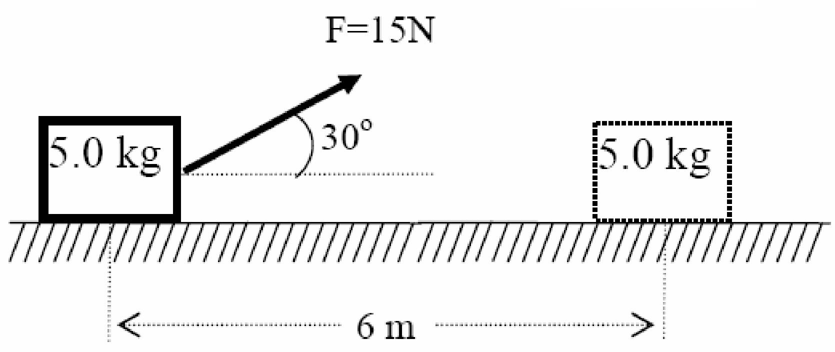
Selected Problems from Chapter 7

1) A 5.0-kg object is pulled along a rough horizontal surface at constant speed by a 15 N force acting 30 degrees above the horizontal (see Fig.). How much work is done by the friction force as the object moves 6.0 m?

A1 -78 J
A2 -82 J
A3 -85 J
A4 -75 J
A5 0 J

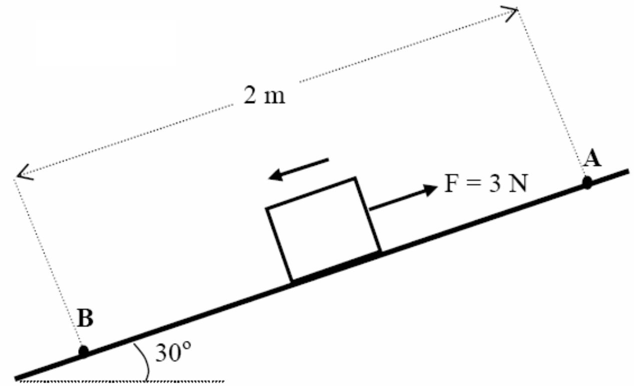


$$\text{the frictional force} : f_k = F\cos 30 = 13 \text{ N}$$

$$W \text{ (frictional force)} = -f_k d = -13 \times 6 = -78 \text{ J}$$

2) A 2.0-kg block slides 2.0 m down a frictionless incline from point A to point B. A force (magnitude F =3.0 N) acts on the block between A and B, as shown in Fig. If the kinetic energy of the block at A is 10 J, what is its kinetic energy at B?

A1 24 J
A2 20 J
A3 27 J
A4 17 J
A5 37 J



$$W_{net} = W_F + W_w + W_N$$

$$W_N = 0, \quad W_w = mgd\sin 30 = 2.0x\,9.8x\,2.0x\,0.5 = 19.6\,J$$

$$W_F = -Fd = -3.0 \times 2.0 = -6.0\,J$$

$$W_{net} = 13.6\,J$$

$$\Delta K = W_{net} \Rightarrow K_B - K_A = 13.6\,J$$

$$K_B = K_A + 15.6 = 10 + 13.6 = 23.6\,J \approx 24\,J$$

3) A 2.0-kg object moves along the +x-axis with a speed of 5 m/s under the influence of a force F= (3i+4j) N. What is the power delivered by this force?

