

1a) $m_f v_f = (m_f + m_a) v_0$

$$v_0 = \frac{m_f}{(m_f + m_a)} v_f = \frac{0,02 \times 60}{2} = 0,6 \text{ m/s}$$

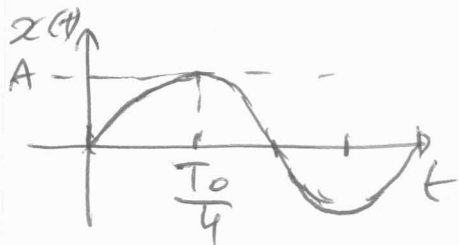
$$\frac{1}{2} m v_0^2 = \frac{1}{2} (2k) A^2 \quad \boxed{A = 0,1 \text{ m}} = 2 \text{ mm}$$

$$m = (m_f + m_a) = 2 \text{ kg} \quad \left(\frac{m v_0^2}{2 A^2} \right) = k$$

$$k = \frac{2 \times 0,6^2}{2 (0,1)^2} = 0,36 \times 100 = \boxed{36 \text{ N/m}}$$

$$\omega_0 = \sqrt{\frac{2k}{m}} = \sqrt{\frac{2 \times 36}{2}} = 6 \text{ rad/s}$$

$$T_0 = \frac{2\pi}{\omega_0} = \frac{6,28}{6} = \boxed{1,047 \text{ s}}$$



$$t_1 = \frac{T_0}{4} = \boxed{0,262 \text{ s}}$$

b) $x(t) = A \sin(\omega_0 t)$ $\omega_0 t_2 = \frac{2\pi}{T_0} \cdot \frac{T_0}{12} = \frac{\pi}{6}$

$$\sin\left(\frac{\pi}{6}\right) = 0,5$$

$$\boxed{x(t_2) = \frac{A}{2} = 0,05 \text{ m}}$$

$$v(t) = A \omega_0 \cos(\omega_0 t)$$

$$v(t_2) = 0,1 \times 6 \times \frac{\sqrt{3}}{2} = \boxed{0,520 \text{ m/s}}$$



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c) sub-crítico

$$A(t) = A_0 e^{-\frac{\gamma}{2} t}$$

$$0,9 = \frac{A}{A_0} = e^{-\frac{\gamma}{2} \times 15}$$

$$\ln 0,9 = -7,5 \frac{\gamma}{2}$$

$$\boxed{\gamma = 0,0140 \text{ s}^{-1}}$$

$$\frac{A(T_0)}{A_0} = e^{-\frac{\gamma}{2} T_0} = e^{-0,007 \times 1,047} = 0,993$$

$$\frac{|\Delta E|}{E} = \frac{\Delta(A^2)}{A^2} = 1 - (0,993)^2 = \boxed{0,0146}$$

$$\frac{|\Delta E|}{E} = 1,46\%$$

d) $A(\omega) = 0,1 \times 10^{-3} = 10^{-4} \text{ m}$

$$A(\omega) = \frac{F_0/m}{\sqrt{(\omega^2 - \omega_0^2)^2 + \gamma^2 \omega^2}}$$

$$\gamma = 0,014$$

$$\omega = 2\pi f$$

$$\omega_0 = 6 \text{ rad/s}$$

$$f = \frac{1800}{60} = 30 \text{ Hz}$$

$$\omega = 30 \times 2\pi = 188,4 \text{ rad/s}$$

$$\omega^2 - \omega_0^2 \approx \omega^2 = 35500 \text{ rad}^2/\text{s}^2 \gg \gamma \omega$$

~~.....~~ $F_0 = m A \omega^2 = 2 \times 10^{-4} \times 35.500$

$$\boxed{F_0 = 7 \text{ N}}$$

e) $\omega = \omega_0 \Rightarrow A = \frac{F_0/m}{\gamma \omega_0} = \frac{7/2}{0,014 \times 6}$

$$\boxed{A = 41,7 \text{ m!}}$$

f) Amort - crítico
($\omega_0 = \frac{\gamma}{2}$)

$$\boxed{\gamma_c = 2\omega_0 = 12 \text{ s}^{-1}}$$