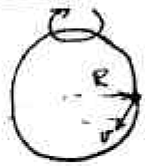
PHYSICS 1401 (1) homework solutions

4-50 When a large star becomes a supernova, its core may be compressed so tightly that it becomes a neutron star, with a radius of about 20 km (about the size of the San Francisco area). If a neutron star rotates once every second,

(a) what is the speed of a particle on the star's equator and
(b) what is the magnitude of the particle's centripetal acceleration?
(c) If the neutron star rotates faster, do the answers to (a) and (b) increase, decrease, or remain the same?

4-50



(a) A point on the surface at the equator travels one circumference $= 2\pi R$ in one period $= T$

Hence, the speed is $v = \dfrac{2\pi R}{T} = 2\pi \dfrac{20\ \text{km}}{1.0\ \text{s}} \times \dfrac{10^3\ \text{m}}{1\ \text{km}}$

$v = 1.26 \times 10^5\ \text{m/s}$

(b) Centripetal acceleration

$$a = \frac{v^2}{R} = \frac{(1.26\times10^5\ \text{m/s})^2}{20\times10^3\ \text{m}} = 7.90\times10^5\ \text{m/s}^2$$

(about 100,000 × bigger than |g|)

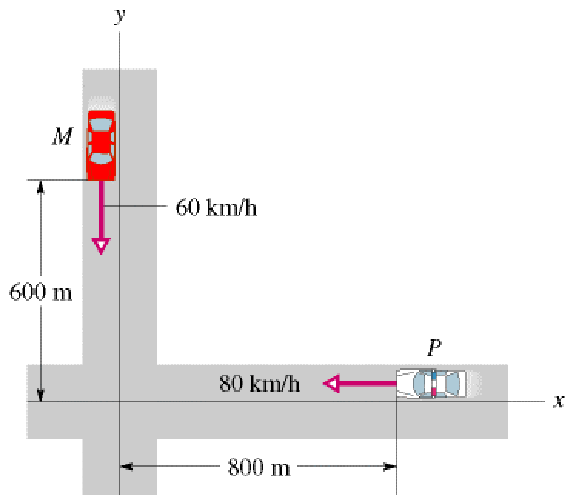
(c) Since rotating faster means T is shorter (smaller)

and $v \propto \frac{1}{T}$ v gets bigger (increase)

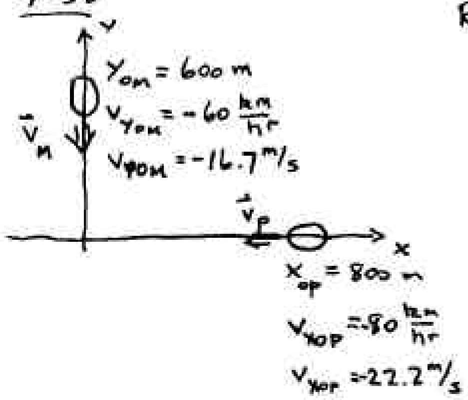
and $a \propto v^2$ a gets even bigger (increase)

4-58 Two highways intersect as shown in Fig. 4-38 . At the instant shown, a police car P is 800 m from the intersection and moving at 80 km/h. Motorist M is 600 m from the intersection and moving at 60 km/h.

(a) In unit-vector notation, what is the velocity of the motorist with respect to the police car?
(b) For the instant shown in Fig. 4-38 ,how does the direction of the velocity found in (a) compare to the line of sight between the two cars?
(c) If the cars maintain their velocities, do the answers to (a) and (b) change as the cars move nearer the intersection?



4-58



Relative to the fixed xy system, the velocities are

$$\vec{v}_M = +v_{yom}\,\hat{j} = -16.7\,\hat{j}\ m/s$$

$$\vec{v}_P = +v_{xop}\,\hat{i} = -22.2\,\hat{i}\ m/s$$

(a) Relative velocity (M rel. to P)

$$\vec{V}_{MP} = \vec{V}_M - \vec{V}_P$$

$$\vec{V}_{MP} = -16.7\,\hat{j} + 22.2\,\hat{i}$$

(b) Relative position (M rel to P)

$$\vec{r}_{MP} = \vec{r}_M - \vec{r}_P = 600\,\hat{j} - 800\,\hat{i}$$

(c) Clearly $\vec{V}_{MP}$ stays fixed with time (since components are constant)

Note $\vec{V}_{MP} = 22.2\,(\hat{i} - 0.75\,\hat{j})$

$\vec{r}_{MP} = -800\,(\hat{i} - 0.75\,\hat{j})$ (Vectors are opposite in direction)

Since $\vec{R}_{MP}(t) = \vec{r}_{MP} + \vec{V}_{MP}\,t = -800\,(\hat{i} - 0.75\,\hat{j})\left(1 - \frac{22.2}{800}t\right)$

general position

so the direction of $\vec{r}_{MP}$ stays same until $t = \frac{800\ m}{22.2\ m/s} = 36.0$ seconds

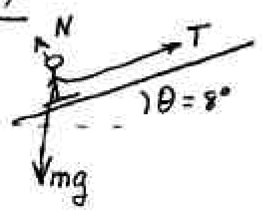
when direction of $\vec{R}_{MP}$ reverses.