A1 15 W
A2 20 W
A3 25 W
A4 35 W
A5 30 W

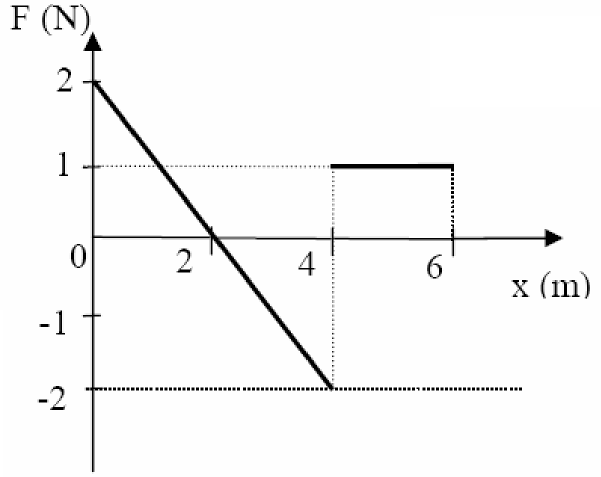
$$P = \overrightarrow{F} . \overrightarrow{v} = (3i + 4j).(5i) = 15W$$

4) Two balls, with masses m and 2m, are dropped to the ground from the roof of a building. (Assume no air resistance.) Just before hitting the ground, the heavier ball has:

A1 two times as much kinetic energy as the lighter one.
A2 as much kinetic energy as the lighter one.
A3 half as much kinetic energy as the lighter one.
A4 four times as much kinetic energy as the lighter one.
A5 a kinetic energy that is impossible to determine.

5) An object is pushed by a variable force, plotted in Fig , as a function of position, x.
How much work has the force done on the object when it has moved from x=0 to x=+6 m?

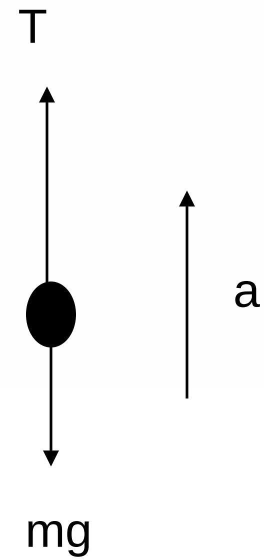
A1 2 J
A2 10 J
A3 -6 J
A4 0 J
A5 12 J



$$W = area\ under\ the\ curve. = \tfrac{1}{2}\times 2\times 2 - \tfrac{1}{2}\times 2\times 2 + 1\times 2 = 2\ J$$

6) A helicopter lifts a 72 kg man 15 m vertically by means of a cable. The acceleration of the man is 1.20 m/s**2. How much work is done on the man by the tension of the cable?

A1 12 kJ
A2 10 kJ
A3 0 kJ
A4 14 kJ
A5 16 kJ

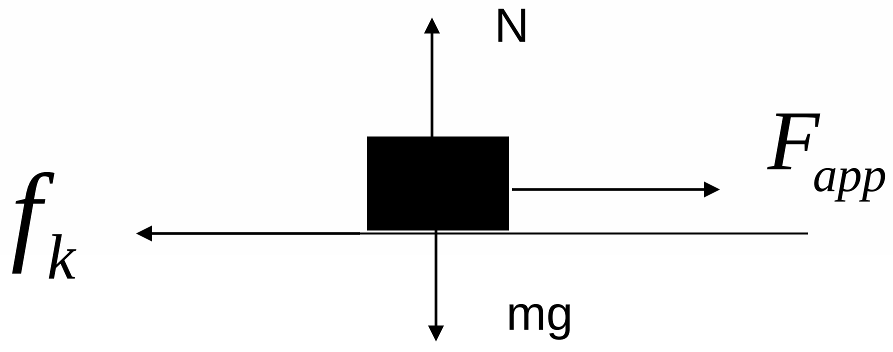


$$T = m(g + a) = 72(9.80 + 1.20) = 792\ N$$

$$W_T = Td = 792 \times 15 = 11880\ J \approx 12\ kJ$$

7) You are supposed to pull a 2000 kg equipment across a horizontal frozen lake by means of a horizontal rope. The coefficient of kinetic friction is 0.05. The amount of work you will do by pulling the equipment 100 m at constant velocity is:

A1 98 kJ
A2 20 kJ
A3 130 kJ
A4 -300 kJ
A5 0 kJ



$$F_{app} = f_k = \mu_k N = \mu_k mg$$

$$W_{F_{app}} = F_{app} d = \mu_k mgd$$

$$= 0.05 \times 2000 \times 9.80 \times 100 = 98\, kJ$$

8) A particle moves from Xi = 0 to Xf = 5.0 m while being acted upon by a single force F = 3*X**2 directed along the X axis. Find the change in the kinetic energy during this motion.

