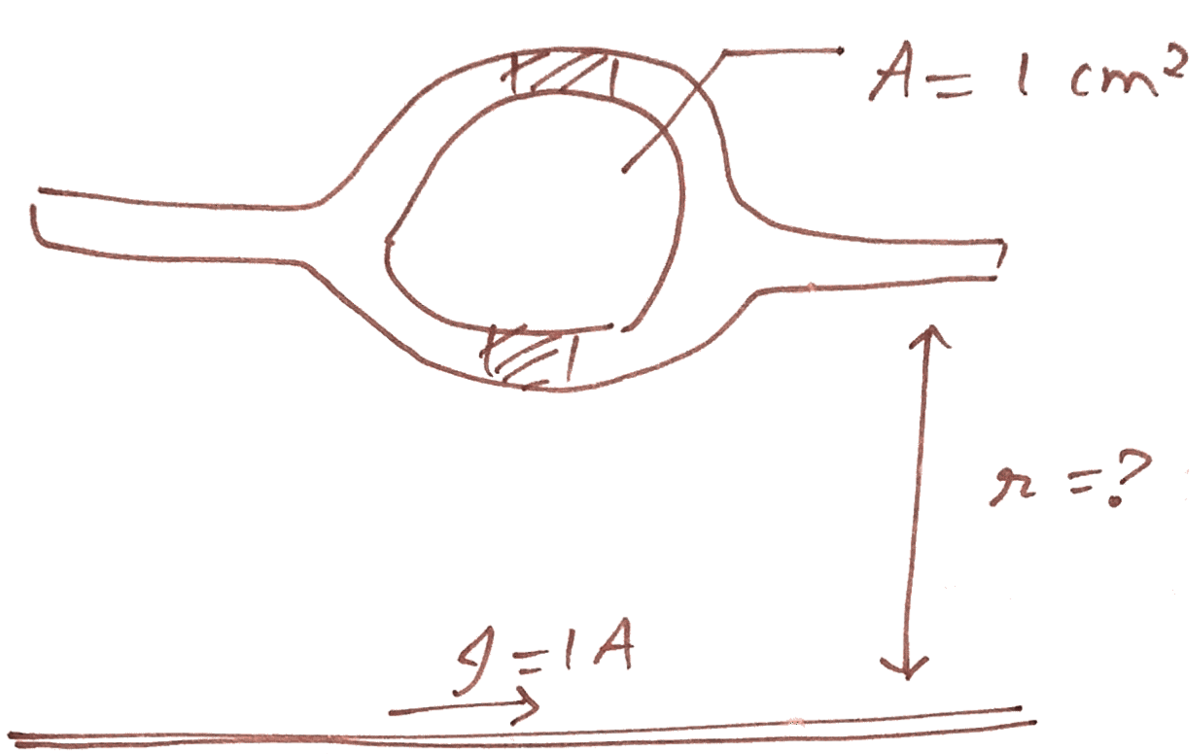
15.2)



$$\phi = BA = \mu HA \quad \text{and} \quad H = \frac{I}{2\pi r}$$

$$\phi = \phi_0 = \mu_0 \frac{I}{2\pi r} \times A$$

$$2.07 \times 10^{-15}\ Tm^2 = \frac{4\pi \times 10^{-7}\ H/m \times 1A \times 10^{-4} m^2}{2\pi r}$$

$$r = \frac{4\pi \times 10^{-7} \times 10^{-4}}{2.07 \times 10^{-15} \times 2\pi}\ m$$

$$\underline{r = 10^4\ m}$$

15.4) 10^{-5} per day $\approx$ 1 second per day (John Harrison Chronometer)

Assuming ship travels at 36 kmph (10 m/s)

Error in position per day = 10 m (1 second)

Error in a month = $\underline{\underline{300\text{ m}}}$

<u>With cesium beam atomic clock</u>

Error $\approx 10^{-15}$

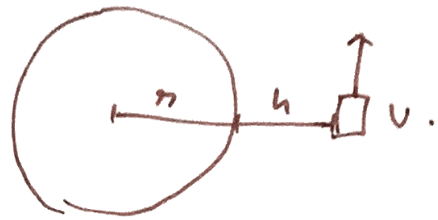
Error per day $\approx 8.6\times10^{-11}$ sec per day

Error in position per day $\approx 8.6\times10^{-10}$ m $\approx 10^{-9}$ m

Error in a month $\approx$ 30 nm

15.5 (a) $h = 20{,}180$ km

$r = 6{,}371$ km



$$\frac{GMm}{r'^2} = \frac{mv^2}{r'} \qquad r' = r + h$$

(Gravitational Force) (Centripetal force)

$$\frac{GM}{r} = v^2 \qquad v = \sqrt{\frac{GM}{r}} = \sqrt{\frac{3.98 \times 10^{14}\ m^3/s^2}{(20{,}180 + 6{,}371) \times 10^3\ m}}$$

$V = 3871.7$ m/s.

(b) Orbital period $= \dfrac{2\pi r'}{v} = 43088.3$ Seconds

$\simeq 12$ hours (11.96)

(c) $$\gamma = \frac{1}{\sqrt{1 - c^2/v^2}} = 1.\underbrace{0000000000}_{10 \text{ zeroes}}83206$$

Clock on GPS satellite goes slower

(d) General relativity gives us $t = \dfrac{1 - \frac{GM}{rc^2}}{1 - \frac{GM}{r'c^2}}\, t'$

$r = 6400$ km, $r' = (20{,}180 + 6400)$ km

$$t = 0.999999991\, t'$$