1)
a) $\theta = 3\times10^{-4}\,\cancel{rad}\ \Big|\ \frac{360^\circ}{2\pi\,\cancel{rad}} = \boxed{0.108^\circ}$

or also, 60 arc min = 1°
60 arc sec = 1 arc min

$\theta = 0.108^\circ\ \Big|\ \frac{60\text{ arcmin}}{1^\circ} = 6.48\text{ arc min}$

$= 388.8\text{ arc sec}$

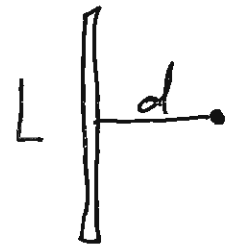
b) $\theta = \frac{x}{r} \rightarrow x = r\theta = 100m \cdot 3\times10^{-4}\,rad = \boxed{0.03m}$
$= \boxed{3\text{ cm}}$

2) This square is made of four rods ($I = \frac{1}{3}ML^2$ about center), each offset from the square's center (parallel axis theorem).

$L = 0.75m$

$d = 0.375m \quad (\frac{1}{2}L)$

$M = 0.50kg$



For one rod,

$$I_p = I_{cm} + Md^2$$

$$= \frac{1}{3}ML^2 + Md^2$$

$$I_p = M(\frac{1}{3}L^2 + d^2)$$

For all four rods

$$I_{TOT} = 4I_p = 4M(\frac{1}{3}L^2 + d^2)$$

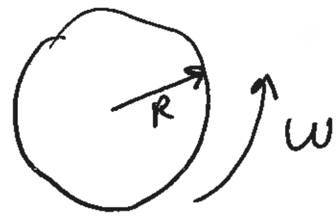
$$= 4 \cdot 0.5(\frac{1}{3} \cdot .75^2 + .375^2)$$

$$= 0.65625$$

Units: $I \sim MR^2$
$kg \cdot m^2$

$$= \boxed{0.66\ kg \cdot m^2}$$

9)



$R = 6{,}371\,km = 6.371 \times 10^6\,m$

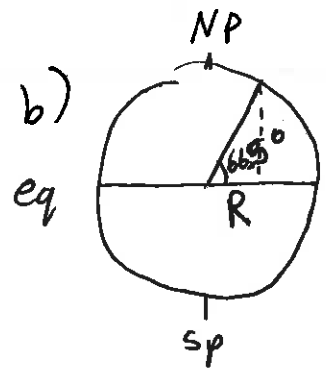
$\omega = \dfrac{1\,rev}{1\,day} \Big| \dfrac{2\pi\,rad}{1\,rev} \Big| \dfrac{1\,day}{24\,hrs} \Big| \dfrac{1\,hrs}{3600\,s} =$

$7.2722\,E\text{-}5\ rad/s$

a) $V = \omega R = 7.2722E\text{-}5 \cdot 6.371E6$

$= 463.312\ m/s = \boxed{463\,m/s}$

b)



$R = R_E \cos 66.5°$

$V = \omega R = \omega R_E \cos\theta$

$= 463.312 \cdot \cos 66.5$

$= \boxed{185\,m/s}$

c) $V = 463.312 \cos 41.3° = 348.07$

$= \boxed{348\,m/s}$

d) found above as $\boxed{\omega = 7.27 \times 10^{-5}\ rad/s}$

e) $\omega_F = 7.2722E\text{-}5\ s^{-1}$ (today's value)

$\omega_0 = \dfrac{1\,rev}{(1\,day + 25_s)} = 7.2701\,E\text{-}5\ s^{-1}$

$\Delta t = (2015 - 1972) = 43\,yrs$

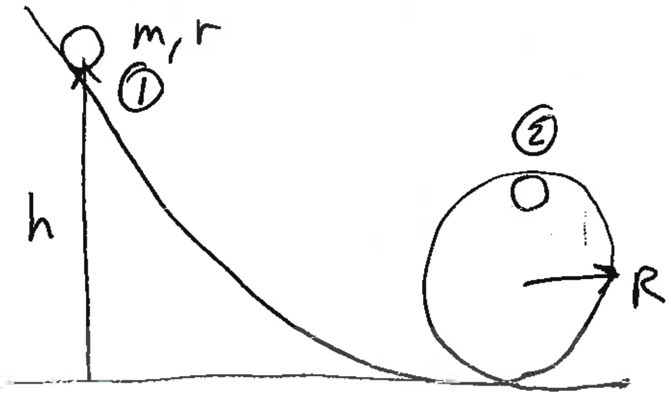
$$\Delta t = \frac{43\,\text{years}}{} \left| \frac{365.25\,\text{days}}{1\,\text{yr}} \right| \frac{24\,\text{hrs}}{1\,\text{day}} \left| \frac{3600\,\text{s}}{1\,\text{hr}} \right.$$