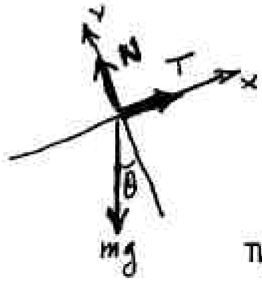
(Actually, of course, they collide at the origin unless somebody blinks!)

5-24 A 50 kg skier is pulled up a frictionless ski slope that makes an angle of 8.0° with the horizontal by holding onto a tow rope that moves parallel to the slope. Determine the magnitude of the force of the rope on the skier at an instant when

(a) the rope is moving with a constant speed of 2.0 m/s and
(b) the rope is moving with a speed of 2.0 m/s but that speed is increasing at a rate of 0.10 m/s^2.

5-24





Force diagram: N = normal force
mg = weight
T = tension in rope
T = force pulling skier
These are the only forces on skier

(a) If skier is moving at constant speed, he is not accelerating. Hence Newton's 2nd Law says that

$$\sum F = ma = 0$$

$$\vec{T} + m\vec{g} + \vec{N} = 0$$

Resolving along x and y

$$\left.\begin{aligned} T - mg\sin\theta &= 0 \\ N - mg\cos\theta &= 0 \end{aligned}\right\} \quad T = mg\sin\theta$$

$$T = (50\,\text{kg})(9.8\,\text{m/s}^2)\sin 8^\circ$$

$$T = 68.2\ \text{N}$$

(b) Clearly, the magnitude of the speed does not matter but the acceleration does!

For $a_x = 0.10\ \text{m/s}^2$ up the slope

Then
$$T - mg\sin\theta = ma_x$$

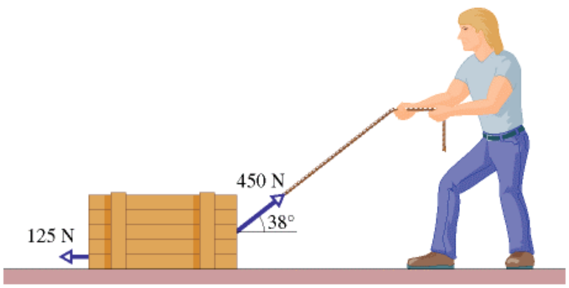
$$T = mg\sin\theta + ma_x$$

$$T = 68.2\,\text{N} + (50\,\text{kg})(0.10)$$

$$T = 73.2\,\text{N}$$

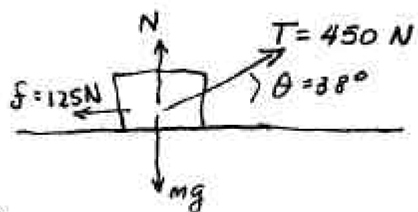
5-38 A worker drags a crate across a factory floor by pulling on a rope tied to the crate (Fig. 5-38). The worker exerts a force of 450 N on the rope, which is inclined at 38° to the horizontal, and the floor exerts a horizontal force of 125 N that opposes the motion. Calculate the magnitude of the acceleration of the crate if

(a) its mass is 310 kg and
(b) its weight is 310 N.



5-38

Forces on the crate →



The normal force, N, of the floor on the crate will balance the other vertical forces (Mg and T sin θ)

Only the horizontal forces matter for the horizontal acceleration

$T\cos\theta - f = ma$

(a) or $a = \dfrac{T\cos\theta - f}{m} = \dfrac{(450)\cos 38^\circ - 125}{310\text{ kg}} = 0.74\ \text{m/s}^2$

(b) Rewrite by multiply numerator + denominator by g

$a = \dfrac{T\cos\theta - f}{mg}\, g$ where $mg = 310\text{ N}$ is the weight

$a = (0.74)(9.8\ \text{m/s}^2)$

$a = 7.26\ \text{m/s}^2$

5-50 Figure 5-46 shows a man sitting in a bosun's chair that dangles from a massless rope, which runs over a massless, frictionless pulley and back down to the man's hand. The combined mass of man and chair is 95.0 kg. With what force magnitude must the man pull on the rope if he is to rise

