PHYS-2010
GENERAL PHYSICS I
DR. LUTTERMOSER'S CLASS
SOLUTION SET #2
TO THE SUPPLEMENTAL PROBLEMS

1.

$m = 0.60\ \mathrm{kg}$

a) $KE_A = \frac{1}{2} m v_A^2 = \frac{1}{2}(0.60\ \mathrm{kg})(2.0\ \frac{\mathrm{m}}{\mathrm{s}})^2$

$= \boxed{1.2\ \mathrm{J}}$

b) $KE_B = \frac{1}{2} m v_B^2, \quad v_B^2 = \frac{2(KE_B)}{m}$

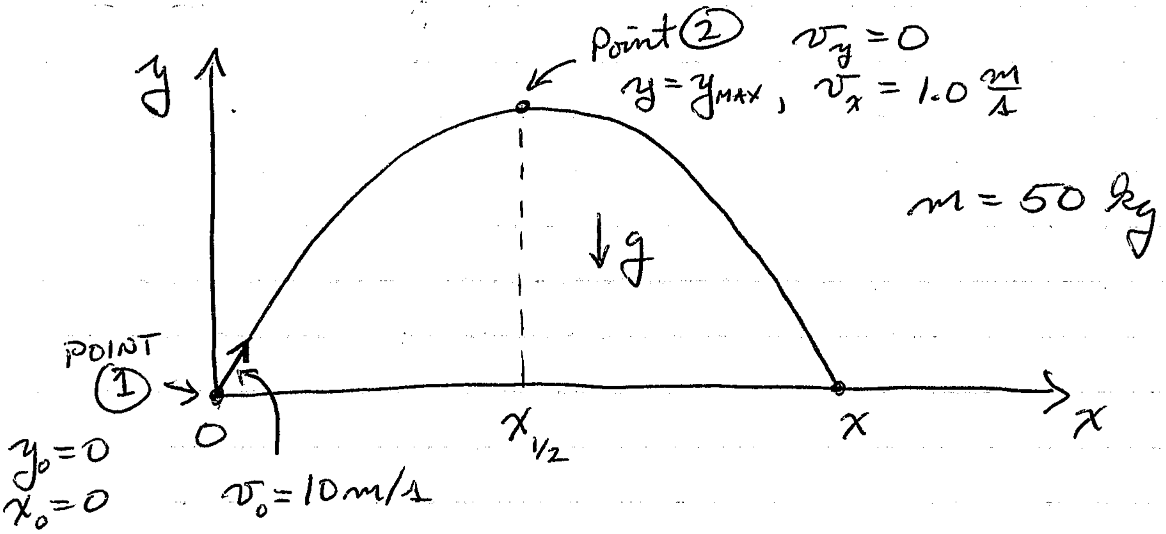
$v_B^2 = \frac{2(7.5\ \mathrm{J})}{0.60\ \mathrm{kg}} = \frac{15.\ \mathrm{kg\,m^2/s^2}}{0.60\ \mathrm{kg}}$

$= 25\ \mathrm{m^2/s^2}$

$\boxed{v_B = 5.0\ \mathrm{m/s}}$

c) $W = KE_B - KE_A = 7.5\ \mathrm{J} - 1.2\ \mathrm{J} = \boxed{6.3\ \mathrm{J}}$

2.



We could solve this with 2-D equations of motion, but here, it is easier to use conservation of energy:

$$KE_1 + PE_1 = KE_2 + PE_2$$

$$\frac{1}{2}mv_0^2 + mgy_0 = \frac{1}{2}mv^2 + mgy_{MAX}$$

At y_{max}: $\quad v = \sqrt{v_x^2 + v_y^2} = \sqrt{(1.0\frac{m}{s})^2 + 0^2}$

$$= 1.0 \text{ m/s}$$

and

$mgy_0 = 0$ since $y_0 = 0$ (the ground)

so

$$\frac{1}{2}v_0^2 + \cancel{gy_0}^{\,0} = \frac{1}{2}v^2 + gy_{MAX}$$

$$gy_{MAX} = \frac{1}{2}(v_0^2 - v^2)$$

$$y_{MAX} = \frac{v_0^2 - v^2}{2g} = \frac{(10 \text{ m/s})^2 - (1.0 \text{ m/s})^2}{2(9.80 \text{ m/s}^2)} = \boxed{5.1 \text{ m}}$$

2-3

3.

