PART A -

1. 

3. 

2. \[ w_s = 16.75 \text{ rad/s}, \quad (f_s = 2.67 \text{ Hz}) \]

\[ w_s = \omega_n = \sqrt{\frac{k}{M+m}} \]

4. 

5. 

There is always some form of bow wave...
PART B-

a) **Terminal Velocity**

\[ F_{\text{drag}} = \frac{1}{2} \rho U^2 C_D A \]
\[ F_B = \frac{1}{4} \rho g A \]
\[ F_g = 1.5 \rho w g A \]
\[ V = \pi d^2 L \]

\[ A = dl \]

@ **Terminal Vel** \( \Sigma F = ma = 0 \)

\[ \Sigma F = F_g - F_B - F_D = 0 \]

\[ F_D = F_g - F_B = \frac{1}{2} \rho w g V = 157 N \]

\[ \frac{V^2}{\left( \frac{1}{2} \rho C_D d \cdot L \right)} = \frac{1}{4} \rho g \pi d^2 / 4 \]

\[ u = \sqrt{\frac{\pi g d}{4C_D}} = \sqrt{0.57/C_D} \]

Laminar \( C_D = 1.2 \quad u = 1.14 \text{ m/s} \quad Re = 228,000 \)

Turb \( C_D = 0.6 \quad u = 1.62 \text{ m/s} \quad Re = 324,000 \)

Wow! V. close could be either, so it ultimately depends on cylinder roughness - either ensurer gets credit.

b) @ \( u = 1.14 \text{ m/s} \quad f = 1.14 \text{ hz} \quad f = \frac{\Delta U}{0.2} u \)
\[ u = 1.62 \text{ m/s} \quad f = 1.62 \text{ hz} \]
PART B

1. Assume \( s = 0.2 = \frac{f d}{u} \)

2. \( f = \frac{0.2 \cdot 1.0}{0.5} \)
   \( f_{\text{top}} = 0.1 \times f_{\text{top}} \)
   \( f_{\text{top}} = 0.4 \) Hz
   \( f_{\text{bottom}} = 0.04 \) Hz

3. b) Frequency of drag is 2 freq of vortex shedding.
   Frequency of lift is = freq of vortex shedding.
   Therefore it directly correlates w/ flow velocity.

4. c) The structure will tend to vibrate more at top exciting forced motion @ bottom. In both cases frequency is low so it's not going to be too violent.
   Shear will complicate shedding & make flow more 3-dimensional.

5. d) Flexible cylinder

   \[ u \rightarrow 0 \rightarrow \text{figure 8} \rightarrow u \uparrow \]
   Figure 8:
   Higher vel, tension up
   motion
   and inline vibe down