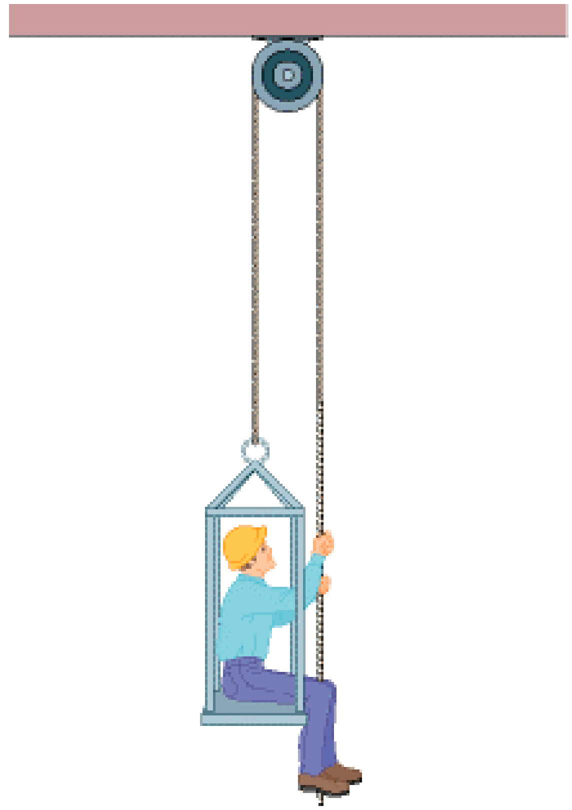
(a) with a constant velocity and
(b) with an upward acceleration of 1.30 m/s^2? (Hint: A free-body diagram can really help.)

Suppose, instead, that the rope on the right extends to the ground, where it is pulled by a co-worker. With what force magnitude must the co-worker pull for the man to rise

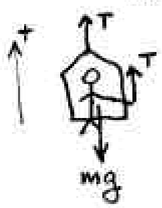
(c) with a constant velocity and
(d) with an upward acceleration of 1.30 m/s^2?

What is the magnitude of the force on the ceiling from the pulley system in

(e) part a; (f) part b; (g) part c, and
(h) part d?



5-50 The "massless" rope has uniform tension, T.



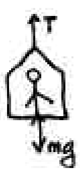
(a) Identify at left all the forces acting on the system of man + chair

If he rises with constant speed, a = 0, the forces must balance (sum to zero)

$2T - mg = 0 \Rightarrow T = \frac{mg}{2} = \frac{(95.0)(9.8)}{2} = 465.5\ N$

(b) If the system accelerates up (+ve) with $a = 1.30\ m/s^2$

$2T - mg = ma \Rightarrow T = \frac{m}{2}(g+a) = \frac{95.0}{2}(9.8 + 1.3) = 527.3\ N$



If the man is no longer holding the end of the rope, then the force diagram (of all forces on the system) looks like picture on left

(c) For $a = 0$ $T = mg = (95.0)(9.8) = 931\ N$

(d) For $a = 1.30\ m/s^2$ $T = m(g+a) = (95.0)(9.8+1.3) = 1055\ N$

e) In (a), force on ceiling is $2T = 931\ N$
f) (b), $2T = 1055\ N$
g) (c) $2T = 1862\ N$
h) (d) $2T = 2109\ N$

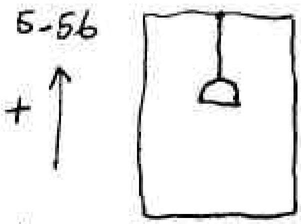
All 4 cases, force on ceiling $= 2T$

5-56 A lamp hangs vertically from a cord in a descending elevator that decelerates at $2.4 m/s^2$.

(a) If the tension in the cord is 89 N, what is the lamp's mass?

(b) What is the cord's tension when the elevator ascends with an upward acceleration of $2.4\ m/s^2$?

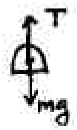
5-56



Note: elevator descending ($v<0$)

Define up as +ve direction.

