INTRODUCTION TO MECHANICAL ENGINEERING



Joshua P. Steimel
Cal Poly Humboldt



Introduction to Mechanical Engineering

This text is disseminated via the Open Education Resource (OER) LibreTexts Project (https://LibreTexts.org) and like the thousands of other texts available within this powerful platform, it is freely available for reading, printing, and "consuming."

The LibreTexts mission is to bring together students, faculty, and scholars in a collaborative effort to provide an accessible, and comprehensive platform that empowers our community to develop, curate, adapt, and adopt openly licensed resources and technologies; through these efforts we can reduce the financial burden born from traditional educational resource costs, ensuring education is more accessible for students and communities worldwide.

Most, but not all, pages in the library have licenses that may allow individuals to make changes, save, and print this book. Carefully consult the applicable license(s) before pursuing such effects. Instructors can adopt existing LibreTexts texts or Remix them to quickly build course-specific resources to meet the needs of their students. Unlike traditional textbooks, LibreTexts' web based origins allow powerful integration of advanced features and new technologies to support learning.



LibreTexts is the adaptable, user-friendly non-profit open education resource platform that educators trust for creating, customizing, and sharing accessible, interactive textbooks, adaptive homework, and ancillary materials. We collaborate with individuals and organizations to champion open education initiatives, support institutional publishing programs, drive curriculum development projects, and more.

The LibreTexts libraries are Powered by NICE CXone Expert and was supported by the Department of Education Open Textbook Pilot Project, the California Education Learning Lab, the UC Davis Office of the Provost, the UC Davis Library, the California State University Affordable Learning Solutions Program, and Merlot. This material is based upon work supported by the National Science Foundation under Grant No. 1246120, 1525057, and 1413739.

Any opinions, findings, and conclusions or recommendations expressed in this material are those of the author(s) and do not necessarily reflect the views of the National Science Foundation nor the US Department of Education.

Have questions or comments? For information about adoptions or adaptions contact info@LibreTexts.org or visit our main website at https://LibreTexts.org.

This text was compiled on 05/15/2026

TABLE OF CONTENTS

Licensing

Chapter 1: Introduction to Mechanical Engineering Discipline

Chapter 2: Statics

Chapter 3: Dynamics and Vibrations

Chapter 4: Materials Science and Engineering

Chapter 5: Controls and Robotics

Introduction to Mechanical Engineering Discipline

- Statics

Index

Glossary

Detailed Licensing

Licensing

*A detailed breakdown of this resource's licensing can be found in **Back Matter/Detailed Licensing**.*

Chapter 1: Introduction to Mechanical Engineering Discipline

Pre-recorded videos that cover this content in more details can be found in the YouTube playlist here: https://www.youtube.com/playlist?lis...EsEpCAAxcKQ5Dt.

Topics Covered in this Class

(1) **Part I:** Introduction to Mechanical Engineering

(2) **Part II:** Statics, Dynamics, Vibrations

(3) **Part III:** Materials, Thermodynamics, Heat Transfer, Controls, and Robotics

First of all congratulations on being accepted into the Mechanical Engineering Department at Cal Poly Humboldt! Mechanical engineering is one of the most difficult engineering disciplines and one of the most broad disciplines in engineering. As such you will be exposed to a tremendous amount of information but also we will go into great depth into a number of different subjects.

Mechanical engineering is a notoriously difficult disciplines at many R1 universities PhD programs will have written qualifying examinations for PhD candidates and the passing rate for these exams can be as low as 10%.

Here at Cal Poly Humboldt we will go into the same depth but we are here to help support you in your academic endeavors. We expect our students to exhibit a tremendous work ethic, intellectual curiosity, and a willingness to learn from both instructors and peers. We want our students to become trusted mechanical engineers and represent yourselves and Cal Poly Humboldt with pride!

Before we get started into the details of Mechanical Engineering at Cal Poly Humboldt it is important to consider an overview of Mechanical Engineering and the many different sub-disciplines of mechanical engineering. This is by no means a comprehensive list but here we will try to classify the sub-disciplines of mechanical engineering in three broad categories those being: **System Design**, **Energy**, and **Biomechanical Engineering**.

Mechanical Engineering Subdisciplines and Careers

We can break down mechanical engineering classes and careers into three broad categories as seen below in Fig.**1**

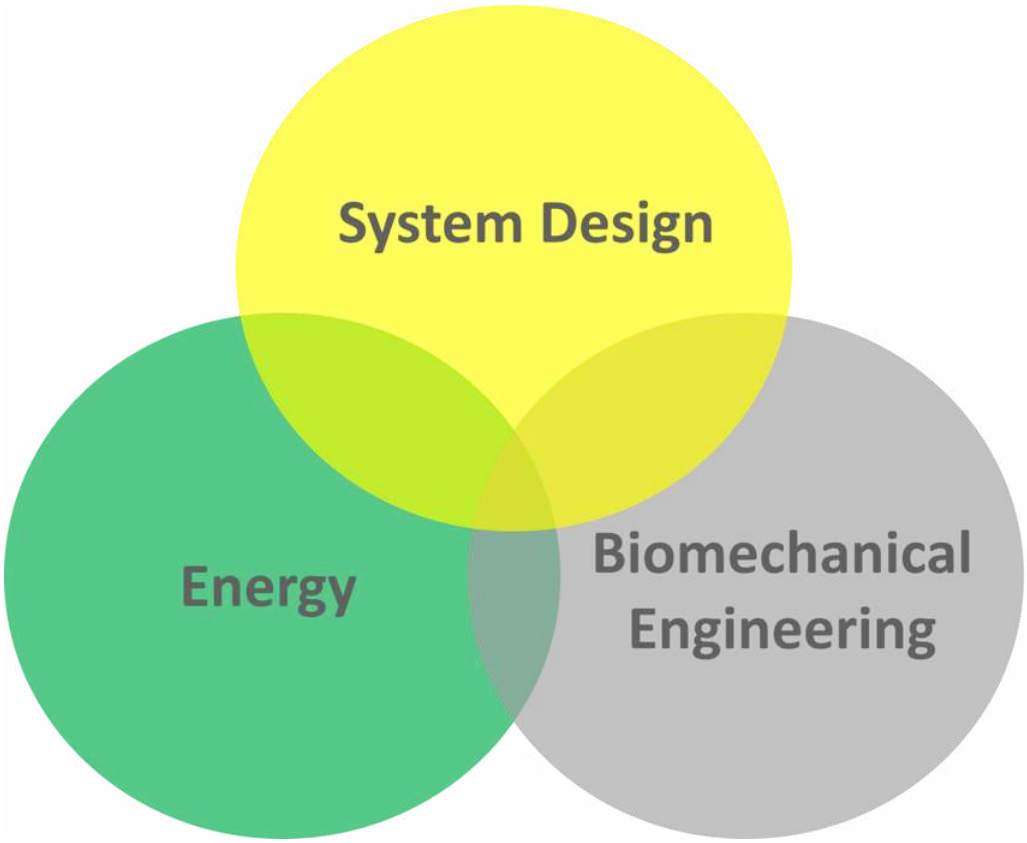


Figure $Chapter 1.1$: Mechanical Engineering Subdisciplines

System Design

The courses that are related to System Design in a mechanical engineering curriculum

- Statics
- Dynamics
- Vibrations
- Materials
- Manufacturing
- Machine Design
- Controls
- Robotics
- Instrumentation

The careers that one can pursue related to System Design include

- Robotics
- Aerospace
- Automotive
- Defense
- Electronics

Energy

The courses that are related to Energy in a mechanical engineering curriculum

• Thermodynamics

• Fluid Dynamics

• Heat Transfer

• Thermodynamics II

• FEM

The careers that one can pursue related to Energy include

• Heat/Thermal Analysis

• Battery Design

• Computational Fluid Dynamics

• Wind Energy

• Solar Energy

Biomechanical Engineering

The courses that are related to Energy in a mechanical engineering curriculum

• Manufacturing

• Materials

• Advanced Manufacturing

• Statics

• Dynamics

• Heat Transfer

• Solid Mechanics

• Advanced Materials

• Robotics

The careers that one can pursue related to Energy include

• Medical School

• Surgical Devices

• Robotic Surgical Systems

• Guiding Surgical Procedures

• Prosthetic Devices

Fundamental Mechanics

There are essential 5 fundamental mechanics courses that make up the foundation of the mechanical engineering curriculum which can be seen below

• Statics

• Dynamics

• Thermodynamics

• Solid Mechanics/Materials

• Fluid Mechanics

Statics will cover Newton's laws specifically Newton's 1st law and will deal with rigid objects under various loading states. You will learn about forces, reactant forces, bending, shear diagrams, trusses, and many many more topics. **Dynamics** will deal primarily with Newton's 2nd Law and you will consider bodies in motion and accelerating both translationally rotationally. **Thermodynamics** is a critical field of study that aims to find the lowest energy state of system and identifying the values of extensive thermodynamic variables that will lead to such a state. **Solid Mechanics and Materials** considers how materials deform under applied loads, thus taking fundamental statics concepts but now considering objects that are no longer rigid but instead are deforming. **Fluid Mechanics** considers the mechanics of fluid but it will also extend to concepts of heat transfer and material kinetics as well.

Cal Poly Humboldt Mechanical Engineering Curriculum

You can find the a typical curriculum plan for an undergraduate degree in mechanical engineering at Cal Poly Humboldt as seen in Fig.2 and Fig.3

Transfer course/Units:			
ACADEMIC YR	FALL COURSE TITLE	SPRING COURSE TITLE	SUMMER COURSE TITLE
1st	MATH 109 [4] ENGR 115 [3] CHEM 109 [5] ENGL 104 [3] [15]	ENGR 205 [3] MATH 110 [4] ENGR 123 [1] NAS 200 [3] PHYS 109 [4] [15]	
2nd	ENGR 225 [3] ENGR 210 [3] MATH 210 [4] BIOL 104 [3] GE Area C Art [3] [16]	ENGR 330 [3] ENGR 331 [3] ENGR 226 [3] PHYX 211 [4] GE Area C Humanities or Arts [3] [16]	
3rd	ENGR 326 [3] ENGR 313 [3] ENGR 333[4] ENGR 430 [4] [14]	ENGR 317 [4] PHYS 315 [3] ENGR 417 [4] ENGR 465 [3] [14]	
4th	Controls [4] ENGR 492B [2] GE Area D American [3] Upper Division GE Area D Social [3] ME Elective [3] [15]	ENGR 492 C [3] Upper Division GE Area C Arts and Humanities [3] ME Elective [3] ME Elective [3] GE Area C humanities [3] [15]	

Figure $Chapter 1.2$: Mechanical Engineering Curriculum

Transfer course/Units:			
ACADEMIC YR	FALL COURSE TITLE	SPRING COURSE TITLE	SUMMER COURSE TITLE
1st	Pre-Calc [4] ENGR 115 [3] CHEM 109 [5] ENGL 104 [3] [15]	ENGR 205 [3] MATH 109 [4] ENGR 123 [1] NAS 200 [3] PHYS 109 [4] [15]	
2nd	ENGR 225 [3] ENGR 210 [3] MATH 110 [4] BIOL 104 [3] GE Area C Art [3] [16]	ENGR 226 [3] PHYX 211 [4] MATH 210 [4] GE Area C Humanities or Arts [3] GE Area C humanities [3] [17]	
3rd	ENGR 330 [3] ENGR 331 [3] ENGR 326 [3] ENGR 333[4] ENGR 313 [3] [16]	ENGR 317 [4] PHYS 315 [3] ENGR 417 [4] ME Elective [3] [14]	
4th	ENGR 430 [4] Controls [4] ENGR 492B [2] Upper Division GE Area D Social [3] ME Elective [3] [16]	ENGR 492 C [3] ENGR 465 [3] Upper Dviison GE Area C Arts and Humanities [3] ME Elective [3] GE Area D American [3] [15]	

Figure $Chapter 1.3$: Mechanical Engineering Curriculum

It should be noted that these are just some of the possible paths in the mechanical engineering curriculum and there is a lot of flexibility. However, it is critical that you take ownership if you curriculum. You need to be sure to communicate with your advisor if there are any changes that need to be made and we want to make sure that you can graduate in 4 years. It is also important to note that Cal Poly Humboldt does not allow you to fail more than one engineering course so it is critical that you make your best attempt to pass all of your classes and hopefully you do even better.

Degrees in Mechanical Engineering

B.S.

You all will be receiving your Bachelors of Science in Mechanical Engineering after 4 years at Cal Poly Humboldt. It is critical that you try to maintain as high a GPA as possible and try an industry internship or research experience during your time at Cal Poly Humboldt. You can also join one of the engineering clubs on campus as well and that will be very helpful to develop your resume.

M.S.

You can pursue a Master's program in Mechanical Engineering and that will typically 1-2 years to complete. Some Master's programs are more focused on taking classes whereas other programs are more research focused. Most Master's programs require a thesis to complete the program. The benefit of a Master's degree is that it open up more opportunities for jobs in industry and typically you will start at a higher salary. The downside is typically there is limited financial aid for Master's Degrees.

PhD

A PhD is a terminal degree for mechanical engineering and is very research focused. A PhD degree will typically take anywhere between 5-8 years. This degree is required for a career in academia and you should pursue a PhD if you have a passion for research. The benefit is typically a PhD program can be funded.

This page titled Chapter 1: Introduction to Mechanical Engineering Discipline is shared under a CC BY-NC-ND license and was authored, remixed, and/or curated by Joshua P. Steimel.

Chapter 2: Statics

Pre-recorded videos that cover this content can be found in the YouTube playlist here: https://www.youtube.com/playlist?lis...qWEZ-QrptGUD1p

Statics

Before you start to explore all that the fascinating world of mechanical engineering and what dynamics has to offer it is critical that we first ensure that we have a solid understanding of statics from which to build upon and to include considerations of Newton's Second Law, speaking of which let's go ahead and start by reviewing Newton right now.

Newtons Laws

• **Newton's 1st Law:** If a body is at rest or moving at a constant velocity in a straight line it will remain at rest or keep moving in a straight line at constant velocity unless acted upon by a force.

• **Newton's 2nd Law:**

$$F = ma \qquad \text{(Chapter 2.1)}$$

• **Newton's 3rd Law:** When two bodies interact they apply forces to one another that are equal in magnitude but opposite in direction, i.e. the law of action and reaction.

