Chapter 8

1. A 5.00-kg block is set into motion up an inclined plane with an initial speed of v_i = 8.00 m/s (Fig. P8.23). The block comes to rest after traveling d = 3.00 m along the plane, which is inclined at an angle of θ = 30.0° to the horizontal. For this motion, determine (a) the change in the block's kinetic energy, (b) the change in the potential energy of the block-Earth system, and (c) the friction force exerted on the block (assumed to be constant). (d) What is the coefficient of kinetic friction?

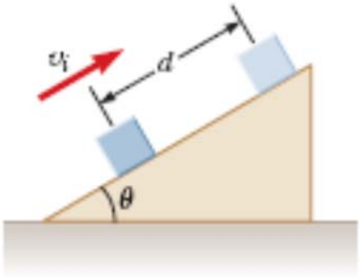


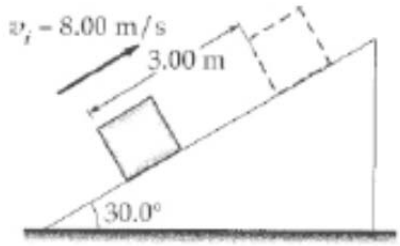
Figure P8.23

Ans:

We consider the block-plane-planet system between an initial point just after the block has been given its shove and a final point when the block comes to rest.

(a) The change in kinetic energy is

$$\Delta K = K_f - K_i = \frac{1}{2}mv_f^2 - \frac{1}{2}mv_i^2$$
$$= 0 - \frac{1}{2}(5.00 \text{ kg})(8.00 \text{ m/s})^2 = \boxed{-160 \text{ J}}$$



ANS. FIG. P8.23

(b) The change in gravitational potential energy is

$$\Delta U = U_f - U_i = mgh$$
$$= (5.00 \text{ kg})(9.80 \text{ m/s}^2)(3.00 \text{ m})\sin 30.0° = \boxed{73.5 \text{ J}}$$

(c) The nonisolated system energy model we write as

$$\Delta K + \Delta U = \sum W_{\text{other forces}} - f_k d = 0 - f_k d$$

The force of friction is the only unknown, so we may find it from

$$f_k \frac{\Delta K - \Delta U}{d} = \frac{+160 \text{ J} - 73.5 \text{ J}}{3.00 \text{ m}} = \boxed{28.8 \text{ N}}$$

(d) The forces perpendicular to the incline must add to zero.

$$\sum F_y = 0: \qquad +n - mg\cos 30.0^\circ = 0$$

Evaluating,

$$n = mg\cos 30.0^\circ = (5.00 \text{ kg})\left(9.80 \text{ m/s}^2\right)\cos 30.0^\circ = 42.4 \text{ N}$$

Now $f_k = \mu_k n$ gives

$$\mu_k = \frac{f_k}{n} = \frac{28.8 \text{ N}}{42.4 \text{ N}} = \boxed{0.679}$$

2. An older-model car accelerates from 0 to speed υ in a time interval of Δt. A newer, more powerful sports car accelerates from 0 to 2υ in the same time period. Assuming the energy coming from the engine appears only as kinetic energy of the cars, compare the power of the two cars.

Ans:

$$P = \frac{\text{W}}{\Delta t}$$

older-model: $W = \frac{1}{2} m\upsilon^2$

newer-model: $W = \frac{1}{2} m(2\upsilon)^2 = \frac{1}{2}\left(4m\upsilon^2\right) \rightarrow P_{\text{newer}} = \frac{4m\upsilon^2}{2\Delta t} = 4\frac{m\upsilon^2}{2\Delta t}$

$\boxed{\text{The power of the sports car is four times that of the older-model car.}}$

Chapter 9.

1. An object has a kinetic energy of 275 J and a momentum of magnitude 25.0 kg · m/s.

   Find the speed and mass of the object.

Ans:

$K = p^2 / 2m$, and hence, $p = \sqrt{2mK}$. Thus,

$$m = \frac{p^2}{2 \cdot K} = \frac{(25.0\,\text{kg} \cdot \text{m/s})^2}{2(275\text{ J})} = \boxed{1.14\,\text{kg}}$$

and

$$\upsilon = \frac{p}{m} = \frac{\sqrt{2m(K)}}{m} = \sqrt{\frac{2(K)}{m}} = \sqrt{\frac{2(275\,\text{J})}{1.14\,\text{kg}}} = \boxed{22.0\,\text{m/s}}$$

2. When you jump straight up as high as you can, what is the order of magnitude of the maximum recoil speed that you give to the Earth? Model the Earth as a perfectly solid object. In your solution, state the physical quantities you take as data and the values you measure or estimate for them.

