Phys 131 2023

Lecture 34

Tues: Warm Up 13

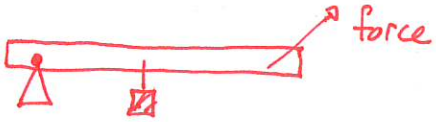
Thurs: Discussion / quiz

Ex: 278, 280, 281, 285, 287, 288, 289

Rotational effects of forces

Forces that act on an object can affect its rotational state of motion

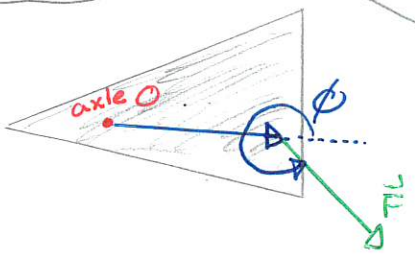
Demo:



The demonstration shows that the rotational effects of the force depend on

1) magnitude of the force
2) point at which force acts
3) angle at which the force acts.

These are included in a new quantity: torque.



Identify the force acting and its location on the object

1) Choose a reference point O (usually an axle or pivot)
2) draw a vector $\vec{r}$ from O to the point where the force acts. Extend this line.
3) let ϕ the angle c.c.w. from the extension to $\vec{F}$
4) The "torque produced by $\vec{F}$ about O" is

$$\tau = r F \sin\phi \qquad \text{Units: Nm}$$

Torques will determine angular acceleration

5) Force tends to change angular velocity $\Rightarrow$ angular acceleration

Warm Up 2 (from last Thurs).

Note: 1) in the definition r, F are never negative

2) the torque can be positive or negative as the result of the angle ϕ.

$0° \leq \phi \leq 180° \Rightarrow \tau \geq 0 \rightsquigarrow$ counterclockwise

$180° \leq \phi \leq 360° \Rightarrow \tau \leq 0 \rightsquigarrow$ clockwise.

When multiple torques act on an object, the net torque is:

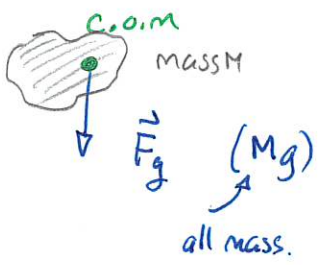
$$\tau = \tau_1 + \tau_2 + \ldots = \sum_{\text{all forces}} \tau_i$$

Quiz! 50% → 80% } 50%-80%

One special situation with rigid objects regards the gravitational force.

For a rigid object the gravitational force acts at the center-of-mass.

The torque produced by the gravitational forces acting on all parts of the object is the same as the torque produced by a single downward with magnitude Mg acting at the center-of-mass.



Equilibrium

An object is in static equilibrium if it is either

1) at rest or
2) moves with constant linear velocity (center-of-mass) and constant angular velocity.

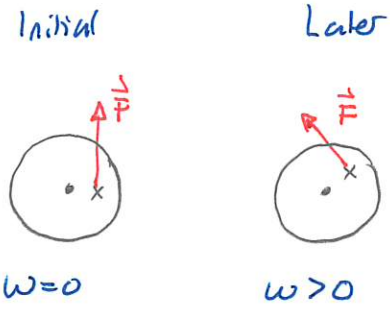
Then:

An object is in static equilibrium $\Leftrightarrow \vec{F}_{net} = 0$ and $\tau_{net} = 0$

Quiz 3

Torques and dynamics

Suppose that there is only one force acting on an object that produces non-zero torque. Observations will show



Non-zero net torque produces changes in angular velocity

↳ $\tau_{net} \neq 0 \Rightarrow \alpha \neq 0$

↳ Angular acceleration is proportional to net torque

↳ $\tau_{net} = I\alpha$

where I is a constant that depends on the mass arrangement.

We aim to formalize this, in principle, starting with Newton's 2nd and 3rd Laws.