For Statics, the 1st and 3rd laws are of critical importance. Dynamics deals with Newton's 2nd law so we will investigate that further in this class. Furthermore, we can make some simplifications to Newton's 1st law and simply re-rewrite it as follows

$$\Sigma F = 0 \qquad \text{(Chapter 2.2)}$$
$$\Sigma M = 0 \qquad \text{(Chapter 2.3)}$$

This is how we will interpret this first law and the third law.

Coordinate System

It is critical that before attempting any problem in statics that you first define a coordinate system if one has not already been defined and identified the dimensionality of the problem. In this lecture we will be examining 2D problems primarily and will be using x-y coordinate systems. Additionally, when discussing moments we will use the convention that counter-clockwise (CCW) is positive and clockwise (CW) is negative. These are the conventions that I will use and you are completely free to use other conventions and if done so the answer will be the same just make sure to be consistent once you choose your notation.

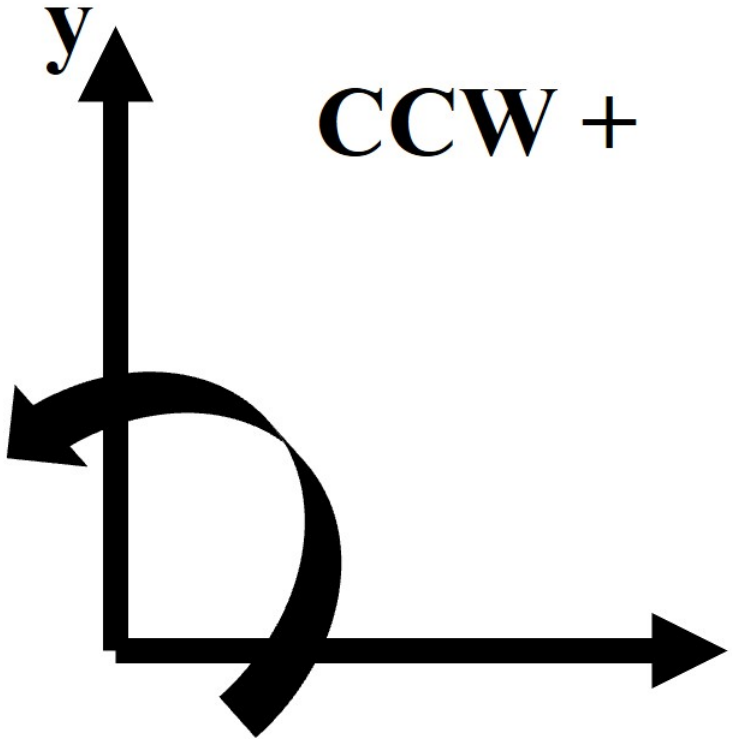


Figure $Chapter 2.1$: Coordinate System for Statics.

Critical Idealizations/Assumptions in Statics Problems:

There are several critical assumptions/idealization that we will utilize when working on statics problems specifically that

• **Particle Assumption:** Particle has mass but we will effectively ignore the geometry of a particle

• **Rigid Body Assumption:** The body will behave rigid, meaning that when a force is applied there will be no deformation, either elastic or plastic, of that body. Therefore the material properties of the body do not exist.

• **Concentrated Force Assumption:** The force will be concentrated and localized at a single point

Force As a Vector or First Rank Tensor Property

Force is not a scalar property it is in fact a vector quantity, meaning force has both **direction** and **magnitude**. Many will also refer to force as a first rank tensor property as well. Let's look at some examples of vectors as a concept first as seen in Fig.2.

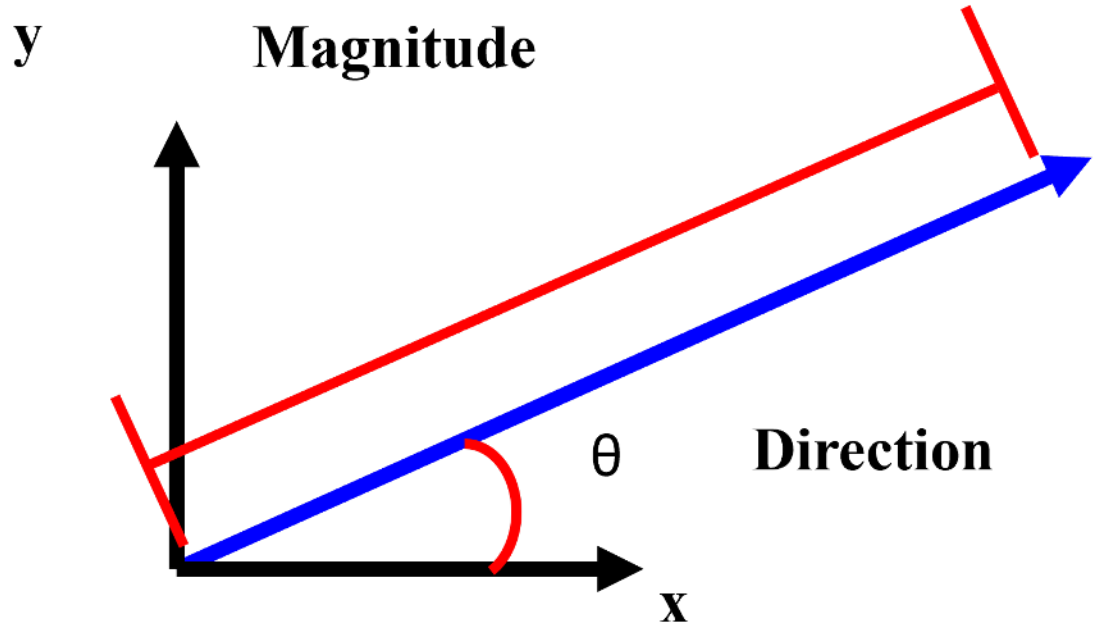


Figure *Chapter*2.2: Force as a vector/first rank tensor property.

This force can also be resolved into x and y components specifically

$$F = F_x i + F_y j \qquad \text{(Chapter 2.4)}$$

where F_x and F_y are respective magnitudes of the force components in the x and y and i and j are Cartesian vector notation. This can be seen in Fig.3

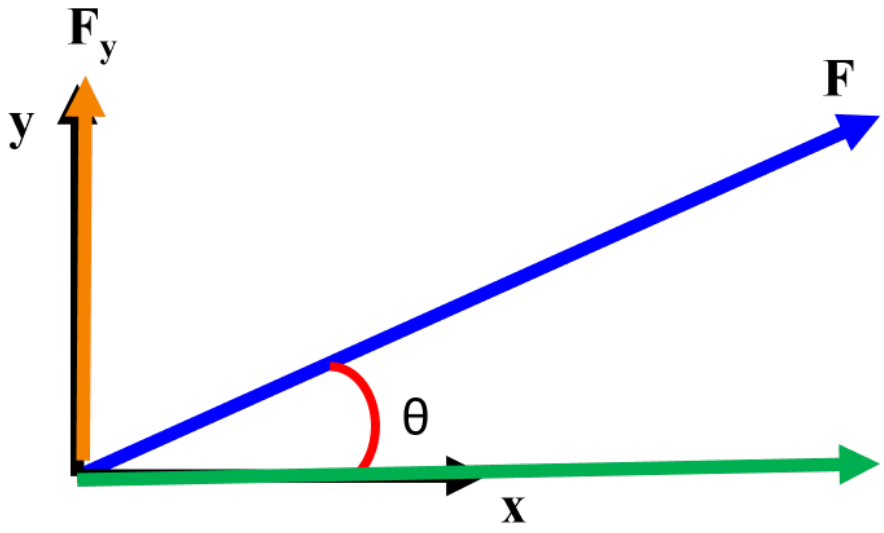


Figure *Chapter*2.3: Force Components.

Additionally as we have the angle, θ we can also define that

$$F_x = F\cos\theta \quad \text{(Chapter 2.5)}$$
$$F_y = F\sin\theta \quad \text{(Chapter 2.6)}$$

We can do an example together and find what is the resultant force in the x and y directions which can be defined as

$$F_{R_x} = \sum F_x \quad \text{(Chapter 2.7)}$$
$$F_{R_y} = \sum F_y \quad \text{(Chapter 2.8)}$$

Here we can see an example below in Fig.4

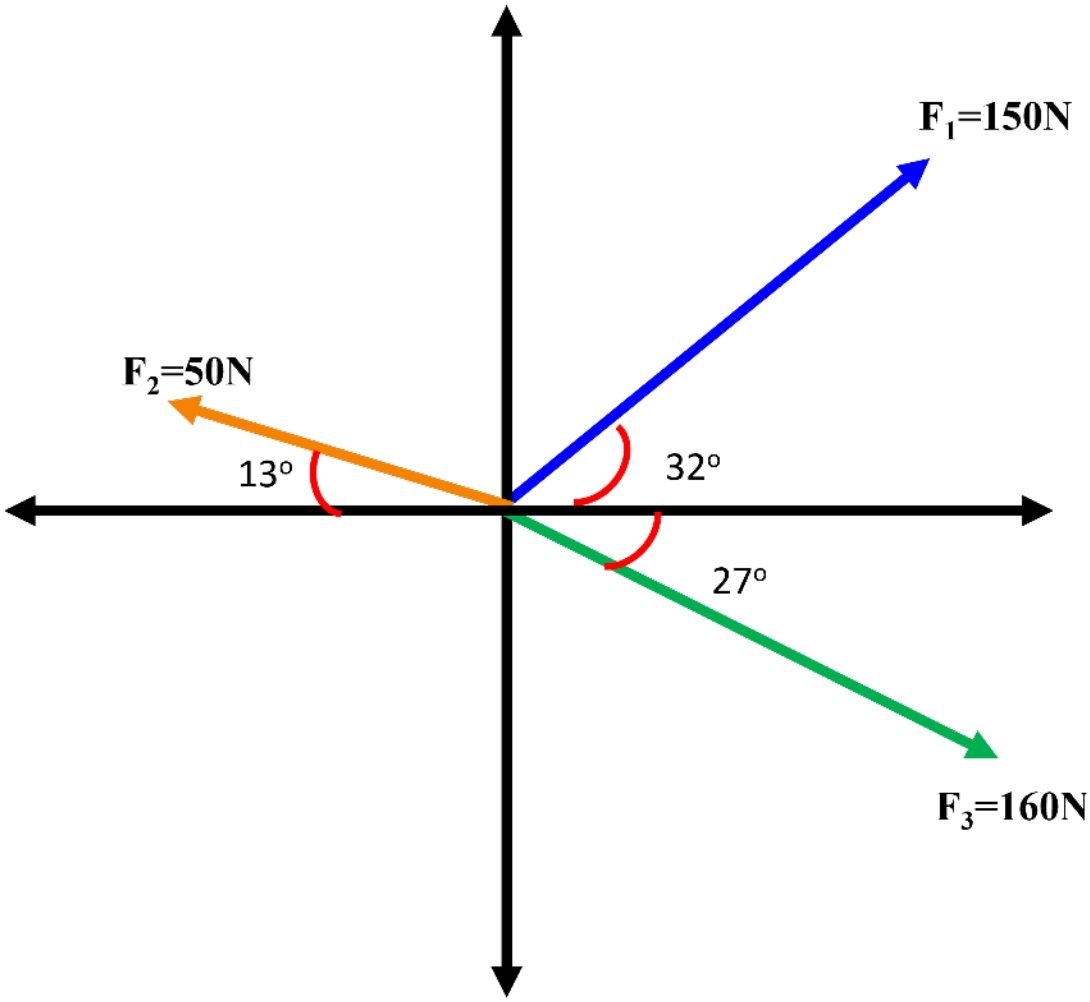


Figure *Chapter*2.4: Force Summation Example.

Sum of Forces Must Be Equal to Zero

We can also apply static equilibrium conditions and Newton's First law to solve for the two unknown forces, F_1 and F_2, as seen in Fig.5.

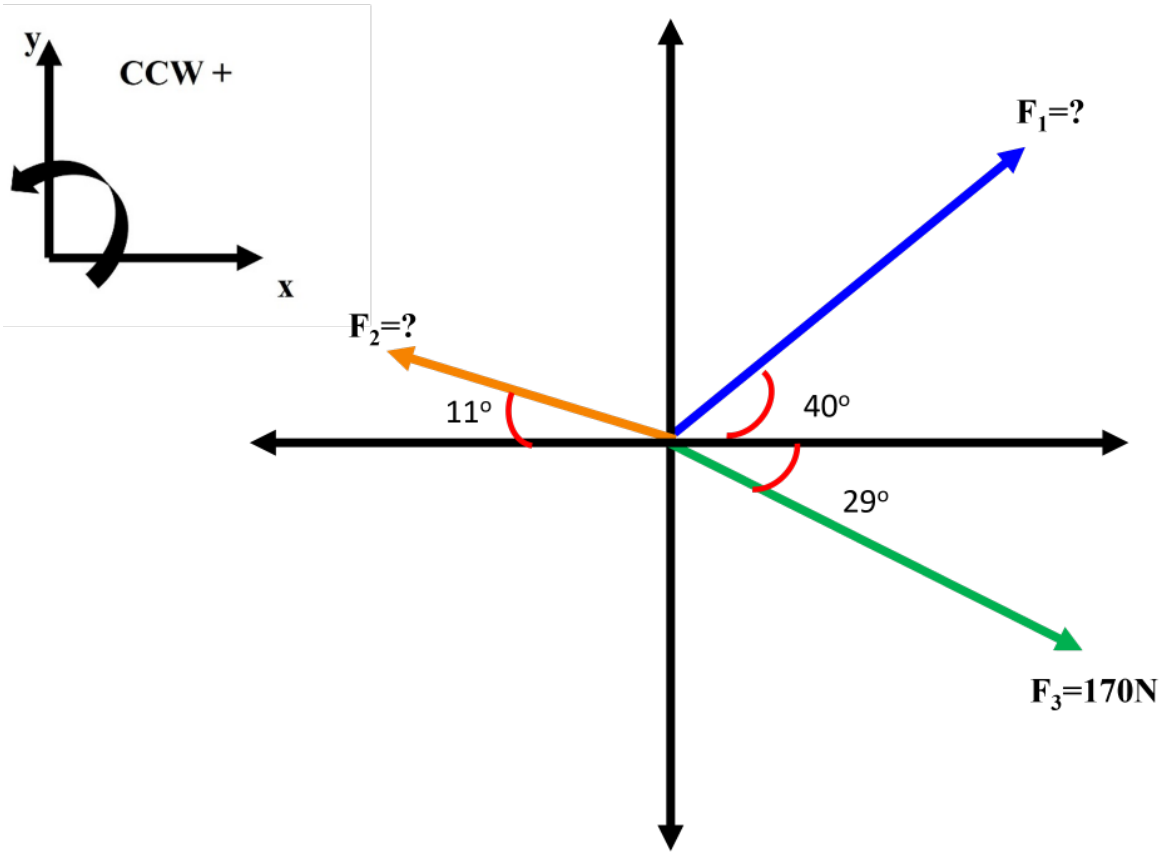


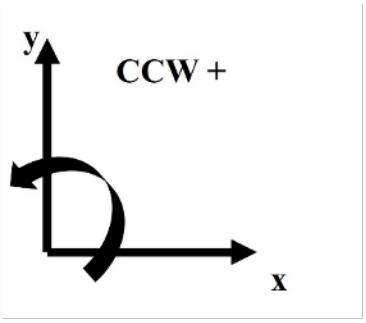
Figure *Chapter*2.5: Sum of forces must be zero.

