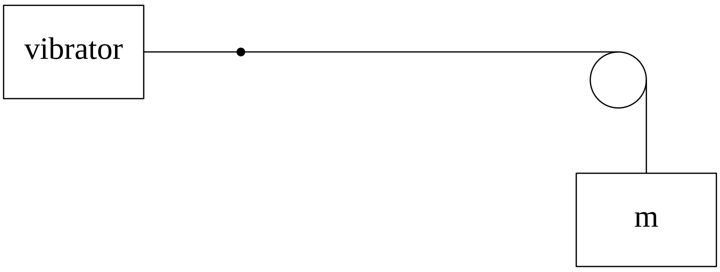
4. (25 pts.) A string of mass 0.005 kg and total length 2.5 m is connected to a vibrator at one end, passes over a light pulley, and is attached to a hanging mass at the other end. The distance from the vibrator to the pulley is 2.0 m.



a. (15 pts.) When the hanging mass is 16 kg, standing waves with 4 loops are observed. What is the frequency of the vibrator?

b. (10 pts.) If the frequency of the vibrator is unchanged, what hanging mass would be required to give rise to standing waves with 3 loops?

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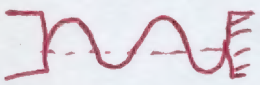

$L = 2\lambda \Rightarrow \lambda = \frac{1}{2}L = 1.0\,m$

$f = \frac{v}{\lambda}, \quad v = \sqrt{\frac{F_T}{\mu}} = \sqrt{\frac{mg}{0.005\,kg/2.5\,m}}$

$v = \sqrt{\frac{(16)(9.8)}{0.005/2.5}} = 280\,m/s$

$f = \frac{v}{\lambda} = \boxed{280\,Hz}$

$\mu = 0.002\,kg/m.$

b. (10 pts.) If the frequency of the vibrator is unchanged, what hanging mass would be required to give rise to standing waves with 3 loops?

$L = \frac{3}{2}\lambda \Rightarrow \lambda = \frac{2}{3}L = 1.33\,m$

$f = 280\,Hz$ still

$v = f\lambda = 373\,m/s$

$v = \sqrt{F_T/\mu} \Rightarrow F_T = \mu v^2 = \left(\frac{0.005}{2.5}\right)(373)^2$

$F_T = 279\,N = m_3 g \Rightarrow \boxed{m_3 = 28.4\,kg}$