Last modification: January 17, 2020

RBE 1001: Introduction to Robotics
C-Term 2019-20
HW 2.1: Fundamentals of Mechanics – Static Analysis

1 Static analysis

In this course, we will concern ourselves with *static analysis*, where all of the forces and moments balance each other exactly, and the system is said to be in *equilibrium*. Though "static" implies that an object is at rest, in fact static analysis can be applied to a moving object so long as it is in equilibrium – accelerating neither in a linear nor angular sense. In this case, Newton's famous law, $\mathbf{F} = m\mathbf{a}$ reduces to the relatively "simple,"

$$\Sigma \mathbf{F} = 0 \tag{1}$$

That is, when in equilibrium, there is no acceleration, so the sum of all of the forces (reaction, applied, body) sum identically to zero. Note that because forces are vectors, in the two-dimensional case, Equation 1 represents two scalar equations,

$$\Sigma \mathrm{F}_x = 0$$
$$\Sigma \mathrm{F}_y = 0$$

That is, the x-component of all of the forces sum to zero, as do the y-components.

Similarly, because there is no angular acceleration (though angular motion is allowed), the sum of the moments must be zero:

$$\Sigma \mathrm{M}_z = 0 \tag{2}$$

where we've explicitly labelled the moments in the z-direction (assuming the forces are in the x,y plane).

We will spend a good deal of time applying the equations of equilibrium to our robots. Doing so will allow us to determine, for example, the motor torque needed lift an object or whether or not the robot will flip over when climbing a hill.

For more background on the equations of equilibrium and their application, see,

- *Statics For Dummies*, Chapters 16 - 17, available online through the Gordon Library.
- *Statics, Learning from Engineering Examples*, Section 4.1, available online through the Gordon Library.

1.1 Practice problems

In *Statics, Learning from Engineering Examples*:

- Prob. 4.1
- Prob. 4.2
- Prob. 4.13
- Prob. 4.15
- Prob. 4.24

Solutions to practice problems are provided elsewhere.

2 To submit

From *Statics, Learning from Engineering Examples*:

1. Prob. 4.34
2. Prob. 4.35