Running person dissipates $0.60\,J/kg/step = W_R$

$m = 60\,kg$, $P = 70\,W$, $l_{STEP} = 1.5\,m$, $v = ?$

$$\text{Power} = \frac{\text{work done}}{\Delta t} = \frac{W}{\Delta t}$$

$$W = (\text{work per step per unit mass})(\text{mass})(\#\text{ of steps})$$
$$= W_R \times m \times N, \quad \text{where } N = \#\text{ of steps}$$

As such, $$P = \frac{W}{\Delta t} = \frac{W_R\, m\, N}{\Delta t} = W_R\, m \frac{N}{\Delta t}$$

or $$\frac{N}{\Delta t} = \frac{P}{W_R\, m} = \frac{70\,W}{\left(0.60\,\frac{J/step}{kg}\right)(60\,kg)} = 1.9\text{ steps/s}$$

Each step covers $l_{STEP} = 1.5\,m$ or the total distance traveled is

$$\Delta x = N\, l_{STEP}$$

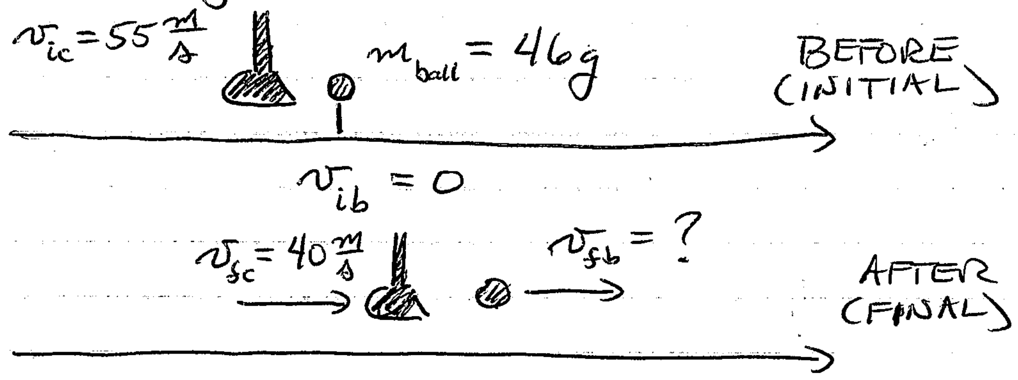
The running speed is then

$$\bar{v} = \frac{\Delta x}{\Delta t} = \frac{N\, l_{STEP}}{\Delta t} = \frac{N}{\Delta t}\, l_{STEP}$$
$$= (1.9\text{ steps/s})(1.5\text{ m/step})$$
$$= \boxed{2.9\text{ m/s}}$$

(2-4)

4.

$m_{CLUB} = 200\,g$



Conservation of momentum:

$$m_c v_{ic} + \cancel{m_b v_{ib}}^{\,0} = m_c v_{fc} + m_b v_{fb}$$

$$m_b v_{fb} = m_c v_{ic} - m_c v_{fc}$$

$$v_{fb} = \frac{m_c}{m_b}\left(v_{ic} - v_{fc}\right)$$

$$= \frac{200\,g}{46\,g}\left(55\,\frac{m}{s} - 40\,\frac{m}{s}\right)$$

$$= \boxed{65\,m/s}$$

5. The ratio of the kinetic energy of the Earth to that of the ball is

$$\frac{KE_\oplus}{KE_b} = \frac{\frac{1}{2} M_\oplus v_\oplus^2}{\frac{1}{2} m_b v_b^2} = \left(\frac{M_\oplus}{m_b}\right)\left(\frac{v_\oplus}{v_b}\right)^2$$

From conservation of momentum,

$p_f = p_i = 0$, giving $M_\oplus v_\oplus + m_b v_b = 0$, or

$$\boxed{\frac{v_\oplus}{v_b} = -\frac{m_b}{M_\oplus}}$$

and then

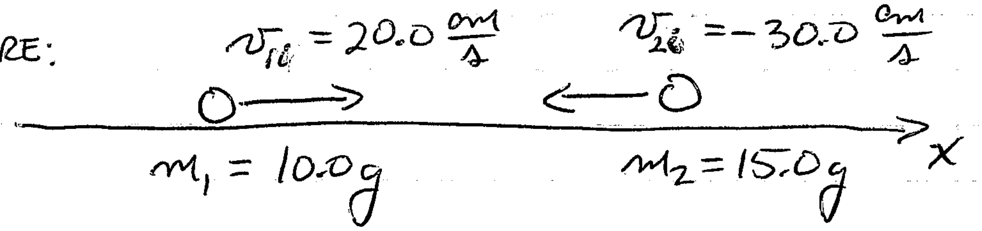
$$\frac{KE_\oplus}{KE_b} = \left(\frac{M_\oplus}{m_b}\right)\left(-\frac{m_b}{M_\oplus}\right)^2 = \boxed{\frac{m_b}{M_\oplus}}$$

