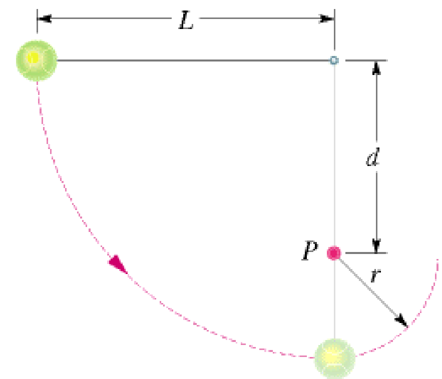
PHYSICS 1401 (1) homework solutions

8-23 The string in Fig. 8-35 is L = 120 cm long, has a ball attached to one end, and is fixed at its other end. The distance d to the fixed peg at point P is 75.0 cm. When the initially stationary ball is released with the string horizontal as shown, it will swing along the dashed arc. What is its speed when it reaches

(a) its lowest point and
(b) its highest point after the string catches on the peg?



8-23

(a) $\Delta U = \Delta K$ so $mgL = \frac{1}{2}mv_0^2$

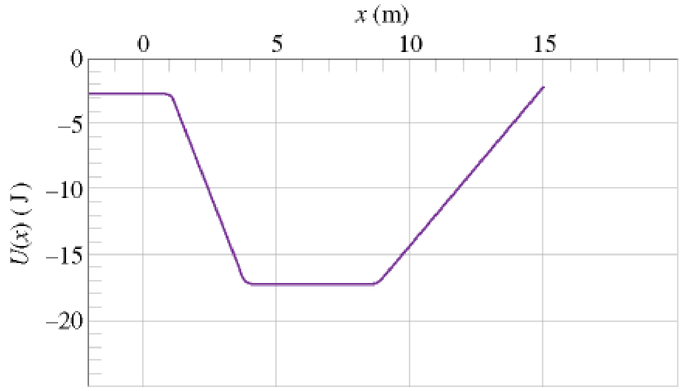
since the ball has traversed vertical height, L, and acquired speed, v_0

$$v_0 = \sqrt{2gL} = \sqrt{2(9.8)(1.20)} = 4.85 \text{ m/s}$$

(b) After the string catches on the peg, it rises a distance of 2r. Hence, at that point it is a vertical distance of L−2r from where it started. Its velocity can be obtained from conservation of energy

Note:
$r = L - d$
$r = 1.20 - 0.75$
$r = 0.45$ m

$$\Delta U = \Delta K$$
$$mg(L-2r) = \frac{1}{2}mv_1^2$$
$$v_1 = \sqrt{2g(L-2r)} = \sqrt{2(9.8)(1.20-0.90)}$$
$$v_1 = 2.42 \text{ m/s}$$

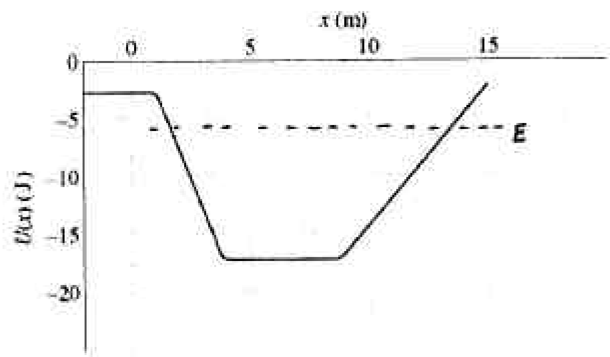


8-36 A conservative force F(x) acts on a 2.0 kg particle that moves along the x axis. The potential energy U(x) associated with F(x) is graphed in Fig. 8-43 . When the particle is at x = 2.0 m, its velocity is -1.5 m/s.

(a) What are the magnitude and direction of F(x) at this position?
(b) Between what limits of x does the particle move?
(c) What is its speed at x = 7.0 m?

8-36 $m = 2.0\,kg$

At $x = 2.0\,m$
$v = -1.5\,m/s$



(a) The potential energy is linear between $x = 1.0\,m$ and $x = 4.0\,m$. Reading from graph

$$F_x = -\frac{dU}{dx} = -\frac{\Delta U}{\Delta x} =$$

$$= \frac{U_4 - U_1}{4-1} = -\frac{-17.4 - (-2.7)}{3}$$

$$F_x = +\frac{14.7}{3} = 4.9 \text{ Newton}$$

(in +x direction)

(b) At $x = 2.0\,m$, $U = -8.0$ Joule (reading from graph)
$K = +\frac{1}{2}mv^2 = \frac{1}{2}(2.0)(1.5)^2 = 2.3$ Joule

so $E = U + K = -8.0 + 2.3 = -5.8$ Joules

This energy is sketched on graph. The range of possible values are between the intersections of E-level with U-graph
$1.5 < x < 13.7\,m$ (outside this $v^2 < 0$!)

