Problem 3.

(a) \( A = \frac{F}{M}, \alpha = 0, \)  
\[
W(t) = \Delta T(t) = \frac{F^2 t^2}{2M}.
\]

(b) \( A = \frac{F}{M}, \alpha = \frac{2F}{(MR)}, \)  
\[
W(t) = \Delta T(t) = \frac{3F^2 t^2}{2M}.
\]

(c) \( A = \frac{2F}{(3M)}, \alpha = \frac{2F}{(3MR)}, \)  
\[
W(t) = \Delta T(t) = \frac{F^2 t^2}{3M}.
\]

(d) \( A = \frac{4F}{(3M)}, \alpha = \frac{4F}{(3MR)}, \)  
\[
W(t) = \Delta T(t) = \frac{4F^2 t^2}{3M}.
\]

The frictional force is to the right.

(e) \( A = \frac{2F(R - r)}{(3MR)}, \alpha = \frac{2F(R - r)}{(3MR^2)}, \)  
\[
W(t) = \Delta T(t) = \frac{4F^2 t^2}{3M}.
\]

The frictional force is to the left.

(The explicit results for \( W(t) \) and \( \Delta T(t) \) are under the assumptions that \( F \) is constant, that it acts for a time \( t \), and that the system is at rest at time \( t = 0 \).)

Problem 4.

(a) magnitude of \( \vec{u}_1 \):  
\[
\vec{u}_1 = \frac{m_1 \cos \theta + \sqrt{m_2^2 - m_1^2 \sin^2 \theta}}{m_1 + m_2}.
\]

(b) velocity of center of mass:  
\[
\vec{v}_{cm} = \frac{m_1}{m_1 + m_2} \vec{v}_1.
\]

(c) initial and final velocities in center-of-mass frame:  
\[
\vec{v}_1' = \frac{m_2}{m_1 + m_2} \vec{v}_1, \\
\vec{v}_2' = -\frac{m_1}{m_1 + m_2} \vec{v}_1, \\
\vec{u}_1' = \vec{u}_1 - \frac{m_2}{m_1 + m_2} \vec{v}_1,
\]
\[ \ddot{u}_2' = \frac{m_1^2}{m_2(m_1 + m_2)} \ddot{v}_1 - \frac{m_1}{m_2} \ddot{u}_1, \]

scattering angle:
\[ \cos \theta' = \sqrt{1 - \frac{m_1^2}{m_2^2} \sin^2 \theta} \cos \theta - \frac{m_1}{m_2} \sin^2 \theta. \]

Problem 6
\[
(m_E + m_M) \ddot{X} = -Gm_S (m_E + m_M) \frac{\ddot{X}}{X^3}
- Gm_S (m_E - m_M) \left( \frac{\ddot{X}}{X^3} - 3 \frac{(\ddot{X} \cdot \dddot{X}) \dddot{X}}{X^5} \right) + \ldots,
\]
\[
\frac{m_E m_M}{m_E + m_M} \ddot{\dddot{x}} = -Gm_E m_M \frac{\dddot{x}}{\dot{x}^3}
- \frac{Gm_S m_E m_M}{m_E + m_M} \left( \frac{\dddot{x}}{\dot{x}^3} - 3 \frac{(\dddot{x} \cdot \dddot{X}) \dddot{X}}{X^5} \right) + \ldots.
\]

Problem 9
general solution:
\[
x(t) = x_0 + \frac{m}{\alpha} \ddot{x}_0 \left( 1 - e^{-\frac{\alpha}{m} t} \right),
\]
\[
y(t) = y_0 + \frac{m}{\alpha} y_0 \left( 1 - e^{-\frac{\alpha}{m} t} \right),
\]
\[
z(t) = z_0 - \frac{m g}{\alpha} t + \frac{m}{\alpha} \left( \ddot{z}_0 - \frac{m g}{\alpha} \right) \left( 1 - e^{-\frac{\alpha}{m} t} \right).
\]
terminal velocity: \(-\frac{m g}{\alpha} \dddot{z}.\)