Using order of magnitude ~~n~~numbers:

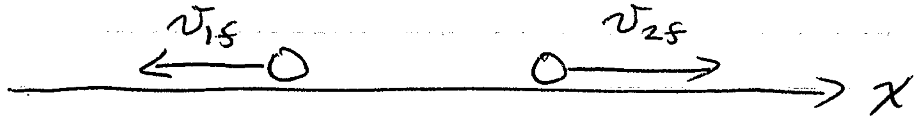
$$\frac{KE_\oplus}{KE_b} = \frac{m_b}{M_\oplus} \approx \frac{1\ \text{kg}}{10^{25}\ \text{kg}} \approx \boxed{10^{-25}}$$

6.

BEFORE:



AFTER:



(1) Conservation of momentum:

$$m_1 v_{1i} + m_2 v_{2i} = m_1 v_{1f} + m_2 v_{2f}$$

(2) Conservation of kinetic energy (2nd form):

$$v_{1i} - v_{2i} = -(v_{1f} - v_{2f})$$

Now, using (1) gives

$$10.0g\,(20.0\ cm/s) + 15.0g\,(-30.0\ cm/s)$$

$$= 10.0g\,(v_{1f}) + 15.0g\,(v_{2f})$$

$$200.\ g\ cm/s - 450\ g\ cm/s = (10.0g)v_{1f} + (15.0g)v_{2f}$$

$$-250.\ g\ cm/s = (10.0g)\,v_{1f} + (15.0g)\,v_{2f}$$

(1a) $\quad -25.0\ \frac{cm}{s} = v_{1f} + 1.50\,v_{2f}$

and using (2) gives

$$20.0\,\frac{cm}{s} - \left(-30.0\,\frac{cm}{s}\right) = -(v_{1f} - v_{2f})$$

(2a) $$50.0\text{ cm/s} = -v_{1f} + v_{2f}$$

Add (1a) & (2a):

$$\begin{aligned} -25.0\text{ cm/s} &= v_{1f} + 1.50\,v_{2f} \\ +\ 50.0\text{ cm/s} &= -v_{1f} + v_{2f} \\ \hline 25.0\text{ cm/s} &= 0 + 2.50\,v_{2f} \end{aligned}$$

$$v_{2f} = \frac{25.0\text{ cm/s}}{2.50} = \boxed{10.0\text{ cm/s}}$$

Plugging this value into (2a):

$$50.0\text{ cm/s} = -v_{1f} + 10.0\text{ cm/s}$$

$$v_{1f} = 10.0\text{ cm/s} - 50.0\text{ cm/s}$$

$$= \boxed{-40.0\text{ cm/s}}$$

7.

$\omega_0 = 0$, after $t = 3.20\,s$, $\omega = 2.51 \times 10^4 \frac{rev}{min}$
$t_0 = 0$ (under constant α)

a) Find angular acceleration:

$$\alpha = \bar{\alpha} = \frac{\omega - \omega_0}{t - t_0} = \frac{2.51 \times 10^4\,rev/min - 0}{3.20\,s - 0}$$

$$= 7.84 \times 10^3 \frac{rev}{min \cdot s} \times \frac{1\,min}{60\,s} = 131\,rev/s^2$$

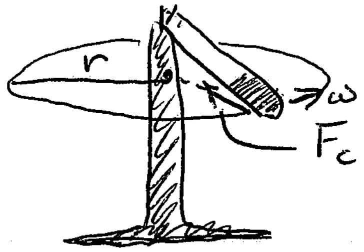
$$= 131 \frac{rev}{s^2} \times \frac{2\pi\,rad}{1\,rev} = \boxed{821\,rad/s^2}$$

b) Total angle turned during this time?

$$\theta = \omega_0 t + \frac{1}{2}\alpha t^2 = 0 + \frac{1}{2}\left(821 \frac{rad}{s^2}\right)(3.20\,s)^2$$

$$= \boxed{4.21 \times 10^3\,rad} = 2.41 \times 10^5 \text{ degrees}$$

8.