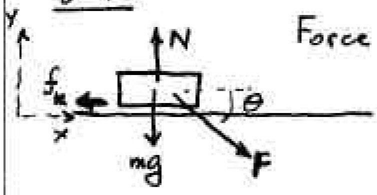
(c) At $x = 7.0\,m$, $U = -17$ Joules, so $K = E - U = -5.8 - (-17) = 11.2$ Joules

$$v = \sqrt{\frac{2K}{m}} = \sqrt{\frac{2(11.2)}{2.0}} = 3.4\,m/s$$

8-42 A worker pushed a 27 kg block 9.2 m along a level floor at constant speed with a force directed 32° below the horizontal. If the coefficient of kinetic friction between block and floor was 0.20, what were

(a) the work done by the worker's force and
(b) the increase in thermal energy of the block–floor system?

8-42



Force diagram illustrating the problem

$m = 27$ kg
$\theta = 32°$
$\mu_k = 0.20$

(a) To find the work done by F over a horizontal distance of $d = 9.2$ m, we must first find $\vec{F}$

Balance x and y force components

$$N - mg - F\sin\theta = 0 \qquad \text{(no motion in y)}$$

$$f_k = F\cos\theta \qquad \text{(constant speed in x)}$$

$$\mu_k N = F\cos\theta$$

Solve y-equation for N and insert into

$$\mu_k(mg + F\sin\theta) = F\cos\theta$$

Solve for F

$$F\left[\cos\theta - \mu_k\sin\theta\right] = \mu_k mg$$

$$F = \frac{\mu_k mg}{\cos\theta - \mu_k\sin\theta} = \frac{(0.2)(27)(9.8)}{.848 - (0.2)(.530)}$$

$$F = 71.3 \text{ Newton}$$

(b) The increase in thermal energy at the block-floor interface is equal to the work done against friction

$$W_k = f_k d = (F\cos\theta)d$$

$$W_k = (71.3)(\cos 32°)(9.2)$$

$$W_k = 556 \text{ Joules}$$

PHYSICS 1401 (1) homework solutions

8-48 Approximately 5.5×10^6 kg of water fall 50 m over Niagara Falls each second.

(a) What is the decrease in the gravitational potential energy of the water–Earth system each second?

(b) If all this energy could be converted to electrical energy (it cannot be), at what rate would electrical energy be supplied? (The mass of 1 m^3 of water is 1000 kg.)

(c) If the electrical energy were sold at 1 cent/kW·h, what would be the yearly cost?

8-48 If a mass of water $\Delta m = 5.5 \times 10^6$ kg falls $50\,m = h$

(a) down Niagara Falls each second, then the potential energy is decreased by

$$\Delta U = (\Delta m) g h = (5.5\times10^6)(9.8)(50)$$

$$\Delta U = 2.70 \times 10^9 \text{ J} \quad \text{each second}$$

[The power lost is

$$P = \frac{\Delta W}{\Delta t} = \frac{\Delta U}{\Delta t} = \frac{2.70\times10^9 \text{ J}}{1 \text{ sec}} = 2.7\times10^9 \text{ Watts}$$]

(b) If, instead of just falling, the water is used to rotate generators that generate electricity with 100% efficiency (unlikely!), then

$$P = 2.7\times10^9 \text{ Watts}$$

(C) For a sale of \$.01/kW-hr (more than factor 10 lower than consumers pay!)

$$\text{Cost} = .01 \frac{\$}{10^3 \text{ W-hr}} \times 2.7\times10^9 \text{ W} \times \left(1 \text{ year} \times \frac{365 \text{ days}}{1 \text{ year}} \times 24 \frac{\text{hr}}{\text{day}}\right)$$

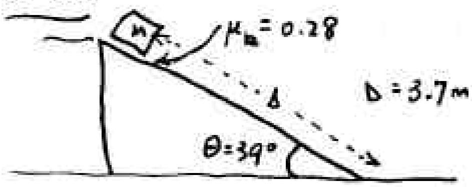
$$\text{Cost} = 2.36 \times 10^8 \text{ \$}$$

[$\sim \frac{1}{4}$ billion dollars => no wonder California is in trouble!
No Niagara Falls!]

8-58 A factory worker accidentally releases a 180 kg crate that was being held at rest at the top of a 3.7 m-long-ramp inclined at 39° to the horizontal. The coefficient of kinetic friction between the crate and the ramp, and between the crate and the horizontal factory floor, is 0.28.

(a) How fast is the crate moving as it reaches the bottom of the ramp?
(b) How far will it subsequently slide across the factory floor? (Assume that the crate's kinetic energy does not change as it moves from the ramp onto the floor.)
(c) Do the answers to (a) and (b) increase, decrease, or remain the same if we halve the mass of the crate?

