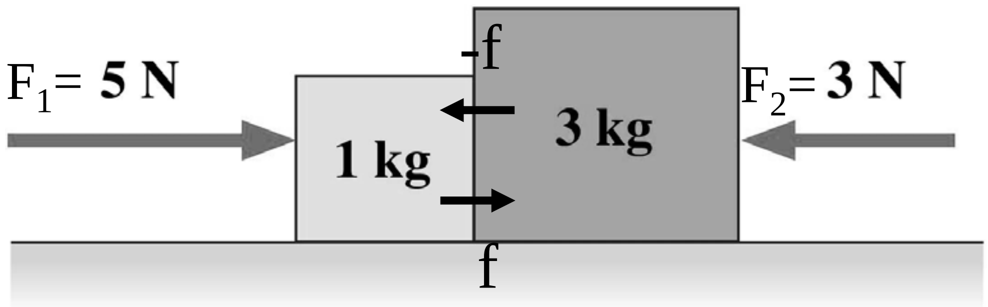
Physics 123/5

- You can find this lecture note at
  http://www.phys.uconn.edu/~kjoo/p123-5-Lecture1.pdf

- If you have any question about this lecture, contact me at
  kjoo@phys.uconn.edu

Got it "4.5"

The figure shows two blocks with two forces acting on the pair. What is the net force on the larger block?



$$F_{net} = F_1 - F_2 = 5 - 3 = 2N$$

$$F_{net} = (m_1 + m_2)a$$

$$a = 0.5\,\mathrm{m/s}^2$$

$$\left(F_1\right)_{net} = f - F_2 \qquad m_1 a = f - F_2 \qquad 3\,\mathrm{x}\,0.5 = f - 3$$

$$f = 4.5\ N \qquad \left(F_1\right)_{net} = 4.5 - 3 = 1.5\ N$$

Excercise 4.28

A 50-kg parachute jumper descends at a steady 40 km/h. What is the force of air on the parachute?

A steady descent means that the vertical acceleration is zero. From Newton's second law, the vertical net force is also zero. The force of gravity (equal to the weight of the parachutist) and the force of the air are the only vertical forces acting, so (with positive upward).

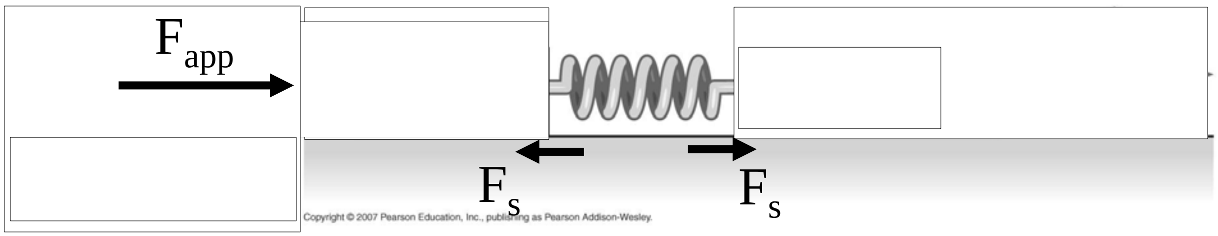
$$F_{\text{air}} - w = 0,$$

or

$$F_{\text{air}} = (50\ \text{kg})(9.8\ \text{m/s}^2) = 490\ \text{N}.$$

Excercise 4.52

Two large crates, with masses 640 kg and 490 kg, are connected by a stiff, massless spring (k=8.1 kN/m) and propelled along essentially frictionless, level factory floor by a force applied horizontally to the more massive crate. If the spring compresses 5.1 cm from its equilibrium length, what is the applied force?



The equations of motion (Newton's second law) for the two crates are the same as those of the masses in the previous problem, namely

$$F_{app} - F_s = Ma$$ (for the larger block) and

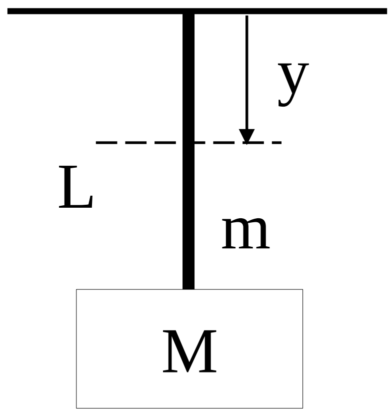
$$F_s = ma$$ (for the smaller block). The magnitude of the compression in the spring is still given by Hooke's law,

$$F_s = k\,|x|.$$ Thus,

$$F_{app} = F_s(1 + M/m) = k\,|x|\,(1 + M/m) = (8.1\ \text{kN/m})(0.051\ \text{m}) \times (1 + 640/490) = 953\ \text{N}.$$

Excercise 4.66

A block of mass M hangs from a rope of length L and mass m. Find an expression for the tension in the rope as a function of the distance y measured vertically downward from the top of the rope.



