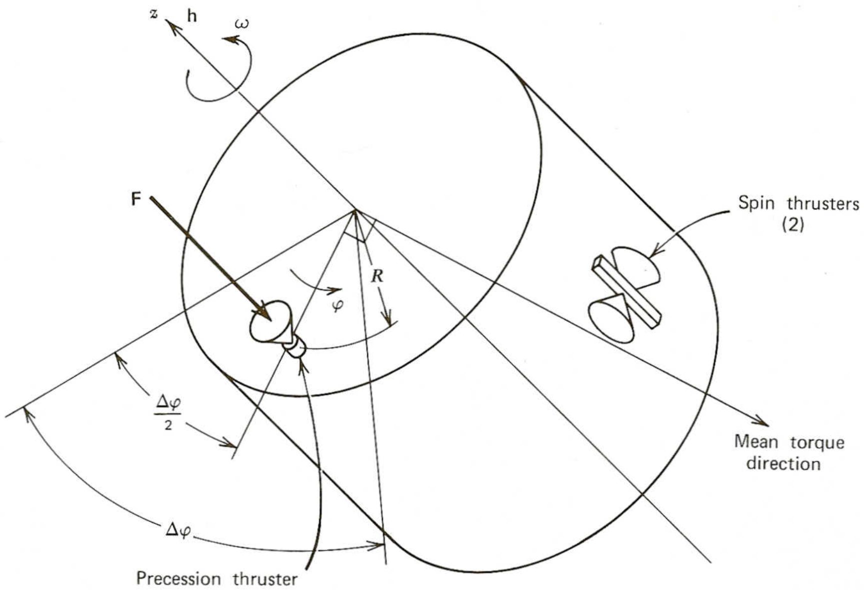

FIGURE 4.2 Momentum precession and spin thruster locations.

to the thrust impulse,

$$I_{\text{thrust}} = 2\int_0^{\Delta\phi/2} F\frac{d\phi}{\omega} = \frac{F\Delta\phi}{\omega} \tag{4.2}$$

by taking the ratio

$$\frac{I_{\text{torque}}}{I_{\text{thrust}}} = R\frac{\sin\left(\frac{\Delta\phi}{2}\right)}{\left(\frac{\Delta\phi}{2}\right)} \tag{4.3}$$

Notice that the ideal torque impulse is RI_{thrust}. Degradation of thrust utilization efficiency is vividly depicted in Figure 4.3. It is apparent that a high level of thrust is desirable for a specified impulse. If this interval of thrust is repeated in synchronism with the spin rate, the momentum vector can be precessed through any desired angle. Each torque impulse corresponds to a rotation of **h** through an angle approximated by I_{torque}/h.

There are many missions which require adjustment of the momentum magnitude, that is, spin adjustment. Several methods have been developed for accomplishing this. The use of thrusters mounted normal to the spin axis, as

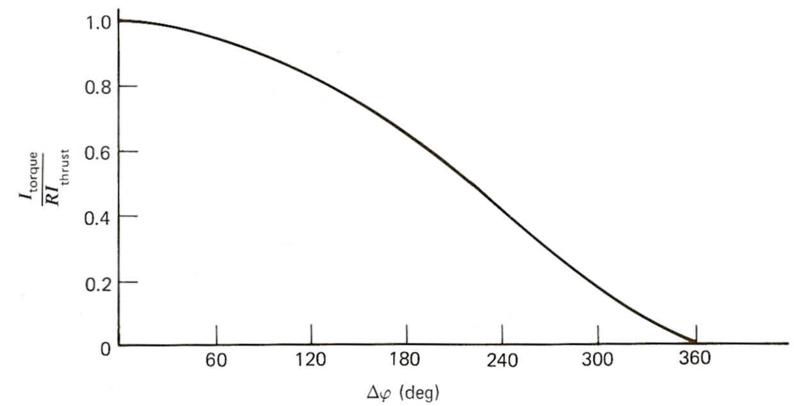

FIGURE 4.3 Thrust effectiveness in momentum precession.

shown in Figure 4.2, is typical. Two such thrusters are required if upward and downward adjustments are to be made. Expendable mass devices, called *yo-yos*, have been used extensively for completely despinning payloads. These are discussed in Section 5.3.

4.2 REORIENTATION WITH CONSTANT MOMENTUM

4.2.1 Energy Dissipation Effects

Many spacecraft have experienced reorientations without the use of thrusters. Unfortunately, a large portion of these were unwanted and unexpected maneuvers caused by unanticipated energy dissipation. This section surveys the adverse effects of energy dissipation and is followed by a potential application of reorientation via dissipation. Early spacecraft designs were small and mechanically simple, and were therefore treated as rigid bodies when predicting attitude motion. Even Explorer I, the first U.S. satellite, defied this simplified approach and quickly tumbled end over end, as described in Section 2.5. Since then spacecraft builders have been aware of the dangers associated with the rigid body assumption. Nevertheless, there have since been several cases of anomalous behavior due to structural flexibility and/or dissipation. Table 4.1 lists just four of the many cases. Notice that in the second and third examples a reduction of angular momentum was experienced as a result of periodic structural bending. Solar energy produced this flexing and solar pressure torques caused a net despin over a large number of spacecraft revolutions. Of particular interest is the sequence of events associated with Applications