Introduction to Mechatronics Terms

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Outline

Where are we going today?

- Mass
- Acceleration/Velocity
- Force
- Torque
- Work/Power/Energy

This may or may not be physics review for you. If it is, skim through, make sure you're comfy. If not, let this be a fun first foray!

Mass

Sitting around like a bump on a log

- Mass (m) is "how much stuff is there?"
- Not weight, but we commonly correlate the two on earth
  - (ignoring buoyancy) things of the same mass weigh the same in a constant gravitational field

Examples

- Kilograms (kg)
- Slugs (slug)
- Pounds-mass (lbm)

Warning

Pounds-Mass is not the same unit as Pounds-Force!

Velocity and Speed

Gotta go Fast!

- Speed is how fast something is going- a scalar quantity
  - Scalar quantity
  - "Travelled 60 miles in one hour"
- Velocity (v) is how fast something is going in a direction
  - Vector quantity
  - "Travelling 30 MPH, Northeast"

Examples

- Miles per Hour (mph)
- Meters per Second (m/s)

Warning

Rotational speed / velocity are different quantities. We'll get there!

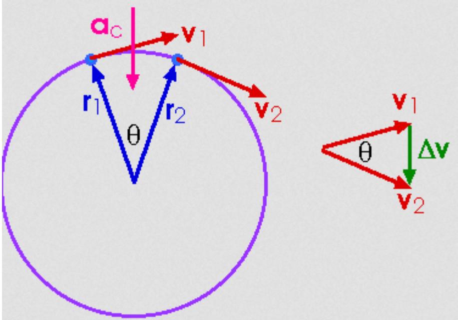
Acceleration

A thrill better than speed!

Acceleration (a) is how fast your velocity is changing.
If you accelerate from 30 ft/s to 10 ft/s in 4 s, that's

$$a = \frac{\Delta v}{\Delta t} = \frac{10 \text{ ft/s} - 30 \text{ ft/s}}{4s} = -5\frac{ft}{s^2}$$

Note: direction matters! You can have acceleration perpindicular to your movement. In the case of circular motion, this is known as centripetal acceleration. The tread of a spinning tire is always accelerating inwards.



Force

May the rate of change of momentum for a closed system be with you.

A long while ago, this fellow Newton had an idea: what if objects interacted with each other via forces? Turns out, it's at least a really good model.

Principle 1 - Proportionality

The net force F on an object causes acceleration inversely proportional to its mass.

$$\sum \vec{F} = m\vec{a} \tag{1}$$

Principle 2 - Reciprocity

When a force is imposed upon object A by B, B sees a force of equal magnitude and opposite direction.

$$[\sum \vec{F}]_{universe} = 0 \tag{2}$$

Rotational Terms

Let's put a twist on things!

We design a lot of things that spin, so we obviously need to describe them. There are three main units for rotation:

$$1 \text{ Revolution (rev)} = 2\pi \text{ Radian (rad)} = 360 \text{ Degree } (^\circ)$$

We can convert the surface AKA tangential position x of a wheel of radius r quite simply, but note that the angular position θ must be in radians.

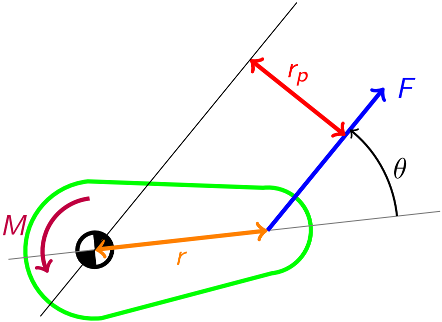
$$x = r \times \theta \tag{3}$$

Note

All points in a rigid body actually have the same rotational velocity, but may have different linear velocities.

Torques / Moments

A torque, often called a "Moment" (τ, T or M) is quite simply put, a force acting on a lever arm.



$$M = r\ F\ sin(\theta) \qquad (4)$$

or

$$M = r_p\ F \qquad (5)$$

Example

- Newton-Meters (N-m)
- Foot-Pounds (ft-lbf)
- Ounce-Inches (oz-in)

Moments of Inertia

Moments produce angular accleration α inversely proportional to the 'moment of inertia' I (sometimes abbreviated MOI)

$$M_{CG} = I_{CG}\alpha \tag{6}$$

The moment of inertia can be taken about anywhere, but taking it about the center of gravity (CG) makes things easier. The more mass, and the more it is spread out from the center, the higher the MOI.

Example

Moment of inertia of a flywheel

$$I_{CG,soliddisk} = \frac{mr^2}{2} \tag{7}$$

Energy

There's this little idea called 'energy' (E) that we came up with, and it too, seems to hold up as a useful model. There are a lot of different types of energy:

- Kinetic energy
- Gravitational potential energy
- Strain potential energy
- Sound energy
- Thermal energy
- Chemical energy
- Many more...

Units may be Joules (J), British Thermal Units (BTU). The dimensions are the same as $force \cdot length$.

Work

You can transfer energy from one thing to another by Work. Work is exerting a force F over a distance l.

$$\Delta E = W = F \cdot l \tag{8}$$

Work can also be transferred by rotational motion.

$$\Delta E = W = M \cdot \theta \tag{9}$$

Power

More power, more better

The rate at which work is done is power (P). Untis can be Watts (W), Horsepower (HP) amongst others. For example,

$$1 \text{ Watt} = \frac{1 \text{ Joule}}{1 \text{ second}}$$

Power can be calculating by looking at the force and velocity.

$$\frac{d}{dt}E = P = F \cdot v \tag{10}$$

$$\frac{d}{dt}E = P = M \cdot \omega \tag{11}$$