d) From a) $\theta - \frac{\Omega t}{2} = \phi$, $J = I$

$\therefore \theta = \phi + \frac{\Omega t}{2}$ $\quad = 1-\gamma$

You should state that the stable fixed point of $\bar{K}$ is equivalent to a stable periodic orbit in the original representation

$q = \sqrt{2I}\sin\theta$
$\quad = \sqrt{2(1-\gamma)}\sin\left(\frac{\Omega t}{2} + \phi\right)$

$p = \sqrt{2I}\cos\theta$
$\quad = \sqrt{2(1-\gamma)}\cos\left(\frac{\Omega t}{2} + \phi\right)$

where $\gamma = \frac{4}{\varepsilon}\left(1 - \frac{\Omega}{2}\right)$

In c) we expanded the Hamiltonian around the stable fixed point

$\bar{K} = \frac{\varepsilon(1-\gamma)}{2}(\phi - \phi_f)^2 + \frac{\varepsilon}{8}(J - J_f)^2$

where $4\phi_f = -\pi \Rightarrow \phi_f = -\frac{\pi}{4}$

$J_f = 1-\gamma$.

Put $\phi - \phi_f = X \Rightarrow \dot{\phi} = \dot{X}$

$J - J_f = Y \Rightarrow \dot{J} = \dot{Y}$

$\bar{K} = \frac{\varepsilon(1-\gamma)}{2}X^2 + \frac{\varepsilon}{8}Y^2$

$\dot{X} = \frac{\partial \bar{K}}{\partial Y} = \frac{\varepsilon Y}{4}$ $\quad \dot{Y} = -\frac{\partial \bar{K}}{\partial X} = -\varepsilon(1-\gamma)X$

3/4

$\ddot{X} = \frac{\varepsilon \dot{Y}}{4} \Rightarrow \ddot{X} = -\frac{\varepsilon^2}{4}(1-\gamma)X$

$\ddot{X} + \frac{\varepsilon^2}{4}(1-\gamma)X = 0$

$X = A\sin\left(\frac{\varepsilon t\sqrt{1-\gamma}}{2} + \delta\right)$

$\dot{Y} = -\varepsilon(1-\gamma)X = -\varepsilon(1-\gamma)A\sin\left(\frac{\varepsilon t}{2}\sqrt{1-\gamma} + \delta\right)$

$Y = 2\sqrt{1-\gamma}\,A\cos\left(\frac{\varepsilon t}{2}\sqrt{1-\gamma} + \delta\right)$

$\phi = \phi_f + X$
$\quad = -\frac{\pi}{4} + A\sin\left(\frac{\varepsilon t}{2}\sqrt{1-\gamma} + \delta\right)$

$J = J_f + Y$
$\quad = (1-\gamma) + 2\sqrt{1-\gamma}\,A\cos\left(\frac{\varepsilon t}{2}\sqrt{1-\gamma} + \delta\right)$