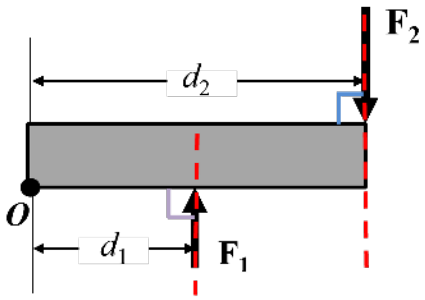
Moment

A **moment** is defined as

$$M_o = Fd \qquad \text{(Chapter 2.9)}$$

where *F* is the magnitude of force and *d* is the perpendicular distance from the origin, *o*, to the line of action of the force as seen below in Fig.6





Magnitude of Moment = d F

where

d: Moment Arm

: **Perpendicular** Distance

FROM the Point TO the LOA of the Force

$$\sum \mathbf{M}_0 = \mathbf{0} \qquad d_1 F_1 - d_2 F_2 = 0 \qquad \sum \mathbf{F}_y = \mathbf{0} \qquad F_1 - F_2 = 0$$

Figure *Chapter*2.6: Moments.

Spring Force

We will often come across springs in mechanical engineering and use springs as idealizations for some elements of mechanical designs and systems. A spring force can be defined as

$$F = k\Delta x \qquad \text{(Chapter 2.10)}$$

where k is a spring constant and Δ is the change in length of a spring this is also seen in Fig.7

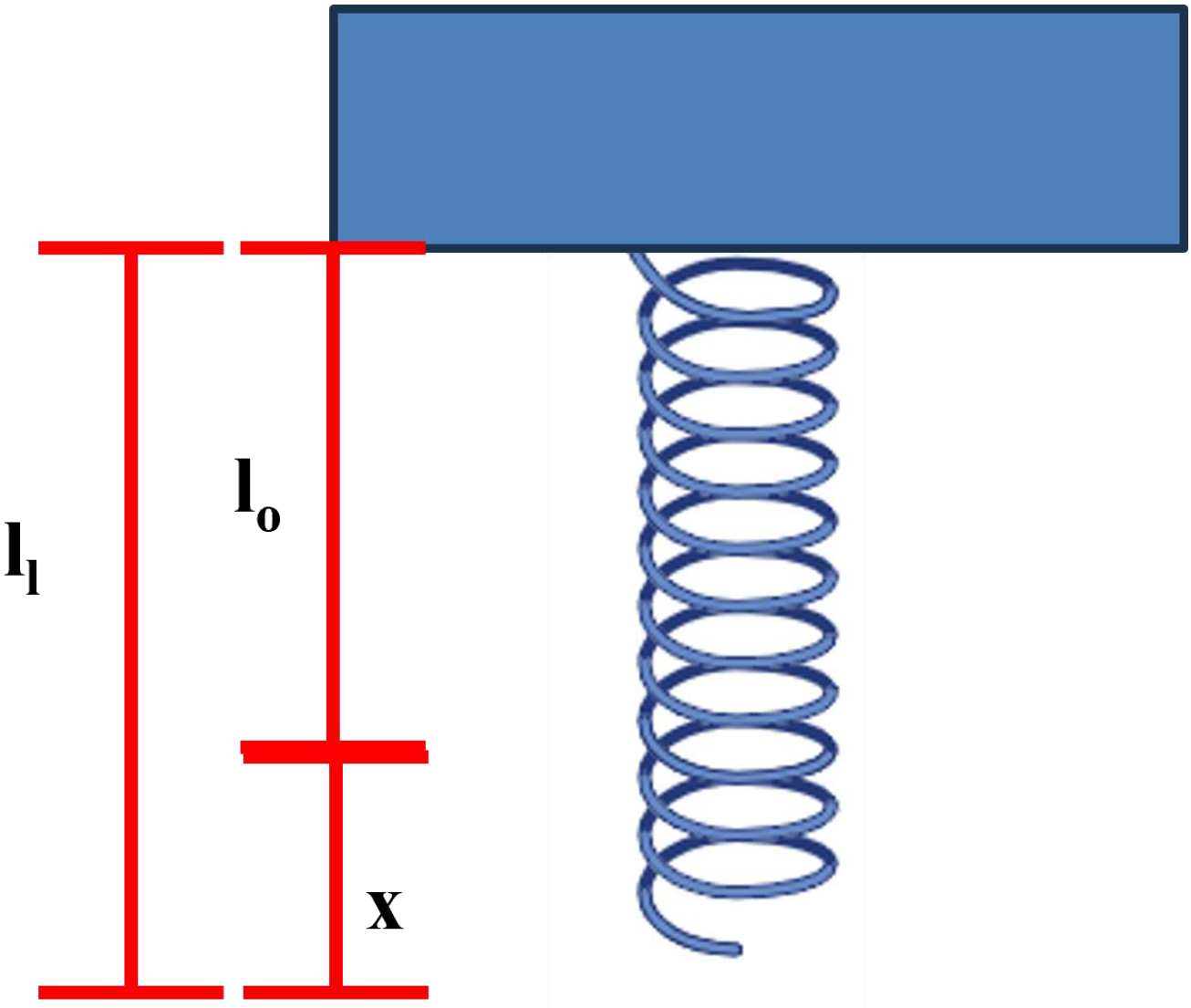


Figure $Chapter 2.7$: Spring Force.

Additionally if you have a mass attached to a cable/pulley/wire you will have **tension** in the wire, *T*, and the mass will have a weight, $W = mg$ which you can see in

Fig.8

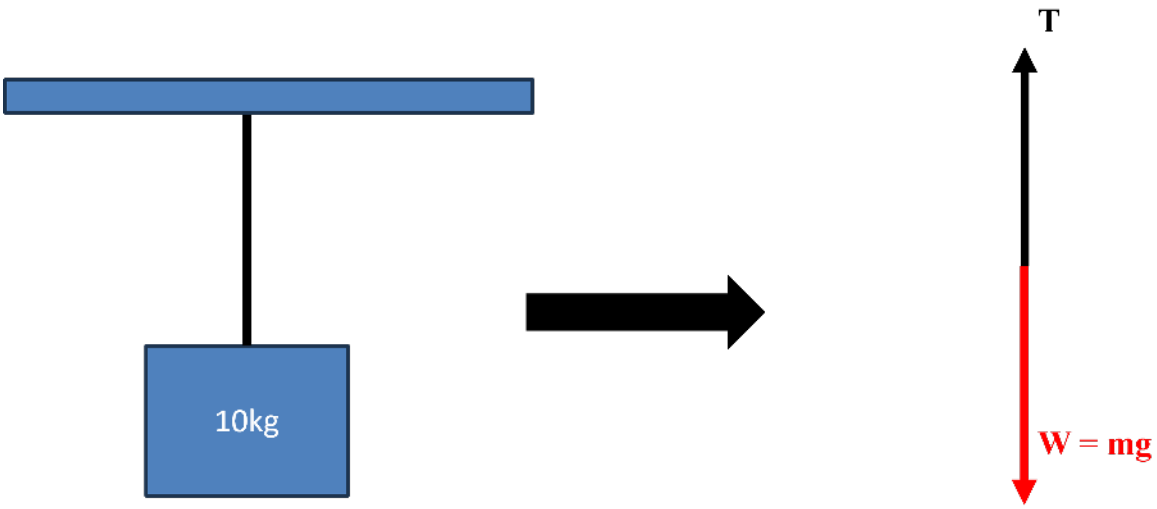


Figure *Chapter*2.8: Tension in wire and weight.

Static Equilibrium Practice Problem!!

To solve this problem let's perform our statics problem solving algorithm.

(1) Idealize Real System

(2) Define Coordinate system

(3) Draw Free Body Diagram (FBD)

(4) Write Equilibrium Expressions

(5) Solve for Unknowns

Consider the situation of a person with a mass of 100kg on a scaffold which is suspended via two cables as seen in Fig.9

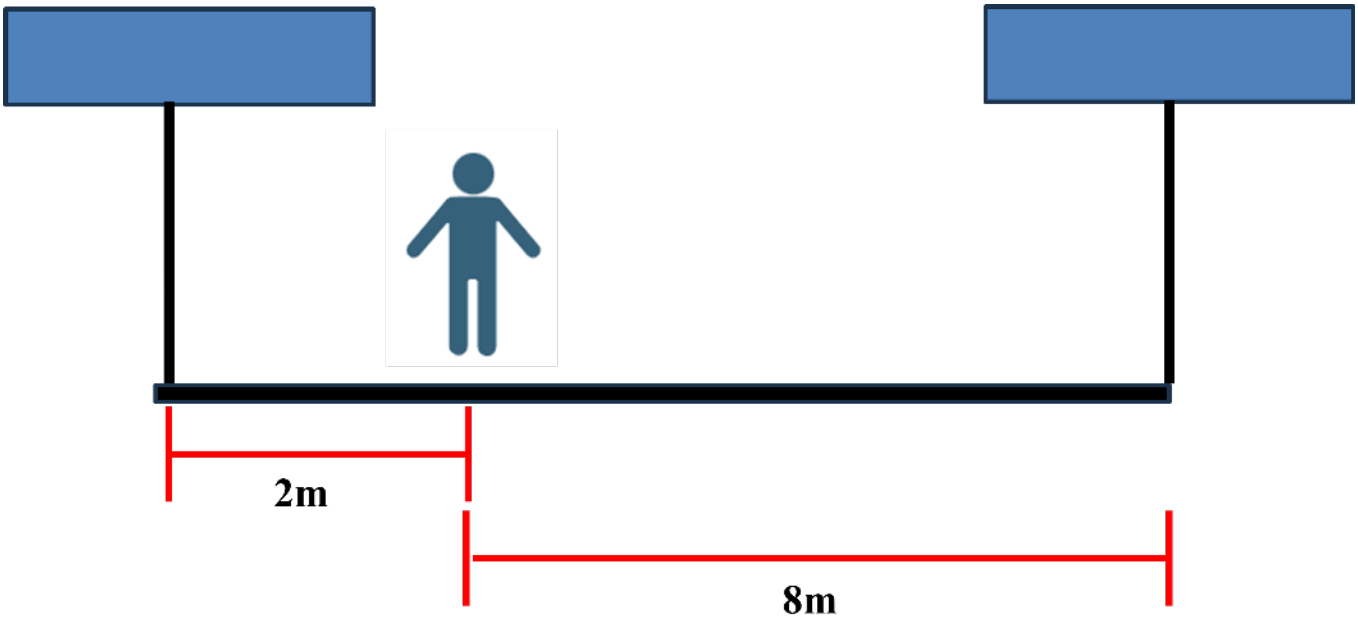


Figure *Chapter*2.9: Person on a scaffold problem.

So in this real system we are going to make several idealizations the biggest being that we will neglect the mass of the scaffold itself and we will ignore friction in this scenario as well. Additionally, we will assume the scaffold is rigid and therefore will not

deform in this system.

We have defined our coordinate system in this diagram and now we will draw our **Free Body Diagram**. To do so we will free the body which has forces exerted on it, i.e. the scaffold. So we will draw the scaffold and free this body from the surroundings and replace the surroundings by idealizing them as forces which can be seen in Fig.10

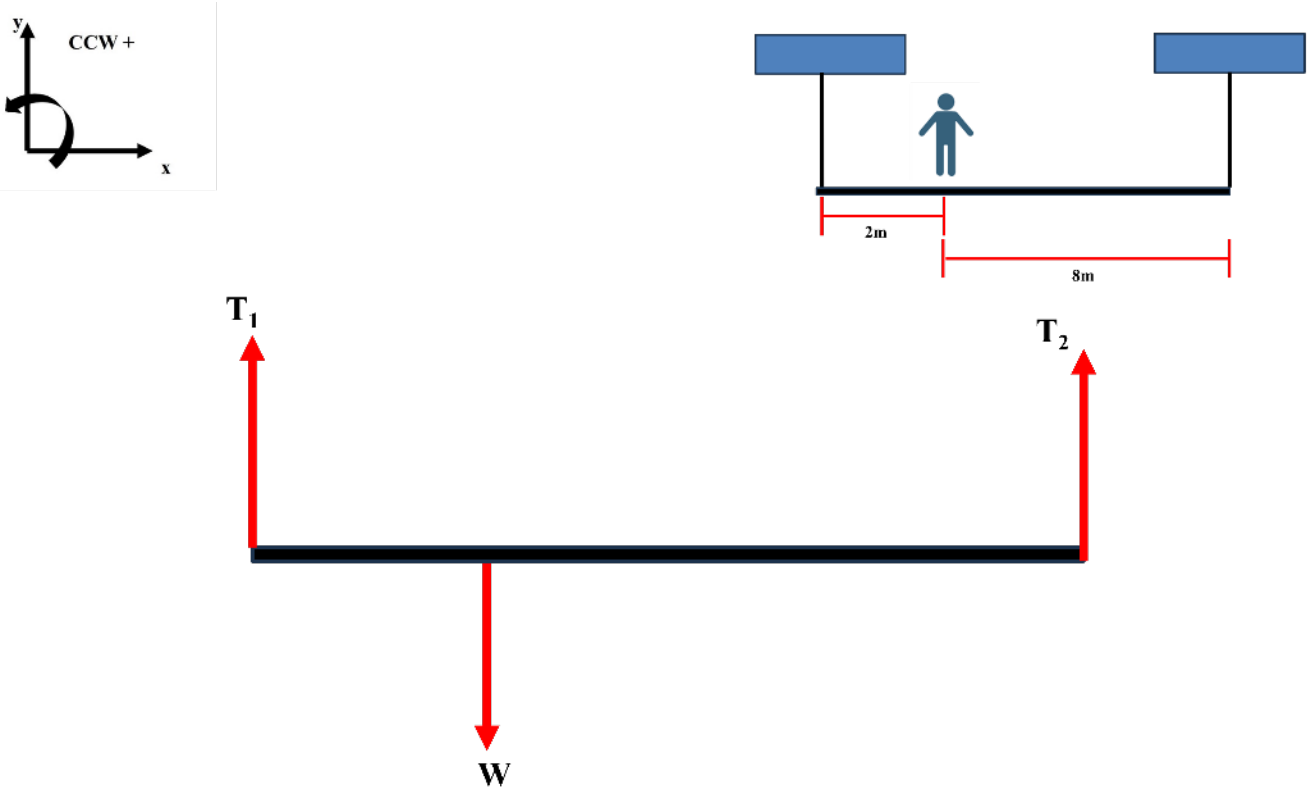


Figure *Chapter*2.10: Free Body Diagram.

