

10)

9) This is tedious. Just look at the answers.

10) For photons, $\mu=0$ so energy equation rearranges to

$$\frac{\dot{r}^2}{h^2} + \frac{1}{r^2} \left(1 - \frac{2\mu}{r} \right) = \frac{1}{b^2} \quad h = r^2 \dot{\phi}, \quad b = \frac{h}{kc}$$

$$\mu = \frac{GM}{c^2}$$

To show that b is the impact parameter, consider the case when $\mu=0$.

If the photon grazes the object at $r=R$, then

$$\frac{dr}{d\phi} \bigg|_{r=R} = 0$$

This eliminates the $\dot{r}^2/\dot{\phi}^2$ term, so

$$b^2 = r^2 \left(1 - \frac{2\mu}{r} \right)^{-1}$$

$$b = r \left(1 - \frac{2\mu}{r} \right)^{-1/2} \quad \text{QED.}$$

Numbers.