Lecture 7

Physics 106
Fall 2006

Intro to Equilibrium

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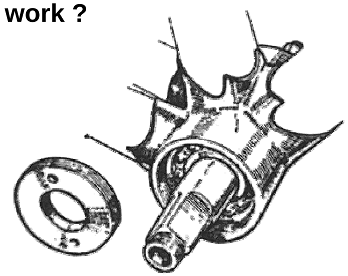
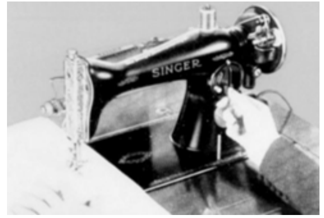
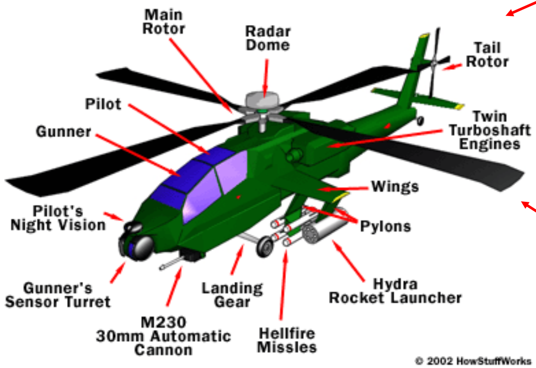
How things work ?

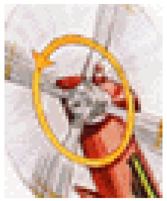




How does it fly ?

anti-torque tail rotor





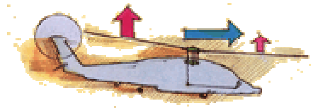
Main rotor

Who is this person?

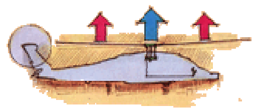
a) Von Zeppelin
b) One of the Wright brothers
c) Igor Sikorsky

Igor Sikorsky
(1889- 1972)
First experiment: 1909
Since 1920's: Stratford, CO

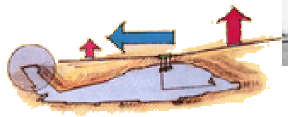
FORWARD



TAKEOFF AND HOVER



BACKWARD



Main rotor

(1931 – 1942)
In WWII: combat rescue and Medevac missions

Equilibrium

Equilibrium

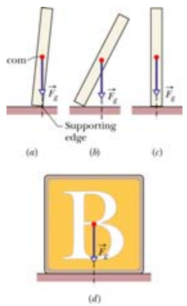
Balance of Forces:

$$\vec{F}_{\text{net}} = \frac{d\vec{P}}{dt} = 0$$

Balance of Torques:

$$\vec{\tau}_{\text{net}} = \frac{d\vec{L}}{dt} = 0$$

$$\vec{P} = 0$$



1. The vector sum of all the external forces that act on the body must be zero.
2. The vector sum of all the external torques that act on the body, measured about any possible point, must be zero.
3. The linear momentum $\underline{P}$ of the body must be zero.
4. The gravitational force $\underline{F}_g$ on a body effectively acts on a single point, called the center of gravity (cog) of the body. If g is the same for all elements of the body, then the body's cog is coincident with the body's center of mass.

Equilibrium

Balance of Forces:

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Balance of Torques:

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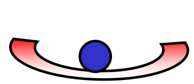
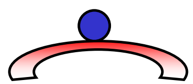
$$\vec{P} = 0$$

Stable vs. Unstable Static Equilibrium

An equilibrium point is stable if small changes in the position lead to restoring forces back to equilibrium.

If it moves away from the equilibrium point when displaced slightly, it is unstable.





Equilibrium

Balance of Forces:

$$\vec{F}_{\text{net}} = \frac{d\vec{P}}{dt} = 0$$

Balance of Torques:

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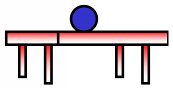
Indeterminate Equilibria

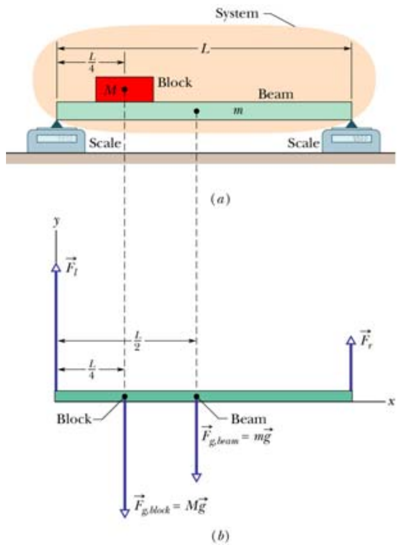
If the force and torque equations lead to more unknown forces than equations, there are an infinite number of solutions.

Examples: Four-legged table
Two axle trailer



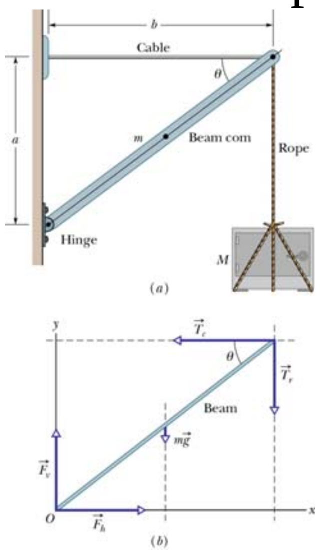
Detailed material properties and history determine the forces.

Sample Problem XIII – 1



A uniform beam of length *L* and mass *m* = 1.8 kg is at rest with its ends on two scales. A uniform block with mass *M* = 2.7 kg is at rest on the beam, with its center a distance *L*/4 from the beam's left end. What do the scales read?

Sample Problem XIII – 3



A safe of mass *M* = 430 kg is hanging by a rope from a boom with dimensions *a* = 1.9 m and *b* = 2.5 m. The boom consists of a hinged beam and a horizontal cable that connects the beam to a wall. The uniform beam has a mass *m* = 85 kg. The masses of the cable and the rope are negligible.

a) What are the tension T_c in the cable? In other words, what is the magnitude of the force $\underline{T}_c$ on the beam from the cable?

b) Find the magnitude *F* of the net force on the beam from the hinge.