We can now write out our fundamental equations which are the sum of the moments and the sum of the forces must be equal to zero if we are indeed in static equilibrium.

Let us first consider the x-direction and even though we have no forces we can still write out that

$$\sum F_x = 0 \qquad \text{(Chapter 2.11)}$$

and this will hold true.

Now we can consider forces in the y-direction and we have that

$$\sum F_y = 0 = -W + T_1 + T_2 \qquad \text{(Chapter 2.12)}$$

where we know that $W = mg$ and we know that the mass of the person is 100kg.

Now we can write the sum of the moments about any origin will be zero and I will choose the origin to be located at T_1 so

$$\sum M_{T_1} = 0 = -W \cdot 2m + T_2 \cdot 10m \qquad \text{(Chapter 2.13)}$$

So we have two equations and two unknowns and now we can solve the problem for the unknowns!

Let's consider another problem this time a SeeSaw!

SeeSaw

To solve this problem let's perform our statics problem solving algorithm.

(1) Idealize Real System

(2) Define Coordinate system

(3) Draw Free Body Diagram (FBD)

(4) Write Equilibrium Expressions

(5) Solve for Unknowns

Consider the situation of a person, P_1 with a mass of 100kg on a SeeSaw and find all the resulting forces to keep the SeeSaw flat as seen in Fig.11

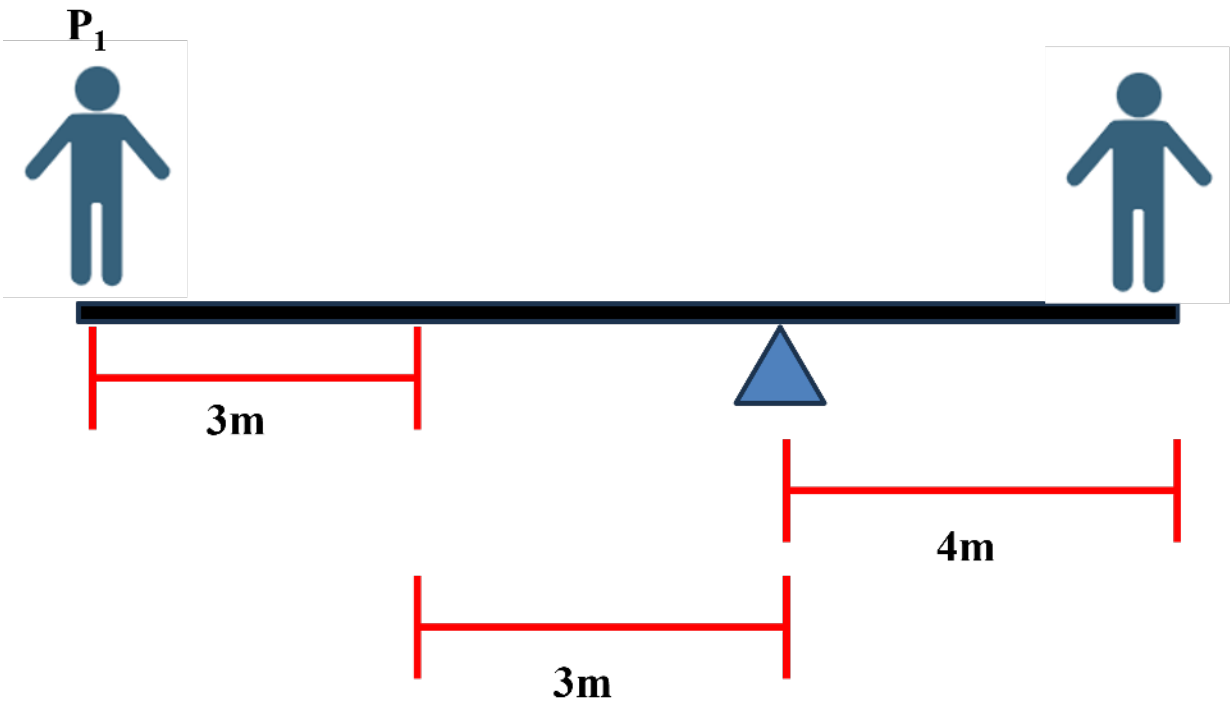


Figure *Chapter*2.11: SeeSaw.

So in this real system we are going to make several idealizations the biggest being that we will neglect the mass of the SeeSaw itself. Additionally, we will assume the SeeSaw is rigid and therefore will not deform in this system.

We have defined our coordinate system in this diagram and now we will draw our **Free Body Diagram**. To do so we will free the body which has forces exerted on it, i.e. the SeeSaw. So we will draw the SeeSaw and free this body from the surroundings and replace the surroundings by idealizing them as forces which can be seen in Fig.12

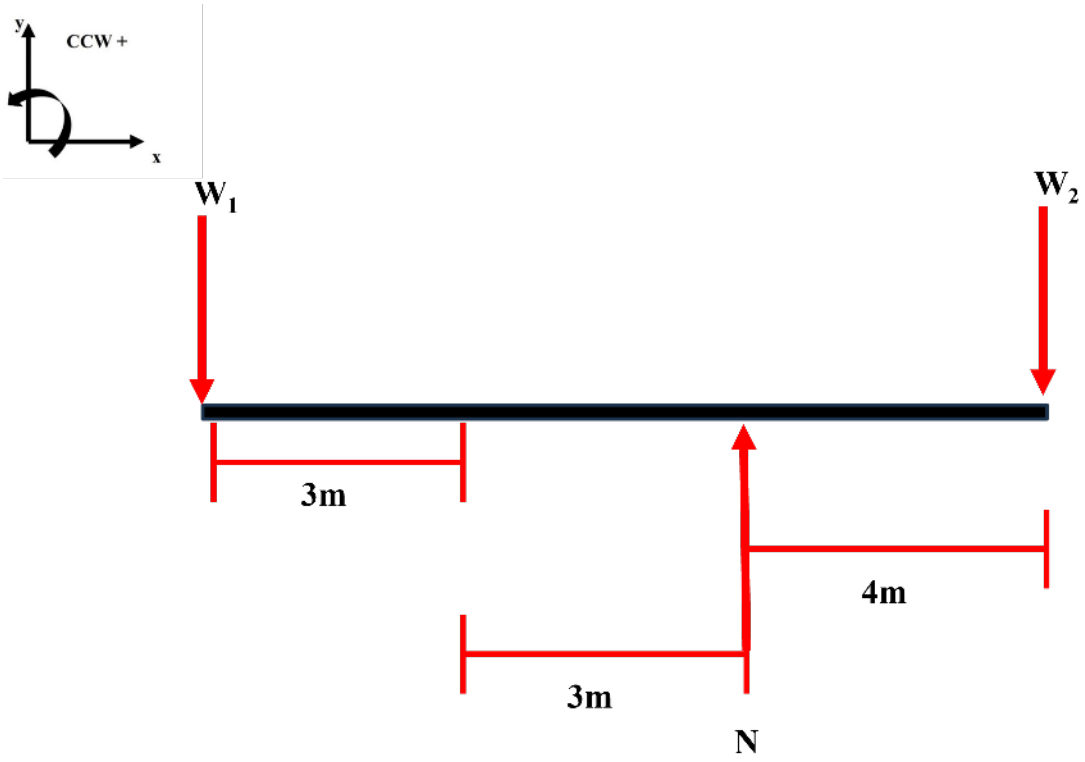


Figure *Chapter*2.12: Free Body Diagram.

We can now write out our fundamental equations which are the sum of the moments and the sum of the forces must be equal to zero if we are indeed in static equilibrium.

Let us first consider the x-direction and even though we have no forces we can still write out that

$$\sum F_x = 0 \qquad \text{(Chapter 2.14)}$$

and this will hold true.

Now we can consider forces in the y-direction and we have that

$$\sum F_y = 0 = -W_1 + N - W_2 \qquad \text{(Chapter 2.15)}$$

where we know that $W_1 = mg$ and we know that the mass of the person is 100kg.

Now we can write the sum of the moments about any origin will be zero and I will choose the origin to be located at W_1 so

$$\sum M_{W_1} = 0 = N \cdot 6m - W_2 \cdot 10m \qquad \text{(Chapter 2.16)}$$

So we have two equations and two unknowns and now we can solve the problem for the unknowns!

Types of Friction:

In this lecture we will predominantly discuss friction in the context of **dry** friction or **Coloumb** friction which occurs between contacting surfaces of bodies when there is no lubricating fluids.

One of the important things to note when considering dry friction is that the friction force F may not be enough to balance the applied force P when the surface is slippery. In fact the value of the frictional force increases as P increases until reaching a maximum value of limit of static frictional force, F_s, which is defined as

$$F_s = \mu_s N \qquad \text{(Chapter 2.17)}$$

where μ_s is the coefficient of static friction and we see that the limiting static frictional force is directly proportional to the resultatn normal. You can also see that friction will oppose the direction of impending motion and is tangent to the contacting surface. Once

the magnitude of P becomes larger than F_s the friction decreases to a smaller value F_k which is the kinetic frictional force defined as

$$F_k = \mu_k N \qquad \text{(Chapter 2.18)}$$

and this can be seen here

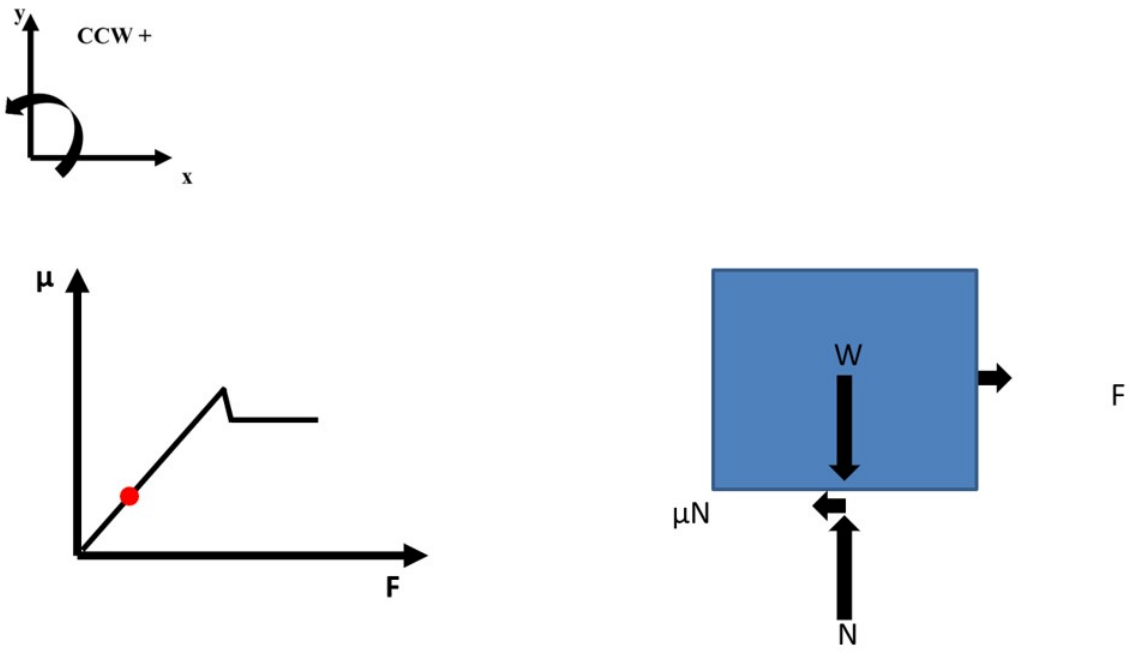


Figure $Chapter 2.13$: Dry Friction: Force is lower than limit of static friction.

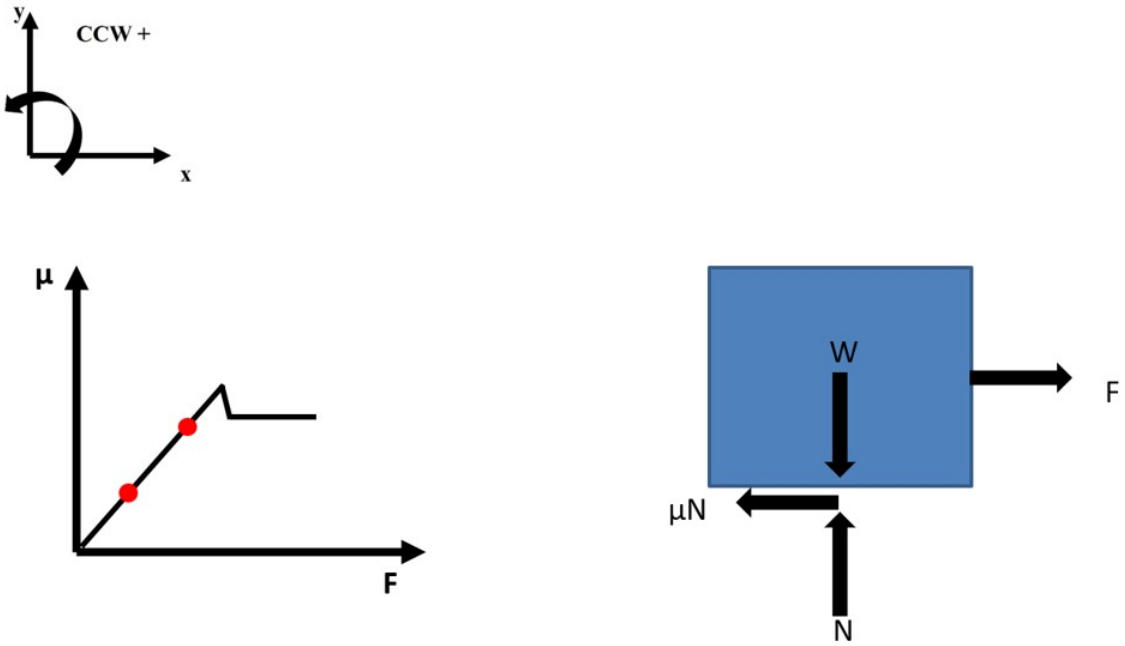


Figure $Chapter 2.14$: Dry Friction: Force is close than limit of static friction.

