1)

Calculation for $2p_z$

$$\varphi_0(2p_z) = \frac{1}{4}\frac{r}{a^{5/2}} e^{-r/(2a)} \quad -(1)$$

$$\frac{d\varphi_0}{dt} = \frac{e^{-r/(2a)}}{4a^{5/2}} - \frac{1}{8a^{7/2}} e^{-r/(2a)} \quad -(2)$$

$$\boxed{\frac{d\varphi_0}{dt} = \frac{1}{4a^{5/2}}\left(1 - \frac{r}{2a}\right) e^{-r/(2a)}} \quad -(3)$$

$$\frac{d^2\varphi_0}{dt^2} = -\frac{1}{8a^{7/2}} e^{-r/(2a)} - \frac{1}{8a^{7/2}}\left(1 - \frac{r}{2a}\right) e^{-r/(2a)}$$

$$= -\frac{1}{4a^{7/2}} e^{-r/(2a)} + \frac{r}{16a^{9/2}} e^{-r/(2a)}$$

$$\boxed{\frac{d^2\varphi_0}{dt^2} = \frac{1}{4a^{7/2}} e^{-r/(2a)}\left(\frac{r}{4a} - 1\right)} \quad -(4)$$

$$\nabla^2\varphi_0 = \frac{e^{-r/(2a)}}{4a^{7/2}}\left(\frac{r}{4a} - 1\right) + \frac{1 \, e^{-r/(2a)}}{2ra^{5/2}}\left(1 - \frac{r}{2a}\right)$$

$$\boxed{\nabla^2\varphi_0 = \frac{e^{-r/(2a)}}{2a^{5/2}}\left(\frac{1}{2a}\left(\frac{r}{4a} - 1\right) + \frac{1}{r}\left(1 - \frac{r}{2a}\right)\right)}$$

(5)

2)

$$= -\frac{4mc}{\hbar}\cdot\frac{1}{4}\,\frac{r}{a^{5/2}}\,e^{-r/(2a)}\,\frac{1}{r_{vac}}$$

Refactor:

$$\frac{1}{2}\left(\frac{1}{2a}\left(\frac{r}{4a}-1\right)+\frac{1}{r}\left(1-\frac{r}{2a}\right)\right) = -\frac{mc}{\hbar}\,\frac{r}{r_{vac}}$$

$$\frac{1}{r_{vac}} = -\frac{\hbar}{2mcr}\left(\frac{1}{2a}\left(\frac{r}{4a}-1\right)+\frac{1}{r}\left(1-\frac{r}{2a}\right)\right)$$

$$\boxed{\frac{1}{r_{vac}} = \frac{\hbar}{2mca}\left(\frac{1}{2r}\left(1-\frac{r}{4a}\right)+\frac{a}{r^2}\left(\frac{r}{2a}-1\right)\right)}$$

— (7)

At $r = 2a$:

$$\boxed{\frac{1}{r_{vac}} = \frac{\hbar}{2mca}\left(\frac{1}{4a}\right) = \frac{0.0180}{a}}$$

— (8)

$$\frac{1}{r_{vac}} = \frac{\hbar}{2mca}\left(\frac{1}{2r}-\frac{1}{8a}+\frac{1}{2r}-\frac{a}{r^2}\right)$$

$$\boxed{\frac{1}{r_{vac}} = \frac{\hbar}{2mca}\left(\frac{1}{r}-\frac{1}{8a}-\frac{a}{r^2}\right)}$$