Draw force diagram of lamp



If cord remains stretched ($T \geq 0$), then lamp's motion is the same as that of the elevator

So, $T - mg = ma$

(a) Given $T = 89\ N$, and $a = +2.4\ m/s^2$

so

$$m(g+a) = T \rightarrow m = \frac{T}{g+a} = \frac{89\ N}{9.8+2.4} = 7.30\ kg$$

Note that $a > 0$ because

i) elevator is descending .... means $V < 0$

ii) elevator is decelerating ... means $|v|$ getting smaller

Since $v<0$, then a is making v more positive

$$a = \frac{dv}{dt} > 0$$

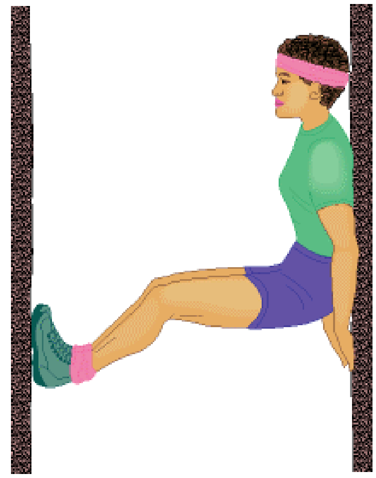
(b) If $v > 0$ (ascending elevator)
and the elevator is accelerating (increasing speed),
then $a = \frac{dv}{dt} > 0$ again

So $a = +2.4\ m/s^2$

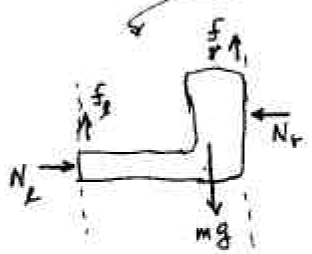
and $T = m(g+a) = 89N$ (what we had in part (a))

6-8 In Fig. 6-20 , a 49 kg rock climber is climbing a "chimney" between two rock slabs. The static coefficient of friction between her shoes and the rock is 1.2; between her back and the rock it is 0.80. She has reduced her push against the rock until her back and her shoes are on the verge of slipping.

(a) Draw a free-body diagram of the climber.
(b) What is her push against the rock?
(c) What fraction of her weight is supported by the frictional force on her shoes?



6-8 (a) Force (free-body) diagram of forces on climber



(b) Total forces (vertical + horizontal) on climber must be zero

$$N_\ell = N_r \qquad \text{(horizontal)}$$
$$f_\ell + f_r = mg \qquad \text{(vertical)}$$

Since $f_\ell = \mu_{s\ell} N_\ell \qquad f_r = \mu_{sr} N_r$

where $\begin{Bmatrix} \mu_{s\ell} \\ \mu_{sr} \end{Bmatrix}$ is the coefficient of static friction between climber and $\begin{Bmatrix} \text{left} \\ \text{right} \end{Bmatrix}$ slabs

So,
$$N_\ell = N_r \qquad \text{(horizontal)}$$
$$\frac{f_\ell}{\mu_{s\ell}} = \frac{f_r}{\mu_{sr}} \quad \text{or} \quad f_\ell = \left(\frac{\mu_{s\ell}}{\mu_{sr}}\right) f_r$$

From vertical equation, we find right-hand slab push on her (which, by action–reaction, equals her push on slab) as follows:

$$\left(\frac{\mu_{s\ell}}{\mu_{sr}}\right) f_r + f_r = mg \quad \text{or} \quad f_r\left[\left(\frac{\mu_{s\ell}}{\mu_{sr}}\right) + 1\right] = mg$$

$$f_r = \frac{mg}{\left(\frac{\mu_{s\ell}}{\mu_{sr}} + 1\right)}$$

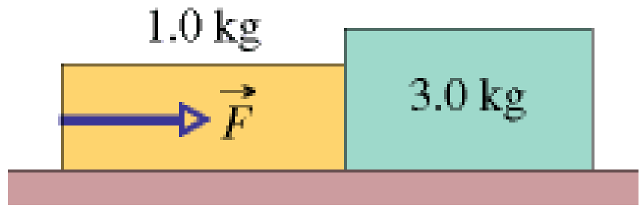
$$N = \frac{f_r}{\mu_{sr}} = \frac{mg}{\mu_{s\ell} + \mu_{sr}} = \frac{(49)(9.8)}{1.2 + 0.8} = 240 \text{ Newtons}$$

is force she applies to left and right slabs

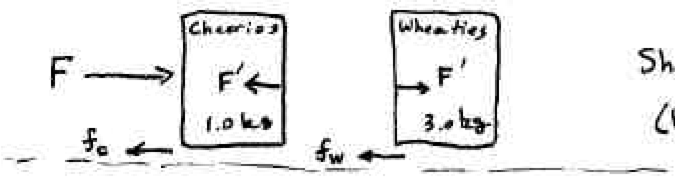
(c) Friction force on her shoes $= f_\ell$

$$\frac{f_\ell}{mg} = \frac{\mu_{s\ell} N}{mg} = \frac{\mu_{s\ell}}{\mu_{s\ell} + \mu_{sr}} = \frac{1.2}{1.2 + 0.8} = \frac{1.2}{2.0} = 0.60 \qquad (60\%)$$

