$$\dot{r}^2(1-\tfrac{a}{r})^{-1} = -(1-\tfrac{a}{r})^2\left[\frac{c^4L^2}{r^2W^2}+\frac{c^6}{W^2}\right]+c^2(1-\tfrac{a}{r})$$

or $$\dot{r}^2 = c^2(1-\tfrac{a}{r})^2 - \left[\frac{c^4L^2}{r^2W^2}+\frac{c^6}{W^2}\right](1-\tfrac{a}{r})^3$$

$$\boxed{\dot{r}^2 = c^2(1-\tfrac{a}{r})^2\left\{1-\left[\frac{c^2L^2}{r^2W^2}+\frac{c^4}{W^2}\right](1-\tfrac{a}{r})\right\}} \quad \text{II}$$

$$u=\frac{1}{r}, \quad \frac{du}{d\phi} = -\frac{1}{r^2}\frac{dr}{d\phi}, \quad \left(\frac{du}{d\phi}\right)^2 = \frac{1}{r^4}\left(\frac{dr}{d\phi}\right)^2$$

$$\left(\frac{dr}{d\phi}\right)^2 = \frac{\dot{r}^2}{\dot{\phi}^2} = c^2(1-\tfrac{a}{r})^2\{\quad\}\frac{r^4W^2}{c^4L^2}(1-\tfrac{a}{r})^{-2}$$

$$\left(\frac{du}{d\phi}\right)^2 = \frac{1}{r^4}\left(\frac{dr}{d\phi}\right)^2 = \frac{W^2}{c^2L^2}\left\{1-\left[\frac{c^2L^2}{r^2W^2}+\frac{c^4}{W^2}\right](1-\tfrac{a}{r})\right\}$$

$$\boxed{\left(\frac{du}{d\phi}\right)^2 = \frac{W^2}{c^2L^2}\left\{1-\left[\frac{c^2L^2}{W^2}u^2+\frac{c^4}{W^2}\right](1-au)\right\}}$$

$$\left(\frac{du}{d\phi}\right)^2 = \frac{W^2}{c^2L^2} - u^2(1-au) - \frac{c^2}{L^2}(1-au)$$

$$\left(\frac{du}{d\phi}\right)^2 + u^2(1-au) = \frac{c^2}{L^2}\left[\frac{W^2}{c^4}-1+au\right]$$

$$\text{Let } \frac{W^2}{c^4}-1 = 2E/c^2 \Rightarrow$$

$$\boxed{\left(\frac{du}{d\phi}\right)^2 + u^2(1-au) = \frac{c^2}{L^2}\left[\frac{2E}{c^2}+au\right]}$$

Which is what we are supposed to get.