A1 125 J
A2 5 J
A3 0 J
A4 75 J
A5 250 J

$$\Delta K = W = \int_{x_i}^{x_f} F(x)dx = \int_0^5 3x^2 dx = x^3 \Big|_0^5 = 5^3 - 0^3 = 125\ J$$

9) A particle moves in the x-y plane from the point (0,1) m to point (3,5) m while being acted upon by a constant force F = 4i + 2j +4k (N). The work done on the particle by this force is:

A1 20 J
A2 10 J
A3 -20 J
A4 30 J
A5 0

$$\vec{d} = (3-0)i + (5-1)j = 3i + 4j$$

$$W = \vec{F}.\vec{d} = (4i + 2j + 4k).(3i + 4j)$$

$$= 4\times 3 + 2\times 4 = 12 + 8 = 20\ J$$

10) Which of the following statements is CORRECT?

A1 The centripetal force acting on a particle rotating in a
A1 circle does no work on the particle.
A2 The work done by a force is always equal to the product of
A2 the force and the distance travelled.
A3 When an object is displaced horizontally, the gravitational
A3 force does work on it.
A4 When an object is displaced horizontally on a table, the normal
A4 force does work on it.
A5 If a person lifts a heavy block a vertical distance, then
A5 his work is zero.

11) A car accelerates from zero to 30 m/s in 1.5 s. Assuming the same average power is delivered by the car, how long does it take to accelerate it from zero to 60 m/s. (Ignore friction).

A1	6.0	s
A2	3.0	s
A3	4.5	s
A4	1.5	s
A5	9.0	s

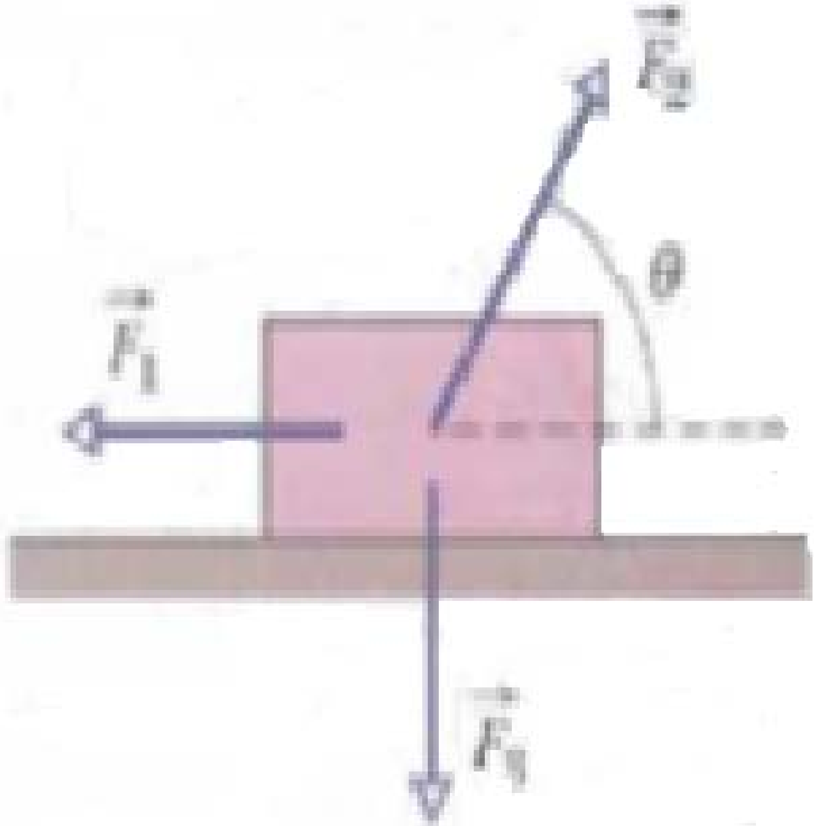
$$P_{1avg} = \frac{W_1}{\Delta t_1} = \frac{\Delta K_1}{\Delta t_1} = \frac{\frac{1}{2} m{v_1}^2}{\Delta t_1}$$

