1. The amplitude is 5 [cm], so $x_{\text{min}} = x_0 - A = 15$ [cm]
2. Energy is conserved, so $1/2kA^2 = 1/2mv^2$, or $v = \omega A = 2\pi f A = 0.44$ [m]
3. $v = \omega r$, so $\omega = v/r = 114$ [rad/s]
4. $v = dx/dt = -A\exp(-\lambda t)[\lambda\cos(\omega t) + \omega\sin(\omega t)]\ \hat{x}$
5. $K = mv^2/2 = mA^2\cos^2(\omega t)\exp(-2\lambda t)/2$
6. If the motion is uniform, then there is no change in velocity after one cycle, so the work is 0:

$$W = \int_\ell F \cdot d\ell = \int_\ell -\frac{mv^2}{r}\hat{r}\cdot\hat{r}_\perp\ d\ell = -\frac{mv^2}{r}\int_\ell \cos(\pi/2)\ d\ell = -\frac{mv^2}{r}\int_\ell 0\ d\ell = 0$$

7. Using energy conservation $kA^2/2 = kx_0^2/2 + mv_0^2/2$, or $A = \sqrt{(kx_0^2 + mv_0^2)/k}$
8. $v = dx/dt = A\omega\cos(\text{stuff that ranges from } -\pi \text{ to } \pi)$, so $v_{\text{max}} = A\omega$, or see (2)
9. $K = mv^2/2 = m^2v^2/2m = p^2/2m$
10. $T = 1/f = 2\pi/\omega = 2\pi\sqrt{\ell/g} \approx 2\sqrt{\ell}$, so $\ell = 1/4$, and we demand $m > 0$ and $\theta > 0$
11. Forces balance so $ky - mg = 0$, or with $y = \ell - \ell_0$, $\ell - \ell_0 = mg/k$. Subsequent oscillations are:

$$y(t) = \ell + (\ell_0 - \ell)\cos(\sqrt{k/m}\ t)$$

12. $F = ma$ and $F = -kx - ax^3$, so $m\ddot{x} + 0\dot{x} + (k + ax^2)x = 0$, which is a nonlinear differential equation
13. Use the method of characteristic equations:

$$F = ma = -kx - bv$$
$$m\lambda^2 + b\lambda + k = 0$$
$$\lambda_\pm = \frac{-b \pm \sqrt{b^2 - 4mk}}{2m}$$
$$x(t) = \alpha_+ e^{\lambda_+ t} + \alpha_- e^{\lambda_- t}$$

With initial conditions:

$$\alpha_+ + \alpha_- = 0$$
$$\alpha_+\lambda_+ + \alpha_-\lambda_- = 1$$
$$\alpha_+ = \frac{1}{\lambda_+ - \lambda_-}; \qquad \alpha_- = \frac{1}{\lambda_- - \lambda_+}$$

14. As $\omega_d \to \omega$, $(k - m\omega_d) \to 0$, so if b is small, the amplitude of oscillations may become (catastrophically) large
15. $\omega_d = 2\pi f_d = 2\pi 120/60 = 4\pi$, with $g \approx 10$, $F_d = mg = 40 \cdot 60 \cdot 10$, so:

$$A = \frac{2400}{\sqrt{(10^6 - 10^5(4\pi)^2)^2 + (4\pi\ 10^4)^2}} = 0.000162 \text{ [m]}$$