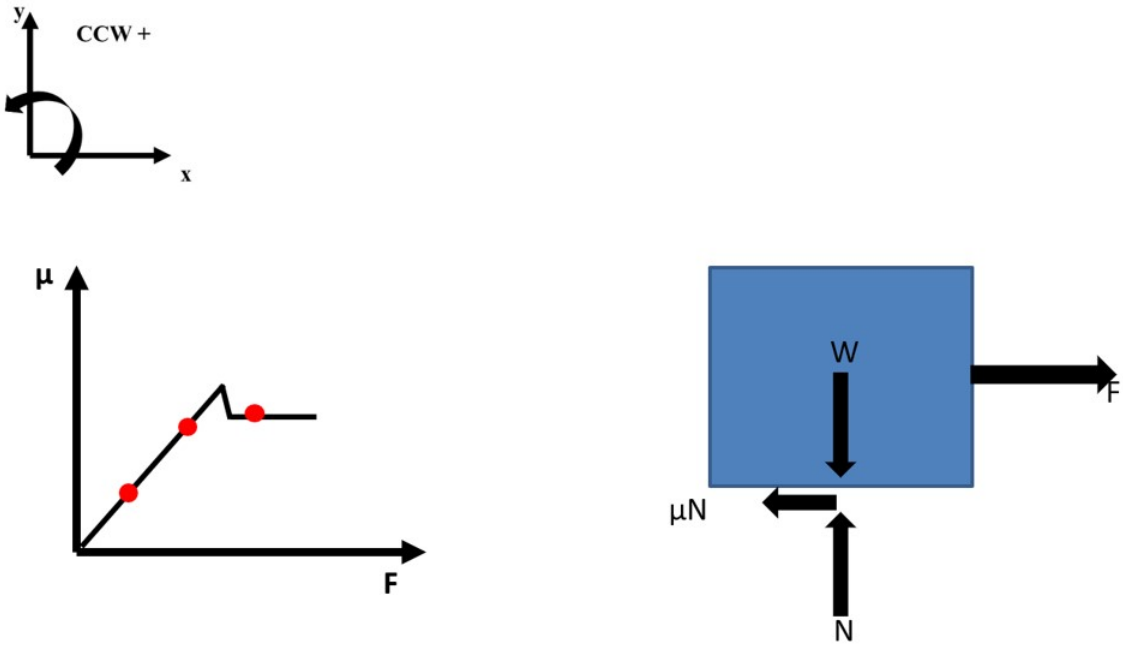


Figure $Chapter 2.15$: Dry Friction: Force is larger than limit of static friction and friction force decreases to limit of kinetic friction.

Typically, when dealing with dry friction you will encounter problems where there will friction that occurs even without any apparent impending motion, impending motion at all points of contact, or impending motion at certain points contact. However, you will still utilize the same problem solving algorithm that we will introduce shortly.

You may also friction when using wedges to adjust the elevation of parts, frictional forces on screws, flat belts, bearings, and rolling resistance as well all of which can be summarized in the figure below however again for this particular lecture we will focus primarily on dry friction.

Tire Blowout 0.7 Miles From ATI Plant in Louisville, Ohio

I worked for a while in Pittsburgh at ATI in the metallurgy industry. Part of the job required driving to a plant in the middle of the night to Louisville, Ohio, a plant in a very small town that is isolated. During my first year I was driving at 3AM in January and only 0.7 miles from the plant my tire ruptured and isolated, alone, I had to pull the car (finally getting to utilize my emergency rope kit) 0.7 long cold miles to the plant. Why didn't I drive might you ask, well I was worried about damaging the tire, it was cold and I was extremely frazzled and tired from the experience.

The Jeep has mass of approximately 1600kg and it is quite cold and slick so the coefficient of friction between the tires and the substrate is approximately μ_s = 0.3 and the front tires were free to rotate but the back tires are locked. I can exert a force of approximately 3000N will the car move?

I exert a force on the cable of approximately 3000N. Considering the mass of the car is 1600kg and the coefficient of friction between the tire and the surface is μ_s = 0.3. Will the car move?

To solve this problem let's perform our statics problem solving algorithm.

(1) Idealize Real System

(2) Coordinate system

(3) Free Body Diagram

(4) Write Equilibrium Expressions

(5) Solve for Unknowns

So we can do the following steps and first idealize the system as seen here.

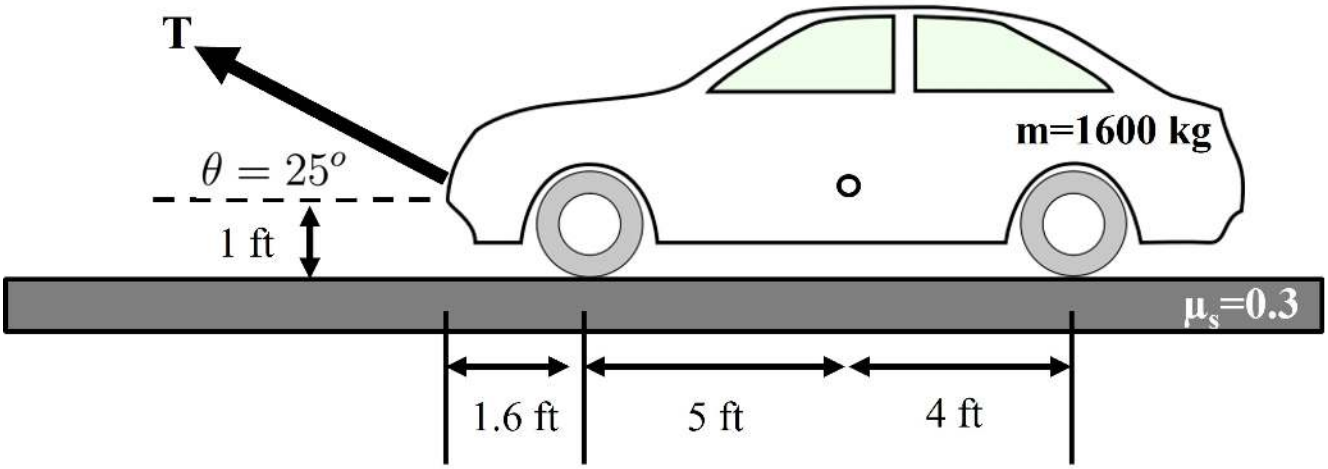


Figure *Chapter*2.16: Idealized System of Pulling Car.

Then we define our coordinate system and can simultaneously draw our free body diagram.

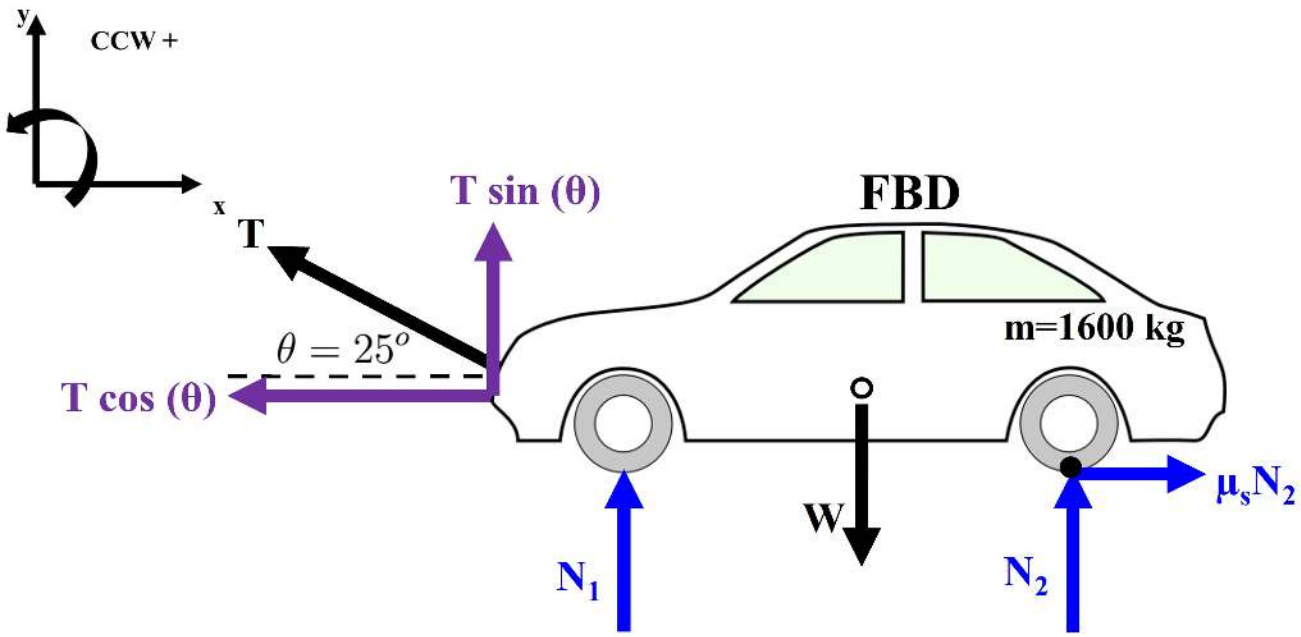


Figure *Chapter*2.17: Free Body Diagram.

The important thing to note here is the determination of the direction of the frictional force. The friction force must be tangent to the contact surface and should oppose the direction of impending motion.

With the FBD complete we can now write out our systems of equilibrium expressions

$$\Sigma F_x = 0 = -T\cos(\theta) + \mu_s N_2 \quad \text{(Chapter 2.19)}$$
$$\Sigma F_y = 0 = T\sin(\theta) + N_1 + N_2 - W \quad \text{(Chapter 2.20)}$$
$$\Sigma M_C = 0 = (4ft)W - (9ft)N_1 + (1ft)T\cos(\theta) - (10.6ft)T\sin(\theta) \quad \text{(Chapter 2.21)}$$

But the car didn't move funnily enough, I suspect that both brakes are locked. Well let's repeat our process and we already have our idealization. Now we can define the coordinate system and free the body.

Now let's write out our systems of equations

$$\Sigma F_x = 0 = -T\cos(\theta) + \mu_s N_2 + \mu_s N_1 \quad \text{(Chapter 2.22)}$$
$$\Sigma F_y = 0 = T\sin(\theta) + N_1 + N_2 - W \quad \text{(Chapter 2.23)}$$
$$\Sigma M_C = 0 = (4ft)W - (9ft)N_1 + (1ft)T\cos(\theta) - (10.6ft)T\sin(\theta) \quad \text{(Chapter 2.24)}$$

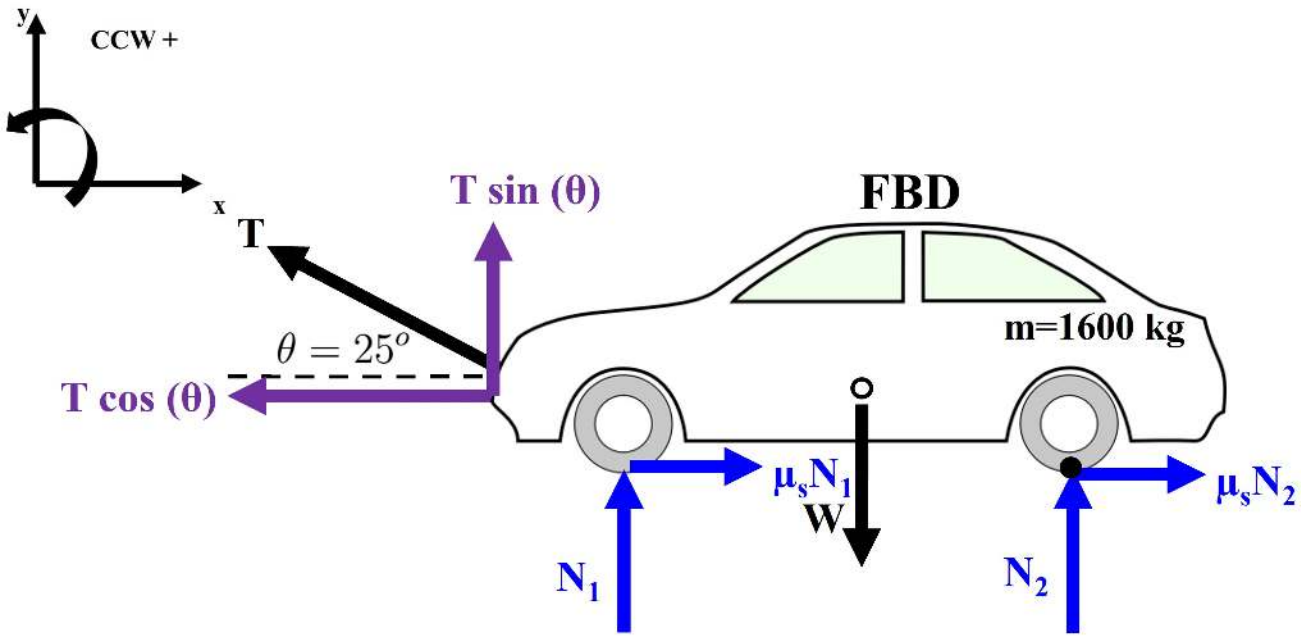


Figure *Chapter*2.18: Free Body Diagram.

Person on a Ladder

Recently I had to take down my holiday lights and this was after cleaning the gutters but before I have to go up on the remove to spray moss remover, so much work to do!!!

Anyway, when I am up on the ladder and lean it against the wall of the house I can feel the difference in friction between the wall and the ground. Now I am using a 4m tall ladder and my mass is approximately 100kg (after a workout).... and the angle is approximately 18^o. The wall is stucco and in contact with the steel ladder the coefficient of friction with that surface is approximately μ_1 = 0.7. What coefficient of friction is required on the ground to prevent the ladder from moving? Is the ladder likely to fall? Do I have to lose weight??

Considering that I have a mass of 100kg we can neglect the mass and weight of the ladder. What is the coefficient of friction, $\mu_{s,2}$ required to prevent the ladder from slipping?

Now let's start with our problem solving algorithm and start to idealize the system as seen here.