Ans:

I have mass 72.0 kg and can jump to raise my center of gravity 25.0 cm. I leave the ground with speed given by

$$\upsilon_f^2 - \upsilon_i^2 = 2a(x_f - x_i) \quad 0 - \upsilon_i^2 = 2(-9.80\,\text{m/s}^2)(0.250\text{ m})$$
$$\upsilon_i = 2.20\,\text{m/s}$$

Total momentum of the system of the Earth and me is conserved as I push the planet down and myself up:

$$0 = (5.98 \times 10^{24}\,\text{kg})(-\upsilon_e) + (85.0\text{ kg})(2.20\text{ m/s})$$
$$\upsilon_e \sim \boxed{10^{-23}\,\text{m/s}}$$

3. The front 1.20 m of a 1 400-kg car is designed as a "crumple zone" that collapses to absorb the shock of a collision. If a car traveling 25.0 m/s stops uniformly in 1.20 m, (a) how long does the collision last, (b) what is the magnitude of the average force on the car, and (c) what is the acceleration of the car? Express the acceleration as a multiple of the acceleration due to gravity.

Ans:

(a) From the kinematic equations,

$$\Delta t = \frac{\Delta x}{\upsilon_{\text{avg}}} = \frac{2\Delta x}{\upsilon_f + \upsilon_i} = \frac{2(1.20\,\text{m})}{0 + 25.0\,\text{m/s}} = \boxed{9.60 \times 10^{-2}\,\text{s}}$$

(b) We find the average force from the momentum-impulse theorem:

$$F_{\text{avg}} = \frac{\Delta p}{\Delta t} = \frac{m\Delta\upsilon}{\Delta t} = \frac{(1\,400\,\text{kg})(25.0\,\text{m/s} - 0)}{9.60 \times 10^{-2}\,\text{s}} = \boxed{3.65 \times 10^{5}\,\text{N}}$$

(c) Using the particle under constant acceleration model,

$$a_{\text{avg}} = \frac{\Delta\upsilon}{\Delta t} \frac{25.0\,\text{m/s} - 0}{9.60 \times 10^{-2}\,\text{s}} = (260\,\text{m/s}^2)\left(\frac{1g}{9.80\,\text{m/s}^2}\right) = \boxed{26.5g}$$

4. A railroad car of mass 2.50×10^4 kg is moving with a speed of 4.00 m/s. It collides and couples with three other coupled railroad cars, each of the same mass as the single car and moving in the same direction with an initial speed of 2.00 m/s. (a) What is the speed of the four cars after the collision? (b) How much mechanical energy is lost in the collision?

Ans:

(a) We write the law of conservation of momentum as

$$m\upsilon_{1i} + 3m\upsilon_{2i} = 4m\upsilon_f$$

or $$\upsilon_f = \frac{4.00\,\text{m/s} + 3(2.00\,\text{m/s})}{4} = \boxed{2.50\text{ m/s}}$$

(b) $$K_f - K_i = \frac{1}{2}(4m)\upsilon_f^2 - \left[\frac{1}{2}m\upsilon_{1i}^2 + \frac{1}{2}(3m)\upsilon_{2i}^2\right]$$

$$= \frac{1}{2}(2.50\times10^4\text{ kg})\Big[4(2.50\text{ m/s})^2 - (4.00\text{ m/s})^2 - 3(2.00\text{ m/s})^2\Big]$$

$$= \boxed{-3.75\times10^4\,\text{J}}$$

5. Four objects are situated along the y axis as follows: a 2.00-kg object is at +3.00 m, a 3.00-kg object is at +2.50 m, a 2.50-kg object is at the origin, and a 4.00-kg object is at − 0.500 m. Where is the center of mass of these objects?

Ans:

The x coordinate of the center of mass is

$$x_{\text{CM}} = \frac{\Sigma m_i x_i}{\Sigma m_i} = \frac{0+0+0+0}{2.00\,\text{kg} + 3.00\,\text{kg} + 2.50\,\text{kg} + 4.00\,\text{kg}} = 0$$

and the y coordinate of the center of mass is

$$y_{\text{CM}} = \frac{\Sigma m_i y_i}{\Sigma m_i}$$

$$= \left(\frac{1}{2.00\,\text{kg} + 3.00\,\text{kg} + 2.50\,\text{kg} + 4.00\,\text{kg}} \right)$$

$$\times [(2.00\,\text{kg})(3.00\,\text{m}) + (3.00\,\text{kg})(2.50\,\text{m})$$

$$+ (2.50\,\text{kg})(0) + (4.00\,\text{kg})(-500\,\text{m})$$

$$y_{\text{CM}} = 1.00\,\text{m}$$

Then $\boxed{\vec{\text{r}}_{\text{CM}} = (0\hat{\mathbf{i}} + 1.00\hat{\mathbf{j}})\,\text{m}}$