8-58



(This could be done with forces. We will use the ideas from ch 8.)

(a) Kinetic energy at bottom is

$$K = U_{top} + W_{friction}$$

where $U_{top} = mgD\sin\theta$ = potential energy at top

Forces:

$$W_{friction} = -f_k D$$

where $f_k = \mu_k N = \mu_k mg\cos\theta$

so $W_{friction} = -\mu_k mgD\cos\theta$

Hence $K = mgD(\sin\theta - \mu_k\cos\theta) = \frac{1}{2}mv^2$ where v = speed at bottom of ramp

Solving $v = \sqrt{2gD(\sin\theta - \mu_k\cos\theta)}$

$$v = \sqrt{2(9.8)(3.7)[\sin 39° - (0.28)\cos 39°]}$$

So $v = 5.46$ m/s

(b) It will slide a distance such that all its kinetic energy has been used up by the friction force. Assuming the same $\mu_k = 0.28$ as on the ramp and Noting that $N = mg$

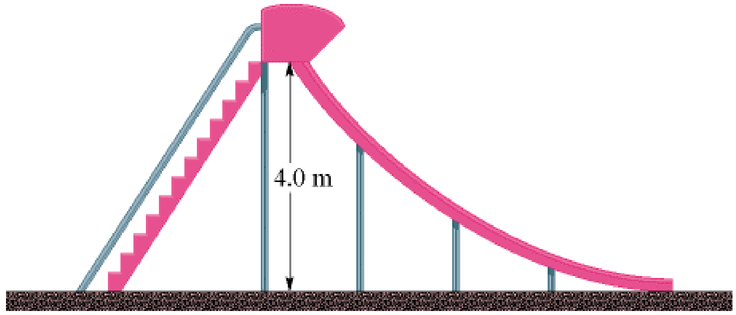
then $\frac{1}{2}\cancel{m}v^2 = f_k' D' = \mu_k \cancel{m} g D'$

$$D' = \frac{v^2}{2\mu_k g} = \frac{(5.46)^2}{2(0.28)(9.8)}$$

$D' = 5.43$ meters

(c) Note that all the above answers (for v and for D') result for expressions in which the mass, m, cancels. (This is a consequence of the dependence $f_k = \mu_k N$) Hence, we get the same answer for any mass of the crate.

PHYSICS 1401 (1) homework solutions

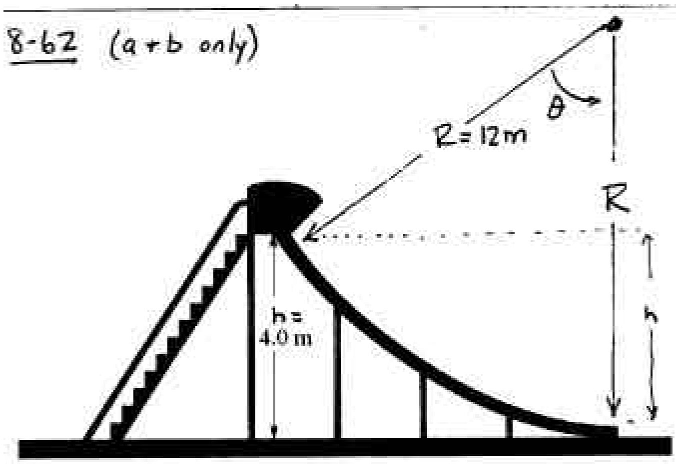


8-62 A playground slide is in the form of an arc of a circle with a maximum height of 4.0 m, with a radius of 12 m, and with the ground tangent to the circle (Fig. 8-49). A 25 kg child starts from rest at the top of the slide and has a speed of 6.2 m/s at the bottom.

(a) What is the length of the slide?

(b) What average frictional force acts on the child over this distance?

8-62 (a+b only)



(a) Note geometry of the slide, which forms the arc of a circle (radius R) and subtending angle, θ.

From plane geometry $h = R - R\cos\theta$

So the arc is $\theta = \arccos\left[\frac{R-h}{R}\right] = \arccos\left[\frac{12-4}{12}\right] = \arccos(.667)$

$\theta = 48.2° = 0.841$ rad

and the length (ℓ) of the arc at the slide is

$\ell = R\theta = (12)(0.841) = 10.1$ meters

(b) The energies: $U = K + W$ where K = kinetic energy at bottom, W = work done by friction

$mgh = \frac{1}{2}mv^2 + f\ell$ where f = average friction force down slide

$f = \frac{m}{\ell}\left[gh - \frac{1}{2}v^2\right] = \frac{25}{10.1}\left[(9.8)(4.0) - \frac{1}{2}(6.2)^2\right] = 49.5$ N