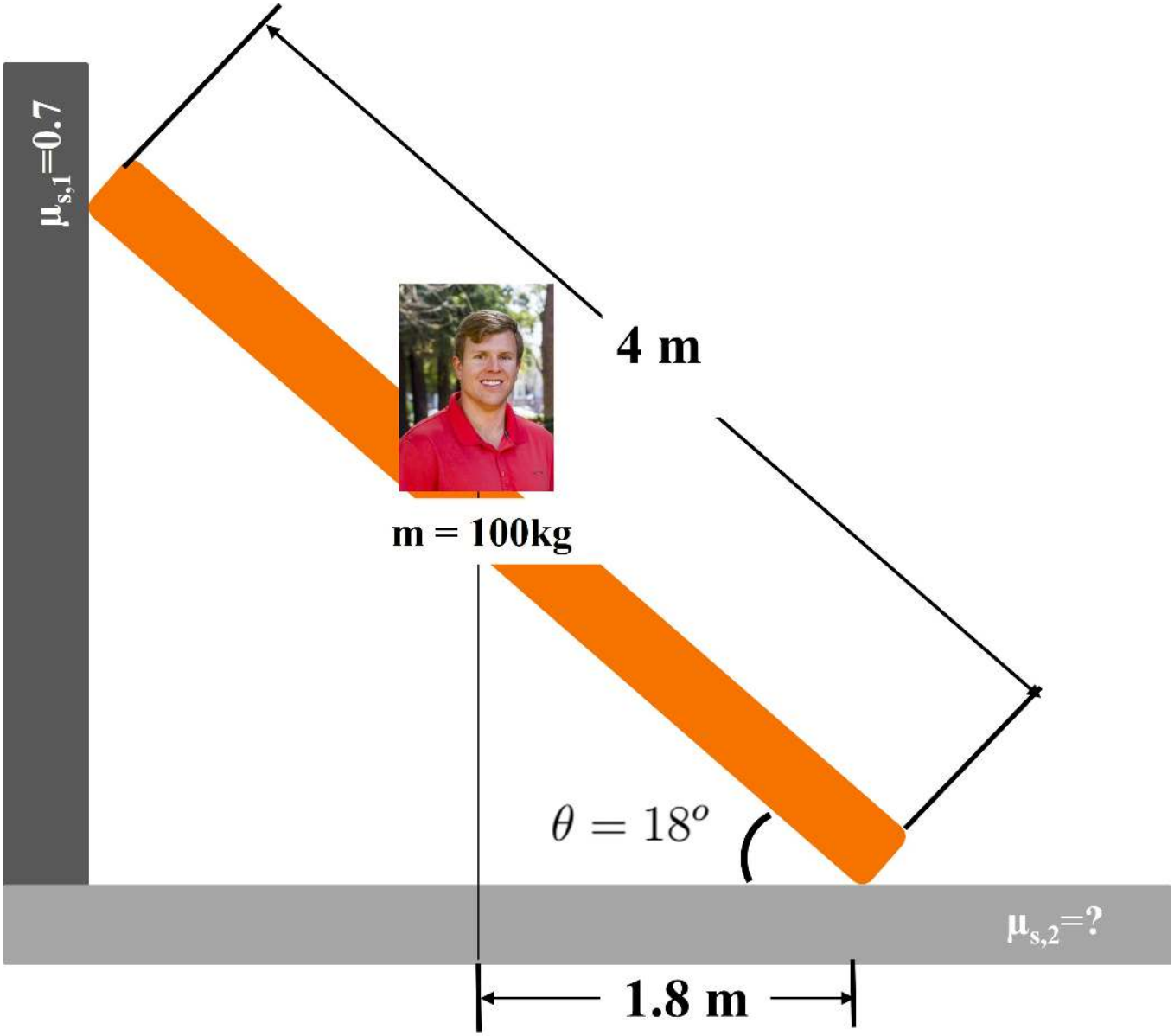


Figure $Chapter 2.19$: Idealization of me cleaning gutters.

Now let's define our coordinate system and free the body

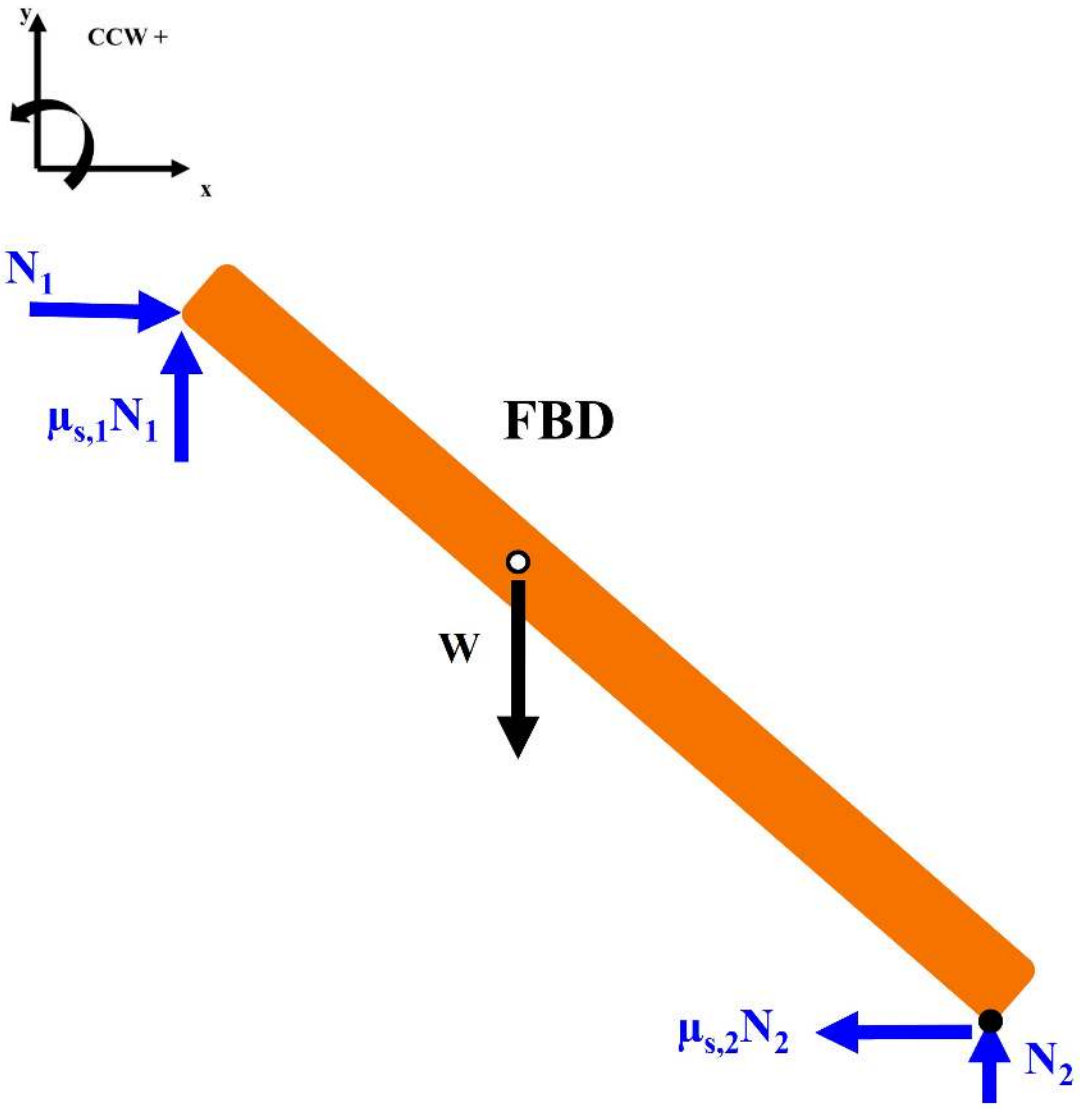


Figure $Chapter 2.20$: Free Body Diagram.

Finally, let's write out our equilibrium expressions and solve

$$\Sigma F_x = 0 = N_1 - \mu_{s,2} N_2 \quad \text{(Chapter 2.25)}$$

$$\Sigma F_y = 0 = \mu_{s,1} N_1 - W + N_2 \quad \text{(Chapter 2.26)}$$

$$\Sigma M_o = 0 = (1.8m)W - (4\sin(\theta)m)N_1 - (4\cos(\theta)m)\mu_{s,1} N_1 \quad \text{(Chapter 2.27)}$$

Chapter 2: Statics is shared under a CC BY-NC-ND license and was authored, remixed, and/or curated by LibreTexts.

Chapter 3: Dynamics and Vibrations

Pre-recorded videos covering these topics can be found in the YouTube playlist here: https://www.youtube.com/playlist?lis...13bhGLLZBQkZhd.

Now that we have the fundamentals of Statics we can start to analyze dynamic systems and we will start to work with **Newton's 2nd Law** as seen below.

Newtons Laws

• **Newton's 1st Law:** If a body is at rest or moving at a constant velocity in a straight line it will remain at rest or keep moving in a straight line at constant velocity unless acted upon by a force.

• **Newton's 2nd Law:**

$$F = ma \tag{Chapter 3.1}$$

• **Newton's 3rd Law:** When two bodies interact they apply forces to one another that are equal in magnitude but opposite in direction, i.e. the law of action and reaction.

For Statics, the 1st and 3rd laws are of critical importance. Dynamics deals with Newton's 2nd law so we will investigate that further in this class. Furthermore, we can make some simplifications to Newton's 1st law and simply re-rewrite it as follows

$$\Sigma F = 0 \tag{Chapter 3.2}$$
$$\Sigma M = 0 \tag{Chapter 3.3}$$

This is how we will interpret this first law and the third law.

Fundamentals of Dynamics

Before we begin to tackle problems it is important to define some critical parameters and terms when it comes to dynamics. We will typically be analyzing the displacement of a system/body and we will define the position of a body as

$$x(t) \tag{Chapter 3.4}$$

The position is a function of time and the velocity can be defined as

$$v = \frac{dx}{dt} \tag{Chapter 3.5}$$

and very importantly the acceleration is defined as

$$a = \frac{dv}{dt} = \frac{d^2x}{dt^2} \tag{Chapter 3.6}$$

These definitions all refer to **Translational Motion** and the fundamental equation that governs translation motion is Newton's 2nd law that

$$\sum F = ma \tag{Chapter 3.7}$$

We can also say that for translation that

$$\sum M_G = 0 \tag{Chapter 3.8}$$

so the sum of the moments about the center of mass will be 0 for a body undergoing translation but you can also solve for the moment about any point *P* and use the following expression

$$\sum M_P = \sum \left(M_k\right)_P \tag{Chapter 3.9}$$

We will also encounter **Rotational Motion** as well and rotational motion occurs when a body rotates around a fixed axis and they body will change the angular position and we will track the angular displacement as defined below

$$\theta(t) \tag{Chapter 3.10}$$

The **angular velocity** can be defined as

$$\omega = \frac{d\theta}{dt} \tag{Chapter 3.11}$$

and **angular acceleration** can be defined as

$$\alpha = \frac{d\omega}{dt} = \frac{d^2\theta}{dt^2} \tag{Chapter 3.12}$$

It is also important to note that in terms of angular acceleration you will typically encounter a normal and tangential component which can be defined as

$$a_t = \alpha r \tag{Chapter 3.13}$$
$$a_n = \omega^2 r \tag{Chapter 3.14}$$

and rotational motion is governed by the fundamental equation that

$$\sum M_G = I_G \alpha \tag{Chapter 3.15}$$

So the fundamental equations of dynamics will be

$$\sum F_x = ma \tag{Chapter 3.16}$$
$$\sum F_y = ma \tag{Chapter 3.17}$$
$$\sum M_G = I_G \alpha \tag{Chapter 3.18}$$

or more generally around some point P .

Problem Solving Dynamics Algorithm

We will follow a similar problem solving algorithm to the one that we performed in

To solve this problem let's perform our dynamics problem solving algorithm.

(1) Idealize Real System

(2) Coordinate System

(3) Free Body Diagram

(4) Kinetic Diagram

(5) Write Equilibrium Expressions

(6) Solve for Unknowns

The key distinction here is the drawing of a kinetic body diagram so now lets start to solve some problems together!

Truck Carrying Load

Let's consider the following problem of a 100kg table on a truck bed that is accelerating. The static coefficient of friction between the legs of the table and the truck bed is μ_s = 0.3. We want to solve for the maximum acceleration of the truck without causing the assembly to move relative to the truck as well as the reaction forces at A and B. The center of the mass of the table is indicated at G.

To solve this problem let's perform our dynamics problem solving algorithm.

(1) Idealize Real System

(2) Coordinate System

(3) Free Body Diagram

(4) Kinetic Diagram

(5) Write Equilibrium Expressions

(6) Solve for Unknowns

We will have to make several idealizations in this problem specifically we will ignore any air resistance and that the truck will move at a constant acceleration as seen in Fig.1

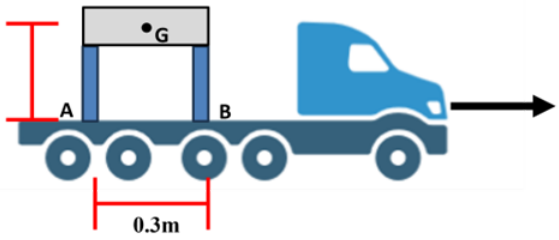


Figure *Chapter*3.1: Table on a Truck Bed.