$$P_{2avg} = \frac{W_2}{\Delta t_2} = \frac{\Delta K_2}{\Delta t_2} = \frac{\frac{1}{2} m{v_2}^2}{\Delta t_2}$$

$$P_{1avg} = P_{2avg} \rightarrow \frac{\frac{1}{2} m{v_1}^2}{\Delta t_1} = \frac{\frac{1}{2} m{v_2}^2}{\Delta t_2}$$

$$\frac{{v_1}^2}{\Delta t_1} = \frac{{v_2}^2}{\Delta t_2} \rightarrow \Delta t_2 = (\frac{v_2}{v_1})^2 \Delta t_1$$

••13 Figure 7-29 shows three forces applied to a trunk that moves leftward by 3.00 m over a frictionless floor. The force magnitudes are $F_1 = 5.00$ N, $F_2 = 9.00$ N, and $F_3 = 3.00$ N, and the indicated angle is $\theta = 60.0°$. During the displacement, (a) what is the net work done on the trunk by the three forces and (b) does the kinetic energy of the trunk increase or decrease? SSM



13. (a) The forces are constant, so the work done by any one of them is given by $W = \vec{F} \cdot \vec{d}$, where $\vec{d}$ is the displacement. Force $\vec{F}_1$ is in the direction of the displacement, so

$$W_1 = F_1 d \cos\phi_1 = (5.00\,\text{N})(3.00\,\text{m})\cos 0^\circ = 15.0\ \text{J}.$$

Force $\vec{F}_2$ makes an angle of 120° with the displacement, so

$$W_2 = F_2 d \cos\phi_2 = (9.00\,\text{N})(3.00\,\text{m})\cos 120^\circ = -13.5\ \text{J}.$$

Force $\vec{F}_3$ is perpendicular to the displacement, so $W_3 = F_3 d \cos\phi_3 = 0$ since $\cos 90^\circ = 0$. The net work done by the three forces is

$$W = W_1 + W_2 + W_3 = 15.0\ \text{J} - 13.5\ \text{J} + 0 = +1.50\ \text{J}.$$

(b) If no other forces do work on the box, its kinetic energy increases by 1.50 J during the displacement.

•17 A helicopter lifts a 72 kg astronaut 15 m vertically from the ocean by means of a cable. The acceleration of the astronaut is $g/10$. How much work is done on the astronaut by (a) the force from the helicopter and (b) the gravitational force on her? Just before she reaches the helicopter, what are her (c) kinetic energy and (d) speed? SSM WWW

17. (a) We use $\vec{F}$ to denote the upward force exerted by the cable on the astronaut. The force of the cable is upward and the force of gravity is *mg* downward. Furthermore, the acceleration of the astronaut is *g*/10 upward. According to Newton's second law, $F - mg = mg/10$, so $F = 11\,mg/10$. Since the force $\vec{F}$ and the displacement $\vec{d}$ are in the same direction, the work done by $\vec{F}$ is

$$W_F = Fd = \frac{11mgd}{10} = \frac{11\,(72\text{ kg})\left(9.8\text{ m/s}^2\right)(15\text{ m})}{10} = 1.164 \times 10^4\text{ J}$$

which (with respect to significant figures) should be quoted as 1.2×10^4 J.