The length of rope below *y* is

$$L - y.$$

Find the mass of rope below y:

$$m_{\text{below}} = \tfrac{m}{L}(L - y).$$

Add the mass *M* at the end, and multiply by *g*:

$$T = \left[\frac{m}{L}(L - y) + M\right]g$$

Excercise 4.67

The general form of Newton's second law is $F = \frac{dp}{dt}$,

and relativistic momentum is $p = \frac{mu}{\sqrt{1-\frac{u^2}{c^2}}}$.

Acceleration is $a = \frac{du}{dt}$.

We'll start by substituting the relativistic momentum into the force law and taking the derivative.

$$F = \frac{dp}{dt} = \frac{d}{dt}\left[\frac{mu}{\sqrt{1-\frac{u^2}{c^2}}}\right] = \frac{m}{\sqrt{1-\frac{u^2}{c^2}}}\left(\frac{du}{dt}\right) - \frac{1}{2}\frac{mu}{\left(1-\frac{u^2}{c^2}\right)^{\frac{3}{2}}}\left(-2\frac{u}{c^2}\right)\left(\frac{du}{dt}\right)$$

$$F = \frac{m}{\left(1-\frac{u^2}{c^2}\right)^{\frac{1}{2}}}(a) + \frac{m}{\left(1-\frac{u^2}{c^2}\right)^{\frac{3}{2}}}\left(\frac{u^2}{c^2}\right)(a)$$

$$F = m\left[\frac{\left(1-\frac{u^2}{c^2}\right)+\frac{u^2}{c^2}}{\left(1-\frac{u^2}{c^2}\right)^{\frac{3}{2}}}\right]a = m\left[\frac{1}{\left(1-\frac{u^2}{c^2}\right)^{\frac{3}{2}}}\right]a$$

Excercise 4.67

As if the mass has increased this factor

$$F = m\left[\frac{1}{\left(1-\frac{u^2}{c^2}\right)^{\frac{3}{2}}}\right]a$$

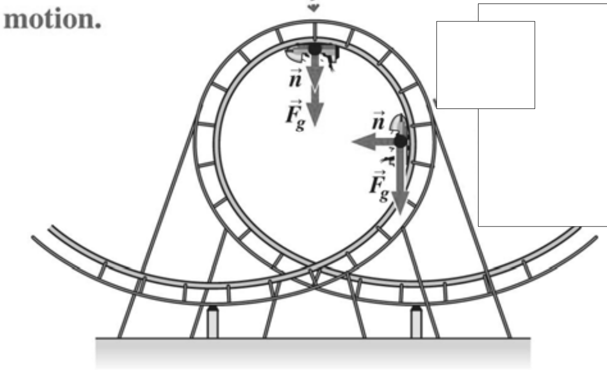
$$\frac{u^2}{c^2} \approx 0 \rightarrow F \approx ma,$$

so we can continue to use the equation F=ma (Newton's Law) as long as our speeds stay "slow."

Excercise 5.38

(a) As shown in Example 5.7, at the top of the loop,

$$n + mg = mv^2/r, \qquad \text{so}$$



$$n = (60\text{ kg})[-9.8\text{ m/s}^2 + (9.7\text{ m/s})^2/6.3\text{ m}] = 308\text{ N}$$

(b) Actually, 308 N is the difference between the normal force of the seat and the force exerted by the seatbelt, i.e.,

$$n = 308\text{ N} + F_{\text{belt}}.$$

The seatbelt, firmly adjusted, perhaps adds a few pounds

(1 lb = 4.45 N),

(c) The seatbelt is required in case of accidents.
it is not needed to contribute to the centripetal force, but it will provide a feeling of the security.

Excercise 5.46

The coefficient of static friction between steel train wheels and Steel rails is 0.58. The engineer of a train moving at 140 km/h spots a stalled car on the tracks 150 m ahead. If he applies the brakes so that the wheels don't slip, will the train stop in time?

When stopping on a level track, the maximum acceleration due to friction is

$$a = -\mu_s g,$$

The minimum stopping distance from an initial speed of (140/3.6) m/s

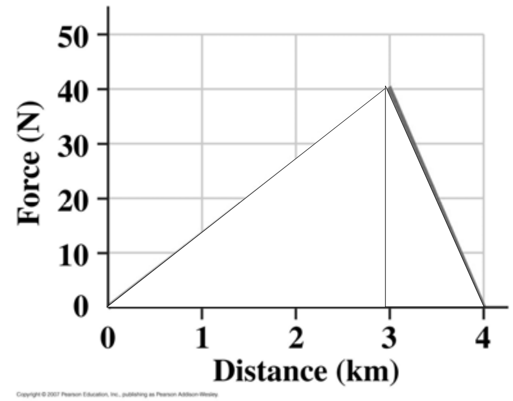
is

$$\Delta x = v_0^2/(-2a) = (38.9 \text{ m/s})^2/\ (2 \times 0.58 \times 9.8 \text{ m/s}^2) = 133\text{m}.$$

With split-second timing, an accident could be averted.