6-24 In Fig. 6-32 , a box of Cheerios and a box of Wheaties are accelerated across a horizontal surface by a horizontal force applied to the Cheerios box. The magnitude of the frictional force on the Cheerios box is 2.0 N, and the magnitude of the frictional force on the Wheaties box is 4.0 N. If the magnitude of ***F*** is 12 N, what is the magnitude of the force on the Wheaties box from the Cheerios box?



6-24 Draw force diagram for each box separately. (Note they are actually in contact!)



Shown are horizontal forces. (Vertical forces such that normal forces balance weight.)

The forces F′ are internal to system of two boxes, but each acts on one box.

Given $f_c = 2.0\,N$ $\quad f_w = 4.0\,N \quad F = 12\,N$

(a) Take system of two boxes (internal forces cancel)

$$F - f_c - f_w = (m_c + m_w)\,a$$

$$a = \frac{F - f_c - f_w}{m_c + m_w} = \frac{12 - 2 - 4}{1 + 3} = \frac{6}{4} = 1.5\ m/s$$

(b) Now look at one box, say Wheaties (you could use either)

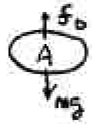
$$F' - f_w = m_w a$$

$$F' = f_w + m_w a = 4.0 + (3.0)(1.5)$$

$$F' = 8.5\ N$$

6-34 The terminal speed of a sky diver is 160 km/h in the spread-eagle position and 310 km/h in the nosedive position. Assuming that the diver's drag coefficient C does not change from one position to the other, find the ratio of the effective cross-sectional area A in the slower position to that in the faster position.

6-34



Drag force $= f_D = \frac{1}{2} C \rho A v_t^2$

The only important point is that it is
a) proportional to area
b) proportional to square of velocity

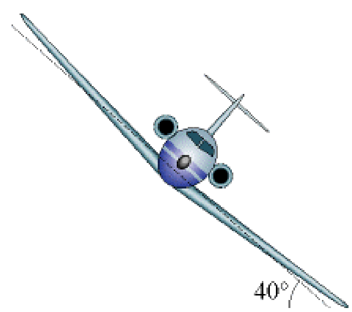
Since in the two cases, the terminal speed occurs when $f_D = mg$

so $f_1 = \frac{1}{2} C\rho A_1 v_1^2$ (spread-eagle) $v_1 = 160$ km/h $f_2 = \frac{1}{2} C\rho A_2 v_2^2$ (nose dive) $v_2 = 310$ km/h

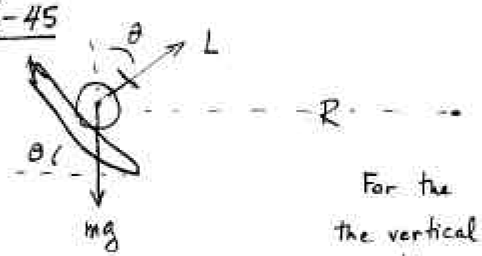
and $f_1 = f_2 = f_D = mg$ so $A_1 v_1^2 = A_2 v_2^2$

$$\frac{A_1}{A_2} = \left(\frac{v_2}{v_1}\right)^2 = \left(\frac{310}{160}\right)^2 = 3.75$$

6-45 An airplane is flying in a horizontal circle at a speed of 480 km/h. If its wings are tilted 40° to the horizontal, what is the radius of the circle in which the plane is flying? (See Fig. 6-38 .) Assume that the required force is provided entirely by an "aerodynamic lift" that is perpendicular to the wing surface.



6-45



The lift, L, is perpendicular to the plane of the wings.

For the airplane oriented as shown, the vertical component of $\vec{L}$ balances the weight, mg. The horizontal component of L provides the centripetal force.

Clearly, the airplane <u>must</u> be oriented as shown.

$L \sin\theta = m \frac{v^2}{R}$

$L \cos\theta = mg$

Ratio: $\tan\theta = \frac{v^2}{Rg}$ or $R = \frac{v^2}{g \tan\theta}$

$$R = \frac{\left(480 \frac{km}{h} \times \frac{1000\ m/km}{3600\ s/h}\right)^2}{(9.8\ m/s^2) \tan 40^\circ} = 2.16 \times 10^3\ m$$

or $R = 2.16$ km