta d = 2.0m$

      $F = 40.0N$

      $W = ?$

      $$\begin{aligned} W &= F\Delta d\cos\theta \\ &= (40.0)(2.0)\cos 0° \\ &= \boxed{80.\,J} \end{aligned}$$

   b. A person pushes a 5.0 *kg* box with a force of 40.0 *N* for 3.0 *s* at a constant speed of 1.2 *m*/*s*.

      $m = 5.0kg$

      $F = 40.0N$

      $\Delta t = 3.0s$

      $v = 1.2m/s$

      $W = ?$

      It is first necessary to find the distance travelled:

      $$v = \frac{\Delta d}{t}$$

      $$1.2 = \frac{\Delta d}{3.0}$$

      $$\Delta d = 3.6m$$

Now the work can be found:

$$W = F\Delta d\cos\theta$$
$$= (40.0)(3.6)\cos 0°$$
$$= \boxed{140J}$$

c. A person pushes a 5.0 *kg* box with a force of 40.0 *N* for 3.0 *s* at an acceleration of 1.2 m/s^2.

$$m = 5.0kg$$
$$F = 40.0N$$
$$\Delta t = 3.0s$$
$$a = 1.2m/s^2$$
$$W = ?$$

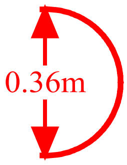
It is first necessary to find the distance travelled:

$$\Delta\vec{d} = \vec{v}_i t + \tfrac{1}{2}\vec{a}t^2$$
$$= 0 + \tfrac{1}{2}(1.2)(3.0)^2$$
$$= 5.4m$$

Now the work can be found:

$$W = F\Delta d\cos\theta$$
$$= (40.0)(5.4)\cos 0°$$
$$= \boxed{220J}$$

7. In peddling a bicycle, a particular cyclist exerts a downward force of 90. *N* during each stroke. If the diameter of the circle traced by each peddle is 36 *cm*, calculate how much work is done in each downward stroke.



Since the force is down, we must use the displacement in the downward direction:

$$\Delta d = 36cm = 0.36m$$
$$F = 90.N$$
$$W = ?$$

$$W = F\Delta d\cos\theta$$
$$= (90.)(0.36)\cos 0°$$
$$= \boxed{32J}$$

8. A father is pulling his 2 girls in their sled (85 *kg*) with a force of 500. *N* for a distance of 22 *m*. Calculate the work that would be done by the father in each of the following cases.
   a. The snow provides no friction.

$$F_p = 500.N$$
$$\Delta d = 22m$$
$$m = 85kg$$
$$W_p = ?$$

$$W_p = F_p \Delta d \cos\theta$$
$$= (500.)(22)\cos 0°$$
$$= \boxed{11000J}$$

   b. One of the children drags her hands in the snow, producing a frictional force of 500. *N*.

$$F_p = 500.N$$
$$F_f = 500.N$$
$$\Delta d = 22m$$
$$m = 85kg$$
$$W_p = ?$$

Since the father is still applying a force of 500. N over the same distance, he is still doing the same amount of work.

$$W_p = F_p \Delta d \cos\theta$$
$$= (500.)(22)\cos 0°$$
$$= \boxed{11000J}$$

   c. What visible difference would you see in the motion between a) and b)?

In (b), the speed will be constant since the net force is zero – there will be no gain in speed and the energy of the sled will stay the same. All of the person's work is being used to overcome friction.

In (a), the sled will be accelerating since there is a net force. It will be gaining energy.

9. A person is pushing a refrigerator across a floor at a constant speed. Is the person doing work? Is the refrigerator gaining energy? Explain.

Yes, the person is doing work since they are applying a force in a direction that the refrigerator is moving. The refrigerator is not, however, gaining energy since it is not going any faster. All of the work that the person is doing is being used to overcome friction and will turn up as heat.