Answers for José and Saletan, Chapter 1

Problem 3.

(a) $A = F/M$,
$\alpha = 0$,
$W(t) = \Delta T(t) = F^2t^2/(2M)$.

(b) $A = F/M$,
$\alpha = 2F/(MR)$,
$W(t) = \Delta T(t) = 3F^2t^2/(2M)$.

(c) $A = 2F/(3M)$,
$\alpha = 2F/(3MR)$,
$W(t) = \Delta T(t) = F^2t^2/(3M)$.

(d) $A = 4F/(3M)$,
$\alpha = 4F/(3MR)$,
$W(t) = \Delta T(t) = 4F^2t^2/(3M)$.
The frictional force is to the right.

(e) $A = 2F(R - r)/(3MR)$,
$\alpha = 2F(R - r)/(3MR^2)$,
$W(t) = \Delta T(t) = 4F^2t^2/(3M)$.
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 $\vec{u}_1$:

$$u_1 = \frac{m_1 \cos\theta + \sqrt{m_2^2 - m_1^2 \sin^2\theta}}{m_1 + m_2}.$$

(b) velocity of center of mass:

$$\vec{v}_{\rm cm} = \frac{m_1}{m_1 + m_2}\vec{v}_1.$$

(c) initial and final velocities in center-of-mass frame:

$$\begin{aligned}
\vec{v}_1^{\,\prime} &= \frac{m_2}{m_1 + m_2}\vec{v}_1, \\
\vec{v}_2^{\,\prime} &= -\frac{m_1}{m_1 + m_2}\vec{v}_1, \\
\vec{u}_1^{\,\prime} &= \vec{u}_1 - \frac{m_2}{m_1 + m_2}\vec{v}_1,
\end{aligned}$$

$$
\vec{u}_2^{\,\prime} = \frac{m_1^2}{m_2(m_1+m_2)}\vec{v}_1 - \frac{m_1}{m_2}\vec{u}_1,
$$

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

$$
\begin{aligned}
(m_E+m_M)\ddot{\vec{X}} &= -Gm_S(m_E+m_M)\frac{\vec{X}}{X^3} \\
&\quad -Gm_S(m_E-m_M)\left(\frac{\vec{x}}{X^3} - 3\frac{(\vec{x}\cdot\vec{X})\vec{X}}{X^5}\right) + \ldots, \\
\frac{m_E m_M}{m_E+m_M}\ddot{\vec{x}} &= -Gm_E m_M\frac{\vec{x}}{x^3} \\
&\quad -\frac{Gm_S m_E m_M}{m_E+m_M}\left(\frac{\vec{x}}{X^3} - 3\frac{(\vec{x}\cdot\vec{X})\vec{X}}{X^5}\right) + \ldots.
\end{aligned}
$$

Problem 9

general solution:

$$
\begin{aligned}
x(t) &= x_0 + \frac{m}{\alpha}\dot{x}_0\left(1-e^{-(\alpha/m)t}\right), \\
y(t) &= y_0 + \frac{m}{\alpha}\dot{y}_0\left(1-e^{-(\alpha/m)t}\right), \\
z(t) &= z_0 - \frac{mg}{\alpha}t + \frac{m}{\alpha}\left(\dot{z}_0 - \frac{mg}{\alpha}\right)\left(1-e^{-(\alpha/m)t}\right).
\end{aligned}
$$

terminal velocity: $-(mg/\alpha)\hat{z}$.