(b) The force of gravity has magnitude *mg* and is opposite in direction to the displacement. Thus, using Eq. 7-7, the work done by gravity is

$$W_g = -mgd = -\,(72\text{ kg})\left(9.8\text{ m/s}^2\right)(15\text{ m}) = -1.058 \times 10^4\text{ J}$$

which should be quoted as $-\,1.1 \times 10^4$ J.

(c) The total work done is $W = 1.164\times10^4\text{ J} - 1.058\times10^4\text{ J} = 1.06\times10^3\text{ J}$. Since the astronaut started from rest, the work-kinetic energy theorem tells us that this (which we round to $1.1\times10^3\text{ J}$) is her final kinetic energy.

(d) Since $K = \frac{1}{2}mv^2$, her final speed is

$$v = \sqrt{\frac{2K}{m}} = \sqrt{\frac{2(1.06\times10^3\text{J})}{72\text{ kg}}} = 5.4\text{ m/s}.$$

18 In Fig. 7-31, a horizontal force $\vec{F}_a$ of magnitude 20.0 N is applied to a 3.00 kg psychology book as the book slides a distance $d = 0.500$ m up a frictionless ramp at angle $\theta = 30.0°$. (a) During the displacement, what is the net work done on the book by $\vec{F}_a$, the gravitational force on the book, and the normal force on the book? (b) If the book has zero kinetic energy at the start of the displacement, what is its speed at the end of the displacement?

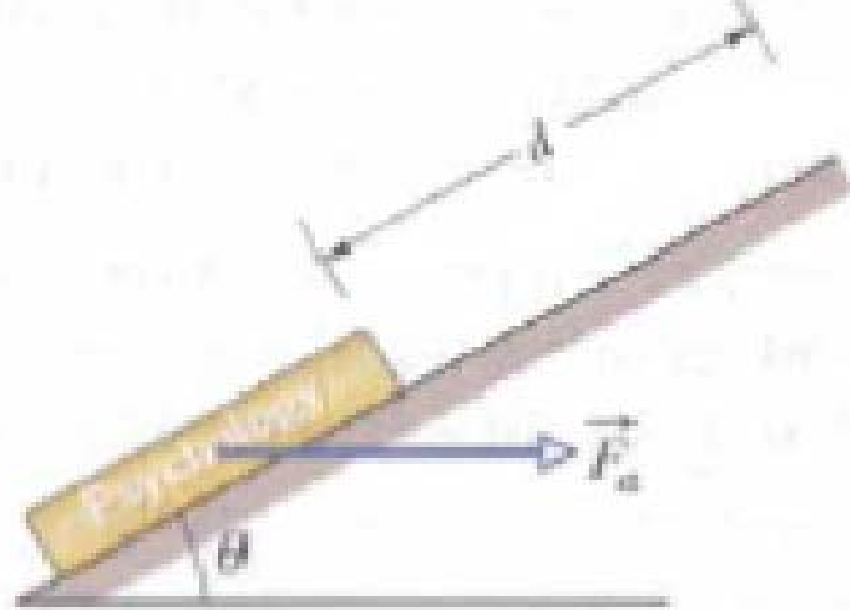


Fig. 7-31 Problem 18.

18. (a) Using notation common to many vector capable calculators, we have (from Eq. 7-8) W = dot([20.0,0] + [0, –(3.00)(9.8)], [0.500 ∠ 30.0º]) = +1.31 J.

(b) Eq. 7-10 (along with Eq. 7-1) then leads to

$$v = \sqrt{2(1.31 \text{ J})/(3.00 \text{ kg})} = 0.935 \text{ m/s}.$$

•25 In Fig. 7-11, we must apply a force of magnitude 80 N to hold the block stationary at $x = -2.0$ cm. From that position, we then slowly move the block so that our force does +4.0 J of work on the spring–block system; the block is then again stationary. What is the block's position? (*Hint:* There are two answers.)