We can then define our coordinate system and draw our free body diagram (FBD)

of our body which is the table in Fig.2

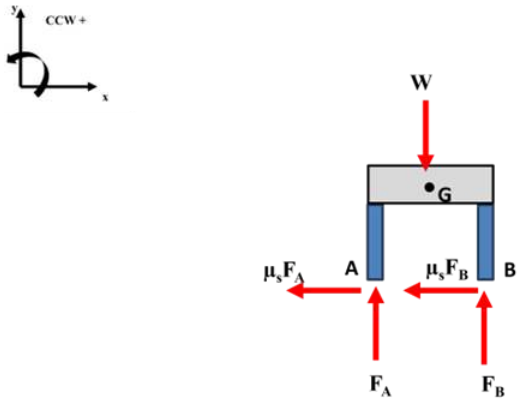


Figure *Chapter*3.2: Free Body Diagram

We can also draw our **kinetic diagram** (KD) for the body as well in table Fig.3

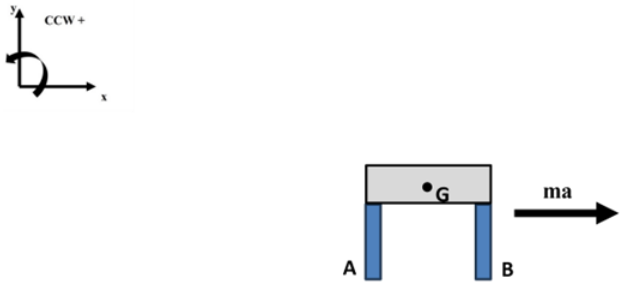


Figure *Chapter*3.3: Kinetic Body Diagram

We can now write out our fundamental equations and let's start out looking at translation first and in the x-direction and because we want it to not move relative to the truck acceleration it must have the same acceleration

$$\sum F_x = ma_x = -\mu_s F_A - \mu_s F_B \qquad \text{(Chapter 3.19)}$$

We can also write out for translation in the y-direction where there is no acceleration

$$\sum F_y = 0 = -W + F_A + F_B \qquad \text{(Chapter 3.20)}$$

Finally we can use the relationship for the sum of the moments about the center of mass to write

$$\sum M_G = 0 = -\mu_s F_A 0.6 - \mu_s F_B 0.6 - F_A 0.15 + F_B 0.15 \quad \text{(Chapter 3.21)}$$

So we have three equations and three unknowns and now we can solve the problem for the unknowns!

Frisbee Problem

Let's make a Frisbee launcher to launch a 0.5m diameter with a mass of 0.05kg and when

it is ejected we want a linear acceleration of 10$\frac{m}{s^2}$ and an angular acceleration of 20 $\frac{rad}{s^2}$. Solve for the values of F_1 and F_2 to meet these criteria. Ignore friction between the Frisbee and launching pads. Additionally the $I_G = \frac{mr^2}{2}$ for a think disk through axis perpendicular to the face of the Frisbee.

To solve this problem let's perform our dynamics problem solving algorithm.

(1) Idealize Real System

(2) Coordinate System

(3) Free Body Diagram

(4) Kinetic Diagram

(5) Write Equilibrium Expressions

(6) Solve for Unknowns

We can then define our coordinate system and draw our free body diagram (FBD) of our body which is the Frisbee in Fig.4

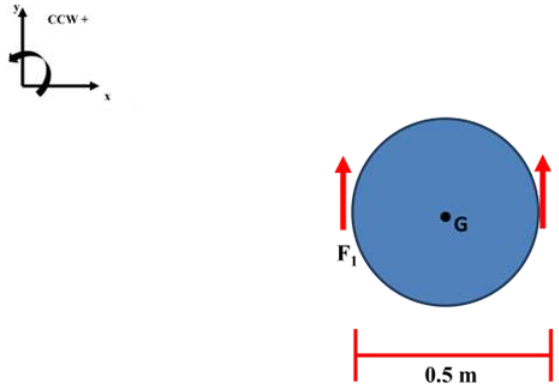


Figure $Chapter 3.4$: Free Body Diagram

We can also draw our **kinetic diagram** (KD) for the body as well in Fig.5

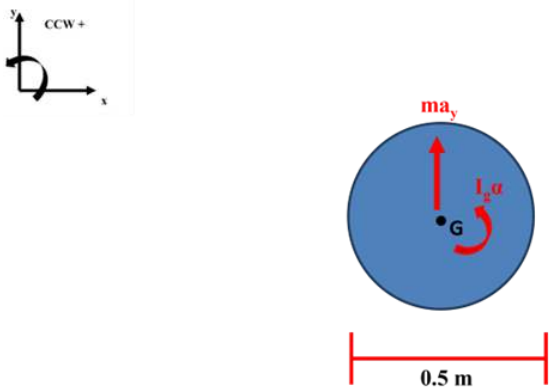


Figure $Chapter 3.5$: Kinetic Body Diagram

We can now write out our fundamental equations and let's start out looking at translations first and in the x-direction and in this direction we have no translational acceleration

$$\sum F_x = 0 \tag{Chapter 3.22}$$

We can also write out for translation in the y-direction where there is acceleration

$$\sum F_y = ma_y = F_1 + F_2 \tag{Chapter 3.23}$$

We can also use the relationship that we have for moments about a point and we will choose the location at 1 so

$$\sum M_1 = 2rF_2 = I_G\alpha + rma_y \tag{Chapter 3.24}$$

So we have two equations and two unknowns and now we can solve the problem for the unknowns!

Vibrations

We will often encounter systems that are vibrating and **vibrations** are the oscillating motion of a body or system from a position of equilibrium. There are many types of vibrations but to give an introduction to concept of vibrations we will consider the oscillation of a mass connected to a spring that is also connected to a wall as seen in Fig.6

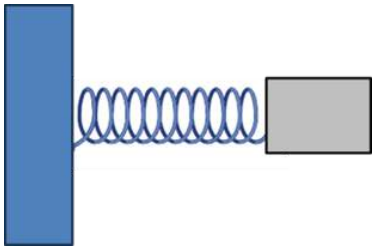


Figure *Chapter*3.6: Spring Mass System

We can then draw our FBD in Fig.7

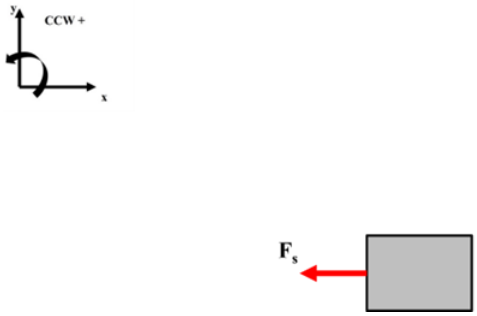


Figure *Chapter*3.7: Free Body Diagram

We can then draw our KBD in Fig.8

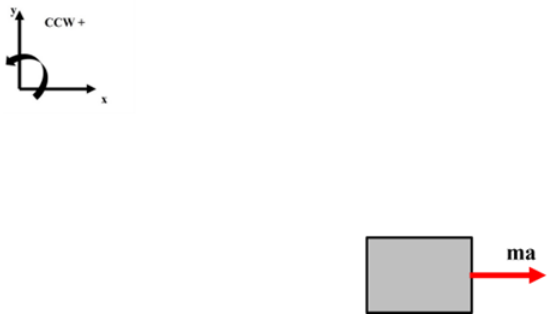


Figure *Chapter*3.8: Kinetic Body Diagram

We can solve this problem like we have done similarly and define our critical equations of motion and we see that

$$\sum F_y = 0 = -mg + N \tag{Chapter 3.25}$$

and the acceleration in the y-direction is zero because there is no motion/vibration in that direction and we can similarly analyze the motion in the x-direction

$$\sum F_x = ma = -kx \tag{Chapter 3.26}$$

We can also re-write this as a time derivative

$$a = \frac{d^2x}{dt^2} = \ddot{x} \tag{Chapter 3.27}$$

So the equation then becomes

$$m\ddot{x} + kx = 0 \tag{Chapter 3.28}$$

or we can define a natural frequency, $\omega_n = \sqrt{\frac{k}{m}}$, and re-write

$$\ddot{x} + \omega^2 x = 0 \tag{Chapter 3.29}$$

This is an example of a second order **ordinary differential equation** because we have a function of position, *x*, as a function of time and it is second order because we are dealing with a second derivative. If we can solve this problem by defining two initial conditions to solve the general solution that will have the form of

$$x(t) = A\sin\omega_n t + B\cos\omega_n t \tag{Chapter 3.30}$$

This type of motion an example of a motion termed **simple harmonic motion** and you will do a fun lab to confirm the natural frequency of a system.

Chapter 3: Dynamics and Vibrations is shared under a CC BY-NC-ND license and was authored, remixed, and/or curated by LibreTexts.

Chapter 4: Materials Science and Engineering

Pre-recorded videos that cover these topics can be found in the YouTube playlist here: https://www.youtube.com/playlist?lis...nO5C_shS_F5oeW.

Sign Conventions:

To begin let's talk about **units and sign conventions**. We will define any forces, stresses, or strain in **tension as positive** and any forces, stresses, or strain under **compression will be considered negative**. Additionally we will consider moments that are **counter clockwise as positive** and **clockwise as negative**.

Stress-Strain Curve:

When a material is placed under a stress state we will typically plot a stress-strain curve and that curve typically will have 3 distinct regions: **I) Elastic, II) Plastic, III) Fracture**.

I) Elastic Regime:

In the **elastic regime** the stress strain response is linear and defined by the expression below which should be familiar (Hooke's Law)

$$\sigma = E\epsilon \qquad \text{(Chapter 4.1)}$$

where E, sometimes Y, is defined as the **Young's Modulus**. It describes the stiffness of the material and is a material constant. **Metals** are typically in the **100s of GPa**, **ceramics** are high **200's and 300's of GPa**, **polymers** are closer to on the order of **1 GPa**. In the elastic region the strain is **completely reversible**, i.e. **there is no permanent or plastic deformation**. You are just **pulling on the bonds not breaking any bonds**.

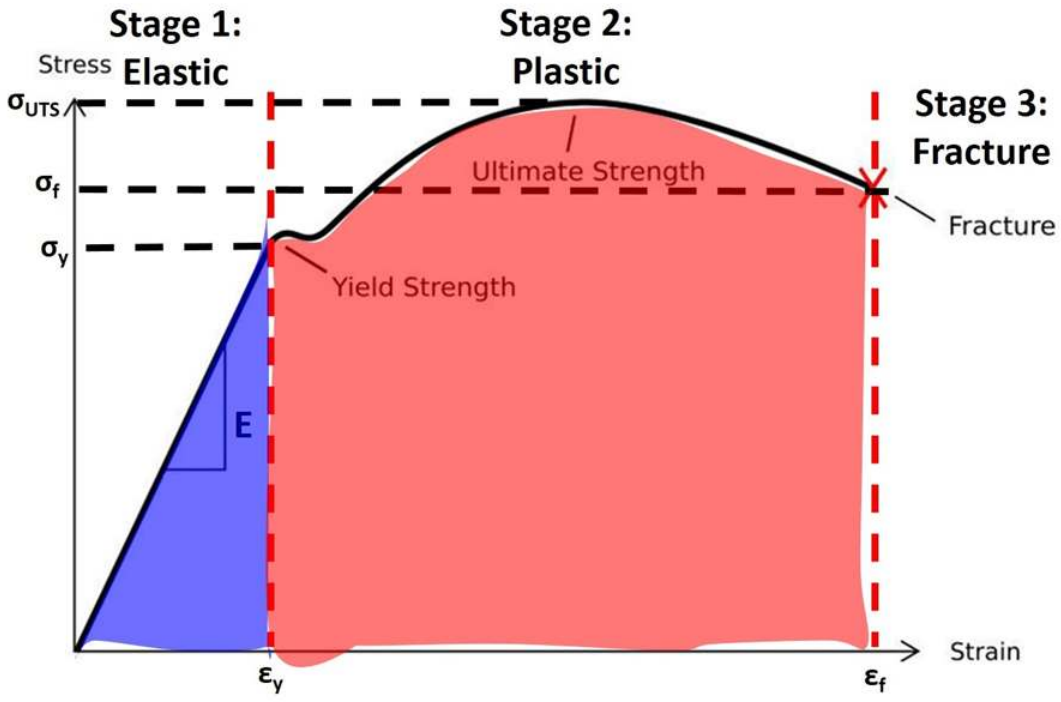


Figure *Chapter*4.1: Stress Strain Curve

II) Plastic Regime:

Here you are **plastically** deforming the material and this is signified microstructurally by the **breaking of bonds** and the **movement of dislocations**. Additionally with **plastic dislocation the strain is not reversible**, if you remove the force the strain remains. It is signified to begin on the stress strain curve by σ_y which is the **yield stress** and ϵ_y the **yield strain**. The σ_{UTS} is the

ultimate tensile strength and it denotes the **onset of necking** which is where the instantaneous area is now smaller than the original area.

III) Fracture:

As the name denotes this is where the material catastrophically fractures and is denoted by σ_f which is the **fracture stress** and the ϵ_f is the **fracture strain**[**?**].

At this point we need to stop and make a clear point about the language that we have to use when discussing the material properties of materials. Word choice is critical here because they mean very different things. When we talk about the **stiffness** of materials we are talking about the **Young's modulus** of the material. The higher the Young's modulus the stiffer the material. When we talk about **strength** we are talking about the **yield strength**, the **ultimate tensile strength**, or the **fracture stress or strength**. We we are talking about how **ductile** a material is we are talking about the **strain at failure**. We also often talk about material resilience and toughness as well.

We define **elastic strain energy (ESE)** which is defined as

$$U_{ESE} = V \int_0^{\epsilon_y} \sigma_{11} d\epsilon_{11} \tag{Chapter 4.2}$$

where V is the volume which gives us units of energy. This is the blue shaded portion. **Toughness** is defined as

$$U_T = V \int_0^{\epsilon_f} \sigma_{11} d\epsilon_{11} \tag{Chapter 4.3}$$

If a material is not as stiff it is called **compliant**, if a material is not strong it is **weak**, and if a material is not **tough** it is termed **brittle**.

Stress

Stress, σ, is a force normalized by the area over which it acts and the force is perpendicular to the area

$$\sigma = \frac{F}{A} = \frac{N}{m^2} = Pa \tag{Chapter 4.4}$$

where F is force and A is the original area. This is the definition of the **engineering stress** the **true stress** would be **normalized** by the **instantaneous area**. In this class we will use the engineering stress primarily in this class. **Shear stress**, τ, is a force normalized by the area over which it acts and the force is parallel to the area.

The shear stress is similarly defined as

$$\tau = \frac{F}{A} \tag{Chapter 4.5}$$

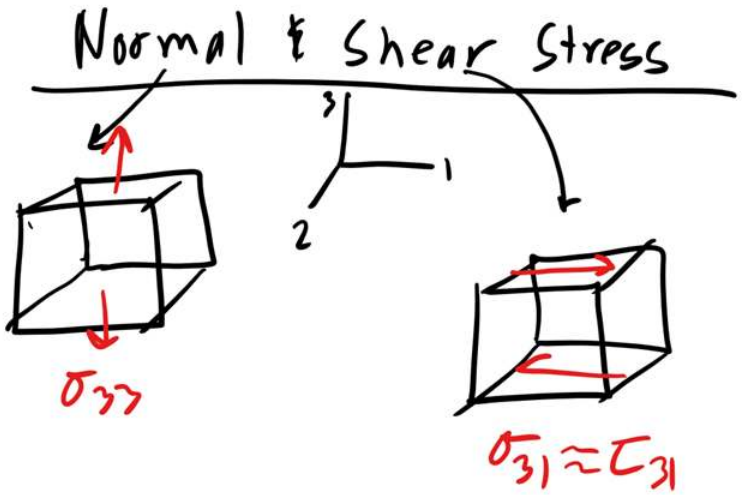


Figure *Chapter*4.2: Normal and Shear Stress.

