$$E = \frac{1}{2}\mu \dot{r}^2 + \frac{1}{2}\frac{l^2}{\mu r^2} - \frac{GM\mu}{r}$$

$$E = U_{eff}$$

$$E = \frac{1}{2}\frac{l^2}{\mu r^2} - \frac{GM\mu}{r}$$

$$Er^2 = \frac{1}{2}\frac{l^2}{\mu} - GM\mu r$$

$$Er^2 + GM\mu r - \frac{1}{2}\frac{l^2}{\mu} = 0$$

$$r = \frac{-GM\mu \pm \sqrt{(GM\mu)^2 + 2E\frac{l^2}{\mu}}}{2E} \quad ; \; E < 0$$

$$r = \frac{-GM\mu \pm GM\mu\sqrt{1 + \frac{2E}{(GM\mu)^2}\frac{l^2}{\mu}}}{2E}$$

$$r = \frac{GM\mu}{2E}\left[-1 \pm \sqrt{1 + \frac{2E}{(GM\mu)^2}\frac{l^2}{\mu}}\right]$$

$$r_0 = \frac{1}{GM}\left(\frac{l}{\mu}\right)^2$$

$$r = \frac{GM\mu}{2E}\left[-1 \pm \sqrt{1 + \frac{2E}{(GM)^2}\left(\frac{L}{\mu}\right)^2 \frac{1}{\mu}}\right]$$

$$r = \frac{GM\mu}{2E}\left[-1 \pm \sqrt{1 + 2E\frac{r_0}{GM\mu}}\right]$$

$$r = \frac{1}{2}R\left[-1 \pm \sqrt{1 + 2\frac{r_0}{R}}\right] \quad ; R = \frac{GM\mu}{E}$$

$$r_{min} = \frac{1}{2}R\left[-1 - \sqrt{\ }\right]$$

$$r_{max} = \frac{1}{2}R\left[-1 + \sqrt{\ }\right]$$

$$a(-1+c) + a(-1-c)$$
$$= -a + ac - a - ac$$
$$= -2a$$

$$a = \frac{1}{2}\left(r_{min} + r_{max}\right)$$

$$a = -\frac{R}{2}$$

$$\left(-\frac{R}{2} - \frac{R}{2}\sqrt{\ }\right)\left(-\frac{R}{2} + \frac{R}{2}\sqrt{\ }\right)$$

$$b = \sqrt{r_{min} r_{max}}$$

$$\frac{R^2}{4} - \frac{R^2}{4}\sqrt{\ } + \frac{R^2}{4}\sqrt{\ } - \frac{R^2}{4}\sqrt{\ }^2$$

$$= \frac{R^2}{4}\left(1 - 1 - \frac{2r_0}{R}\right)$$

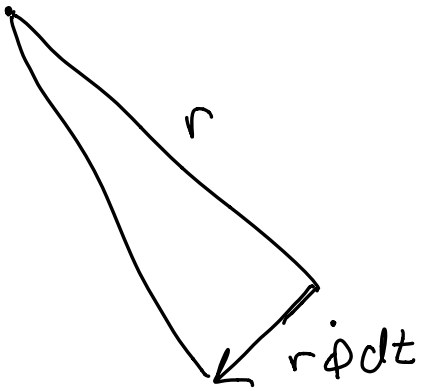
$$b = \sqrt{-\frac{R r_0}{2}}$$

$$= \frac{R^2}{4}\left(-\frac{2r_0}{R}\right)$$

$$= -\frac{R r_0}{2}$$

$$A = \pi ab$$

$$ab = \frac{-R}{2}\sqrt{\frac{-Rr_0}{2}}$$



$$dA = \frac{1}{2} r^2 \dot{\phi}\, dt$$

$$\frac{dA}{dt} = \frac{1}{2} r^2 \dot{\phi} \; ; \; l = \mu r^2 \dot{\phi}$$

$$\dot{\phi} = \frac{l}{\mu r^2}$$

$$\frac{dA}{dt} = \frac{1}{2} r^2 \frac{l}{\mu r^2} = \frac{1}{2}\frac{l}{\mu}$$

$$\frac{dA}{dt} = \frac{1}{2}\frac{l}{\mu}$$

$$A = \pi ab$$

$$ab = \frac{-R}{2}\sqrt{\frac{-Rr_0}{2}}$$

$$A = -\frac{\pi R}{2}\sqrt{\frac{-Rr_0}{2}}$$

$$\tau = A \Big/ \frac{dA}{dt} = -\frac{\pi R}{2}\sqrt{\frac{-Rr_0}{2}}\left(\frac{2\mu}{\ell}\right)$$

$$\tau = -\pi R\sqrt{\frac{-Rr_0}{2}}\left(\frac{\mu}{\ell}\right)$$

$$\tau^2 = \pi^2 R^2\left(\frac{-Rr_0}{2}\right)\left(\frac{\mu}{\ell}\right)^2$$

$$\tau^2 = -\frac{\pi^2 R^3}{2} r_0 \left(\frac{\mu}{\ell}\right)^2$$

$$r_0 = \frac{1}{GM}\left(\frac{\ell}{\mu}\right)^2$$

$$\tau^2 = -\frac{\pi^2 R^3}{2}\frac{1}{GM}, \quad R = -2a$$

$$R^3 = -8a^3$$

$$= \frac{-\pi^2(-8a^3)}{2}\frac{1}{GM}$$

$$\tau^2 = \frac{4\pi^2 a^3}{GM}$$