$m_{cell} = 3.0 \times 10^{-16}\ kg$

$F_c = 4.0 \times 10^{-11}\ N$ toward center of circle

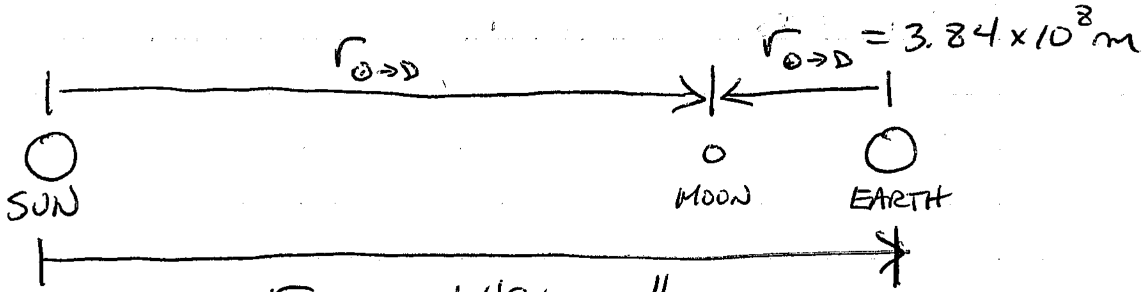
$r = 0.150\ m \quad \left(= \frac{15.0\ cm}{100\ cm/m}\right)$

$$F_c = m\frac{v_t^2}{r} = mr\omega^2$$

$$\omega = \sqrt{\frac{F_c}{mr}} = \sqrt{\frac{4.0 \times 10^{-11}\ N}{(3.0 \times 10^{-16}\ kg)(0.150\ m)}}$$

$$= 9.4 \times 10^2\ \frac{rad}{s} \times \frac{1\ rev}{2\pi\ rad} = \boxed{1.5 \times 10^2\ \frac{rev}{s}}$$

9.



$$r_{\odot \to D} = r_{\odot \to \oplus} - r_{\oplus \to D} = 1.496 \times 10^{11}\ m - 3.84 \times 10^8\ m$$
$$= 1.492 \times 10^{11}\ m$$

a) $$F_{\odot \to D} = \frac{G M_D M_\odot}{r_{\odot \to D}^2} = \frac{(6.673 \times 10^{-11}\ N m^2/kg^2)(7.36 \times 10^{24}\ kg) \times (1.991 \times 10^{30}\ kg)}{(1.492 \times 10^{11}\ m)^2}$$

$$\boxed{F_{\odot \to D} = 4.39 \times 10^{20}\ N}$$

(2-10)

b) $F_{\oplus\to D} = \dfrac{G M_\oplus M_D}{r_{\oplus\to D}^2} = \dfrac{(6.673\times10^{-11}\,Nm^2/kg^2)\times(5.98\times10^{24}\,kg)(7.36\times10^{22}\,kg)}{(3.84\times10^{8}\,m)^2}$

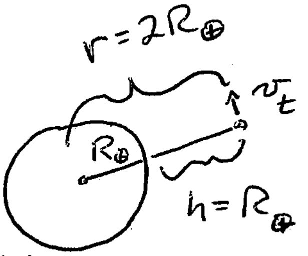
$$\boxed{F_{\oplus\to D} = 1.99\times10^{20}\,N}$$

c) $F_{\odot\to\oplus} = \dfrac{G M_\odot M_\oplus}{r_{\odot\to\oplus}^2} = \dfrac{(6.673\times10^{-11}\,Nm^2/kg^2)(1.991\times10^{30}\,kg)\times(5.98\times10^{24}\,kg)}{(1.496\times10^{11}\,m)^2}$

$$\boxed{F_{\odot\to\oplus} = 3.55\times10^{22}\,N}$$

10.

a)



Set gravitational force = centripetal force

$F_c = F_g$

m = satellite mass = 600 kg

$$m\frac{v_t^2}{r} = \frac{G M_\oplus m}{r^2}$$

$$v_t = \sqrt{\frac{G M_\oplus}{r}} = \sqrt{\frac{G M_\oplus}{2R_\oplus}}$$

$$= \sqrt{\frac{(6.67\times10^{-11}\,Nm^2/kg^2)(5.98\times10^{24}\,kg)}{2(6.38\times10^{6}\,m)}}$$

$$= \boxed{5.59\times10^{3}\,m/s}$$

2-11

b) The period of the satellite's motion is

$$T = \frac{2\pi r}{v_t} = \frac{2\pi\left[2(6.38\times10^{6}\,m)\right]}{5.59\times10^{3}\,m/s}$$

$$= \boxed{1.43\times10^{4}\,s} \times \frac{1\,hr}{3600\,s} = \boxed{3.98\,hr}$$

c) The gravitational force acting on the satellite:

$$F = \frac{GmM_{\oplus}}{r^2} = \frac{GmM_{\oplus}}{4R_{\oplus}^2}$$

$$= \frac{(6.67\times10^{-11}\,Nm^2/kg^2)(600\,kg)(5.98\times10^{24}\,kg)}{4(6.38\times10^{6}\,m)^2}$$

$$= \boxed{1.47\times10^{3}\,N}$$