

8.9 *Landing Aircraft*

An aircraft lands at a speed v . Before it touches down, its wheels are not rotating. Describe in words what happens when the wheels touch the ground. Assuming that each wheel has radius R and moment of inertia I and supports a weight Mg , and that the pilot does not apply reverse thrust until the aircraft is no longer skidding, how fast is the plane moving when it stops skidding?

~~8.10 *Toy Gyroscope* page 353, problem 50~~

~~8.11 *Flywheel to Stabilize Ship* page 353, problem 51~~

~~8.12 *Spin Stabilization*~~

~~Angular momentum can make a freely moving object remarkably stable. To analyze the effect of spin, consider a cylinder (mass m , length l , and radius r) moving freely in space. Suppose that a small perturbing constant force F acts on the cylinder for time Δt . F is perpendicular to the cylindrical axis of symmetry, and the point of application is a distance d from the center of mass. We want you to first consider the case where the cylinder has zero spin about its axis of symmetry.~~

~~a) Calculate the precession angular velocity ω which results from this impulse.~~

~~Now consider the same situation except that the cylinder is rapidly spinning about its axis with angular momentum L .~~

~~b) Calculate the angle through which the cylinder precesses in time Δt . Notice the cylinder now slightly changes its orientation while the force is applied and then stops precessing. The faster the spin, the smaller is the angle, and thus the smaller is the effect of the perturbing force.~~

Problem 8.9

Initially the plane is moving too fast and the tires too slow to satisfy the rolling constraint. Friction acts on the wheels. This creates a linear acceleration that slows the plane down and an angular acceleration that spins the tires. At some moment the linear speed of the plane and angular speed of the tires are appropriate for rolling. Static friction will then maintain the rolling.

Each tire supports a weight Mg where the total mass is given by $M_{TOT} = nM$ where n is the number of tires. Now suppose the runway exerts a friction force F_{fric} on each tire. The force equation for the plane is

$$nMa = nF_{\text{fric}} \quad \implies \quad a = \frac{F_{\text{fric}}}{M}$$

The friction force while sliding is constant; hence the velocity is given by

$$v = v_0 - at = v_0 - \frac{F_{\text{fric}}}{M} \cdot t$$

The torque equation (about the center of a tire) is

$$I\alpha = RF_{\text{fric}} \quad \implies \quad \alpha = \frac{RF_{\text{fric}}}{I}$$

Again, the friction force is constant; hence the angular velocity is given by

$$\omega = \frac{RF_{\text{fric}}}{I} \cdot t$$

Rolling occurs when

$$v = R\omega \quad \implies \quad v_0 - \frac{F_{\text{fric}}}{M} \cdot t = R \cdot \frac{RF_{\text{fric}}}{I} \cdot t$$

The solution to the above equation is

$$t = \frac{v_0}{F_{\text{fric}} \left(\frac{1}{M} + \frac{R^2}{I} \right)}$$

The velocity at this time is

$$v = v_0 \cdot \frac{\frac{MR^2}{I}}{1 + \frac{MR^2}{I}} = \frac{v_0}{1 + \frac{I}{MR^2}}$$