25. We make use of Eq. 7-25 and Eq. 7-28 since the block is stationary before and after the displacement. The work done by the applied force can be written as

$$W_a = -W_s = \frac{1}{2}k(x_f^2 - x_i^2).$$

The spring constant is $k = (80\text{ N})/(2.0\text{ cm}) = 4.0\times10^3\text{N/m}$. With $W_a = 4.0\text{ J}$, and $x_i = -2.0\text{ cm}$, we have

$$x_f = \pm\sqrt{\frac{2W_a}{k} + x_i^2} = \pm\sqrt{\frac{2(4.0\text{ J})}{(4.0\times10^3\text{ N/m})} + (-0.020\text{ m})^2} = \pm0.049\text{ m} = \pm4.9\text{ cm}.$$

••29 The only force acting on a 2.0 kg body as it moves along a positive x axis has an x component $F_x = -6x$ N, with x in meters. The velocity of the body at $x = 3.0$ m is 8.0 m/s. (a) What is the velocity of the body at $x = 4.0$ m? (b) At what positive value of x will the body have a velocity of 5.0 m/s? SSM ILW WWW

29. (a) As the body moves along the x axis from $x_i = 3.0$ m to $x_f = 4.0$ m the work done by the force is

$$W = \int_{x_i}^{x_f} F_x \, dx = \int_{x_i}^{x_f} -6x \, dx = -3(x_f^2 - x_i^2) = -3\,(4.0^2 - 3.0^2) = -21 \text{ J}.$$

According to the work-kinetic energy theorem, this gives the change in the kinetic energy:

$$W = \Delta K = \frac{1}{2}m\left(v_f^2 - v_i^2\right)$$

where v_i is the initial velocity (at x_i) and v_f is the final velocity (at x_f). The theorem yields

$$v_f = \sqrt{\frac{2W}{m} + v_i^2} = \sqrt{\frac{2(-21)}{2.0} + (8.0)^2} = 6.6 \text{ m/s}.$$

(b) The velocity of the particle is $v_f = 5.0$ m/s when it is at $x = x_f$. The work-kinetic energy theorem is used to solve for x_f. The net work done on the particle is $W = -3\left(x_f^2 - x_i^2\right)$, so the theorem leads to

$$-3\left(x_f^2 - x_i^2\right) = \frac{1}{2}m\,\left(v_f^2 - v_i^2\right).$$

Thus,

$$x_f = \sqrt{-\frac{m}{6}\left(v_f^2 - v_i^2\right) + x_i^2} = \sqrt{-\frac{2.0 \text{ kg}}{6 \text{ N/m}}\left((5.0 \text{ m/s})^2 - (8.0 \text{ m/s})^2\right) + (3.0 \text{ m})^2} = 4.7 \text{ m}.$$

•41 A 100 kg block is pulled at a constant speed of 5.0 m/s across a horizontal floor by an applied force of 122 N directed 37° above the horizontal. What is the rate at which the force does work on the block? SSM ILW

41. The power associated with force $\vec{F}$ is given by $P = \vec{F} \cdot \vec{v}$, where $\vec{v}$ is the velocity of the object on which the force acts. Thus,

$$P = \vec{F} \cdot \vec{v} = Fv\cos\phi = (122\ \text{N})(5.0\ \text{m/s})\cos 37° = 4.9\times 10^2\ \text{W}.$$

73 An elevator cab has a mass of 4500 kg and can carry a maximum load of 1800 kg. If the cab is moving upward at full load at 3.80 m/s, what power is required of the force moving the cab to maintain that speed?

73. A convenient approach is provided by Eq. 7-48.

$$P = F\,v = (1800\text{ kg} + 4500\text{ kg})(9.8\text{ m/s}^2)(3.80\text{ m/s}) = 235\text{ kW}.$$

Note that we have set the applied force equal to the weight in order to maintain constant velocity (zero acceleration).