Excercise 6.22

Find the total work done by the force shown in the figure as the object on which it acts on moves (a) from x=0 to x=3 km and (b) from x=3 km to x=4 km.



$$W = \int_{x_1}^{x_2} F(x)\,dx.$$

$F(x)$ is a linear function in the two intervals specified:

Use the slope/intercept equation for a straight line

$$F(x) = \begin{cases} (40\text{ N}/3\text{ km})x, & \text{for } 0 \le x \le 3\text{ km} \\ 40\text{ N} - (40\text{ N/km})(x - 3\text{ km}), & \text{for } 3\text{ km} \le x \le 4\text{ km} \end{cases}$$

$$y = mx + b,$$

(a)

$$W_{0\to 3} = \int_0^{3km} \left(\frac{40\text{ N}}{3\text{ km}}\right) x\,dx = \left(\frac{40\text{ N}}{3\text{ km}}\right)\frac{(3\text{ km})^2}{2} = 60\text{ kJ},$$

(b)

$$W_{3\to 4} = \int_{3\text{ km}}^{4\text{ km}} \left(\frac{40\text{ N}}{\text{km}}\right)(4\text{ km} - x)\,dx = \left(\frac{40\text{ N}}{\text{km}}\right)\left|(4\text{ km})x - \frac{x^2}{2}\right|_{3\text{ km}}^{4\text{ km}} = 20\text{ kJ},$$

Of course, the triangular areas under the force vs distance curve could have been calculated in one's head; however, it's instructive to understand the general method.

After a tornado, a 0.50-g drinking straw was found embedded 4.5 cm in a tree. Subsequent measurements showed that the tree would exert a stopping force of 70N on the straw. What was the straw's speed when it hit the tree?

Since the stopping force (70 N) is so much larger than the weight of the straw (0.0049 N), we may assume that the net work done is essentially that done by just the stopping force, and use the work-energy theorem,

$$W_{\text{net}} = \Delta K.$$

The force is opposite to the displacement, so $-F\Delta r = 0 - \frac{1}{2}mv^2,$

or $v = \sqrt{2F\Delta r/m} = \sqrt{2(70\text{ N})(0.045\text{ m})/0.5\times10^{-3}\text{ kg}} = 112\text{ m/s } (\sim 250\text{ mi/h}).$

Excercise 6.30

A force is given by $F = a\sqrt{x}$. acts in the x direction, where A=9.5 N/m$^{1/2}$. Calculate the work done by this force acting on an object as it moves (a) from x=0 to x=3m; (b) from 3m to 6m; and (c) from 6m to 9m.

Since we are dealing with a varying force $F(x)$,

we need to integrate $W = \int_{x_1}^{x_2} F\,dx$

With $F = a\sqrt{x}$, we obtain $W_{x_1 \to x_2} = \int_{x_1}^{x_2} a x^{1/2} dx =$

(a) $W_{0\to 3} = \frac{2}{3}(9.5\ \text{N/m}^{1/2})(3\ \text{m})^{3/2} = 32.9\ \text{J}$

(b) $W_{3\to 6} = \frac{2}{3}(9.5\ \text{N/m}^{1/2})[(6\ \text{m})^{3/2} - (3\ \text{m})^{3/2}] = 60.2\ \text{J}$

(c) $W_{6\to 9} = \frac{2}{3}(9.5\ \text{N/m}^{1/2})[(9\ \text{m})^{3/2} - (6\ \text{m})^{3/2}] = 77.9\ \text{J}$

Excercise 6.71

A machine delivers power at a decreasing rate $P = P_0 t_0^2/(t+t_0)^2$, where P_0 and t_0 are constant. The machine starts at t=0 and runs Forever. Show that it nevertheless does only a finite amount of work equal to $P_0 t_0$.

To find the work done in a given time interval, we need to integrate:

$$W = \int_{t_1}^{t_2} P\,dt.$$

With $P = P_0 t_0^2/(t+t_0)^2$, we obtain

$$W = \int_0^{\infty} \frac{P_0 t_0^2}{(t+t_0)^2}\,dt = P_0 t_0^2 \int_0^{\infty} \frac{dt}{(t+t_0)^2} =$$