$$= 1.35698\,E9\ \text{s}$$

$$\alpha = \frac{\Delta \omega}{\Delta t} = \frac{(7.2722 - 7.2701)\,E{-5}}{1.35698\,E9} = 1.54755\,E{-17}$$

$$= \boxed{1.55 \times 10^{-17}\ \text{rad}/\text{s}^2}$$

94)



Find h based on m, r, R, and marble shape.

$I = \frac{2}{5} m r^2$

First, assume $r \ll R$ so height at 2 is just $2R$

As before, use forces to get v @ 2, then compare energy of 2 to 1, adding K_{rot}.

2 $\quad a = v^2/R \quad$ barely makes it, so $a = g$

$v = \sqrt{gR}$

2→1 $\quad U_1 = U_2 + K_{rot\,2} + K_{trans\,2}$

$mgh = mg2R + \frac{1}{2} I\omega^2 + \frac{1}{2} mv^2$

$\omega = v/r$ because rolling

assume solid sphere, $I = \frac{2}{5} mr^2$

$\cancel{m}gh = 2\cancel{m}gR + \frac{1}{2}\left(\frac{2}{5}\cancel{m}r^2\right)\frac{v^2}{r^2} + \frac{1}{2}\cancel{m}v^2$

$$gh = 2gR + \frac{1}{5}v^2 + \frac{1}{2}v^2$$

$$gh = 2gR + \frac{7}{10}v^2$$

$$\cancel{g}h = 2\cancel{g}R + \frac{7}{10}\cancel{g}R$$

$$\boxed{h = \frac{27}{10}R}$$

Sanity check:
2.7R compared to previous 2.5R → need a higher height because some of the mgh is used up in spinning.

This will depend on shape of ball, the $\frac{2}{5}mr^2$.

Next approximation, instead of $U_2 = mg(2R)$, use $U_2 = mg\,2(R-r)$ and repeat. Should have an r in final solution, or r/R.

a correction term

$$v^2 = g(R-r) = gR\left(1-\frac{r}{R}\right) \qquad \omega = \frac{v}{R(1-r/R)}$$

$$\cancel{m}gh = \cancel{mg}\,2R\left(1-\frac{r}{R}\right) + \frac{1}{2}\left(\frac{2}{5}\cancel{m}r^2\right)\frac{v^2}{R^2\left(1-\frac{r}{R}\right)^2} + \frac{1}{2}\cancel{m}v^2$$

this one stays same b/c shape of ball

$$\cancel{g}h = 2\cancel{g}R\left(1-\frac{r}{R}\right) + \frac{1}{5}r^2 \frac{\cancel{g}\cancel{R\left(1-\frac{r}{R}\right)}}{R^{\cancel{2}}\left(1-\frac{r}{R}\right)^{\cancel{2}}} + \frac{1}{2}\cancel{g}R\left(1-\frac{r}{R}\right)$$

$$h = 2R\left(1-\frac{r}{R}\right) + \frac{1}{5}\frac{r}{R\left(1-\frac{r}{R}\right)} + \frac{1}{2}R\left(1-\frac{r}{R}\right)$$

$$\boxed{h = \frac{5}{2}R\left(1-\frac{r}{R}\right) + \frac{r}{5R\left(1-\frac{r}{R}\right)}}$$

Sanity check 1: Units on each term - do they work out?

Sanity Check 2: if $r \ll R$, then $r/R \to 0$

$$h = \frac{5}{2}R(1-0) + \frac{1}{5}\cdot 0 \cdot \frac{1}{(1-0)}$$

$h = \frac{5}{2}R$ which is what we had for the roller coaster.