Now it should be noted here that stress is a second rank tensor, σ_{ij}, and so is strain, ϵ_{ij}. For stress *i* denotes the **normal to the plane, on which the force is acting** and *j* is the **direction of the force**

$$\sigma_{ij} = \frac{F_j}{A_i} \tag{Chapter 4.6}$$

So our full stress tensor or our most generic stress state would be

$$\sigma = \begin{bmatrix} \sigma_{11} & \sigma_{12} & \sigma_{13} \\ \sigma_{21} & \sigma_{22} & \sigma_{23} \\ \sigma_{31} & \sigma_{32} & \sigma_{33} \end{bmatrix} \tag{Chapter 4.7}$$

Now this looks like a complex matrix with 9 independent components however they are not completely independent. If we assume that our cube volume element (**representative volume element (RVE)**is in equilibrium (not rotating) then we have the condition that

$$\sigma_{12} = \sigma_{21} \tag{Chapter 4.8}$$
$$\sigma_{23} = \sigma_{32} \tag{Chapter 4.9}$$
$$\sigma_{31} = \sigma_{13} \tag{Chapter 4.10}$$

so our matrix reduces to 6 independent components for our RVE

$$\sigma = \begin{bmatrix} \sigma_{11} & \sigma_{12} & \sigma_{13} \\ \sigma_{12} & \sigma_{22} & \sigma_{23} \\ \sigma_{13} & \sigma_{23} & \sigma_{33} \end{bmatrix} \tag{Chapter 4.11}$$

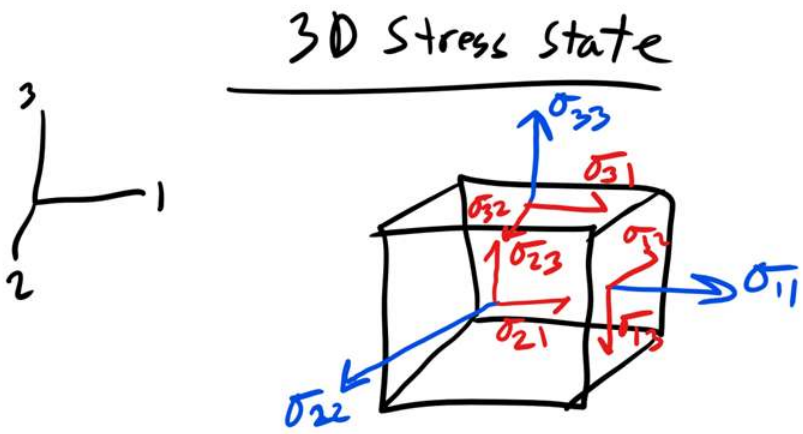


Figure *Chapter*4.3: 3D Stress State.

Strain:

All machines, structural members, and materials will deform to some extend when externally loaded by a force or stress. That deformation results in a displacement or **strain**, ϵ

$$\epsilon = \frac{dL}{L} \tag{Chapter 4.12}$$

$$\epsilon_t = \int_{L_1}^{L_2} \frac{dL}{L} = ln\frac{L_2}{L_1} \tag{Chapter 4.13}$$

where L_1 is the original length. This is the definition of **true strain**, ϵ_t but typically we work with a simpler form called the **engineering strain**, ϵ_e,

$$\epsilon_e = \frac{L_2 - L_1}{L_1} = \frac{\Delta L}{L_1} \tag{Chapter 4.14}$$

Typically engineers work with *microstrain* or parts per million. **Poisson's Ratio:**

Now what happens to the dimensions perpendicular to the direction of applied force when a the material is subjected to uniaxial tension? We know from experience that a **body begin pulled in tension will contract laterally**. This **lateral strain** is described by the **Poisson's Ratio**:

$$\nu = -\frac{\epsilon_L}{\epsilon_A} \tag{Chapter 4.15}$$

where ϵ_L is the lateral strain and ϵ_A is the axial strain. Note the **negative sign which signifies a decrease in length**. The Poisson's ratio is typically around **0.3 for metals**, **0.5 for rubber**, **0.4-0.5 for polymeric materials or biomaterials**, and **0.2 for ceramics**.

Stress-Strain Curve **Analysis**

Here we can find which material on these stress-strain curves is the most

• Stiffest

• Compliant

• Toughest

• Brittle

• Ductile

• Strongest

• Weakest

Linear Elastic Cubic Material Uniaxial Problems

Consider the following block of aluminum and there is an applied force of 18kN in Fig.4

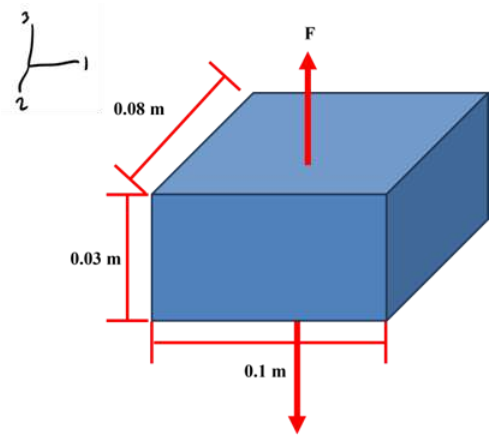


Figure $Chapter 4.4$: Solid Mechanics Problem

Calculate the following values

• Stress

• Strain

• Final Length in the 3 direction

• Final Length in the 1 direction

• Final Length in the 2 direction

Let's do this question if now we were under compression.

Bending

There are many scenarios where an object will undergo bending and we can calculate the stress in that beam

$$\sigma = -\frac{My}{I} \qquad \text{(Chapter 4.16)}$$

where $I = \frac{bh^3}{12}$ is the moment of inertia of a rectangular beam and y is the distance from the neutral axis of the beam.

Let us consider a classical example of a cantilever beam made of Nylon 6-6 with a length of 100cm, a width of 3cm, and a thickness of 0.1cm in Fig.5.

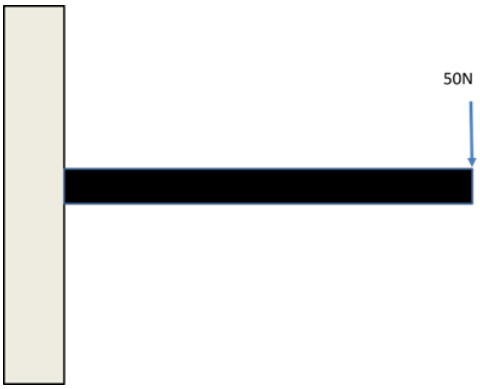


Figure $Chapter 4.5$: Bending Problem

Let solve for the stress at the support of the wall.

Buckling

Buckling is an instability phenomenon that can occur for columns under simple uniaxial compression and the critical load for buckling is

$$P_{cr} = \frac{\pi^2 EI}{l^2} \qquad \text{(Chapter 4.17)}$$

Now in terms of what *n* refers to physically it is the number of half-wavelengths along a column of length *l*. We see several interesting but expected phenomenon in this equation the first is that the critical load for buckling is linearly dependent on the flexural modulus but also scales as $l^{-}2$ so the longer the beam the lower the critical load which makes sense intuitively. So if we Ideally we would also want a constant *I* about all cross sectional axes and to have the same buckling load about all axes.

Chapter 4: Materials Science and Engineering is shared under a CC BY-NC-ND license and was authored, remixed, and/or curated by LibreTexts.

Chapter 5: Controls and Robotics

Pre-recroded videos that cover these topics can be found in the YouTube playlist here: https://www.youtube.com/playlist?lis...pRLnulPYtfcwL4.

Introduction to Controls and Robotics

Controls and **Robotics** is a critical subdiscipline of mechanical engineering. There is an entire series of courses that you will soon explore in these topics that are extremely useful like PID control systems but we will explore some concepts of controls, robotics, navigation, and programming using Arduinos and Parallax BOE shields.

This is just meant as a very very broad introduction to robotics and controls and to have some fun as well!!

Prototype and LED Control

Before we start designing cool robotics systems and applications we first need to get use to working with the Arduino interface, how to program with Arduino, and then to connect to our systems.

Let's first look at the Arduino software as seen in Fig.1

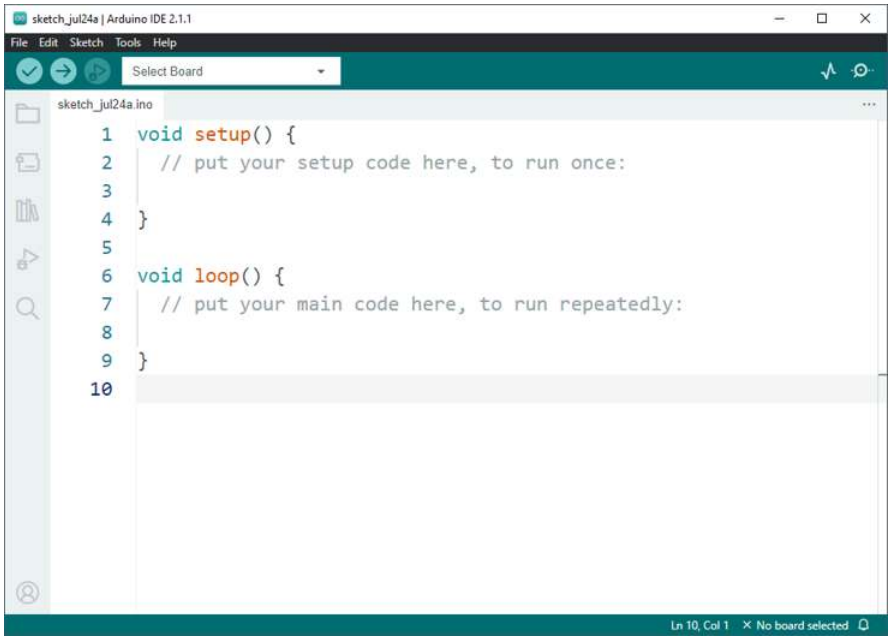


Figure *Chapter*5.1: Arduino Software.

The check in the upper left hand corner is a button you should push once you have written your code to verify the code and to see if there are any immediate error messages. I fyou click the arrow that points the right next to check will actually run the code and send it to the Arduino when connected. It is also important that whensending the code to the Arduino UNO board you select that board as well. You will also notice that there are two sections

• Void setup

• Void loop

The **setup** will contain code and statements and will execute any statements within this but only **once**. This code is run first and then moves to the next section, i.e. the **loop**. The **loop** will run that code repeatedly and continuously and forever so it is distinct from the setup section. Typically this will contain the main behavior of the program. After these two main sections you can typically create functions below these sections and you can make definitions or initializations above the setup section as well.

So let's start to build our first test bed and prototype a blinking LED control and we can see the circuit pins here in Fig.2 and the LED has an anode lead that is longer than the cathode end which should be connected to the ground.

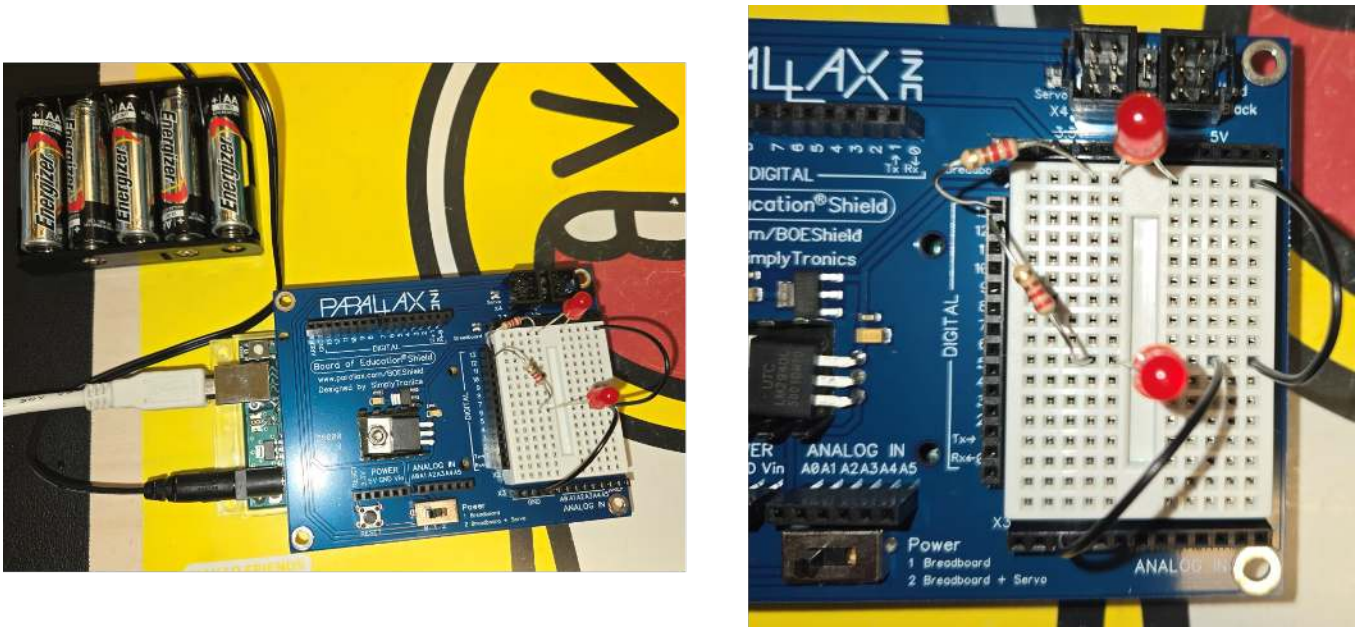


Figure *Chapter*5.2: LED Pin Board

We can note start to build our Arduino code and we need to set pin 12 and 13 as our output within the setup and then in the loop we can set the LED to turn on and turn off as seen in Fig.3.

In the delay function that is time in ms and when the write is high the voltage is 5V and when it is low the voltage will be set to 0V.

This was a fantastic proof of concept but now we can move to working with our **Servo Motors!**.

Controlling Servo Motors



Figure *Chapter*5.3: LED Arduino Code.

Now let's start to control motors specifically our **Servo Motors**. This will be critical to drive and navigate our robot but first we need to connect the motors to our board as seen in Fig.4

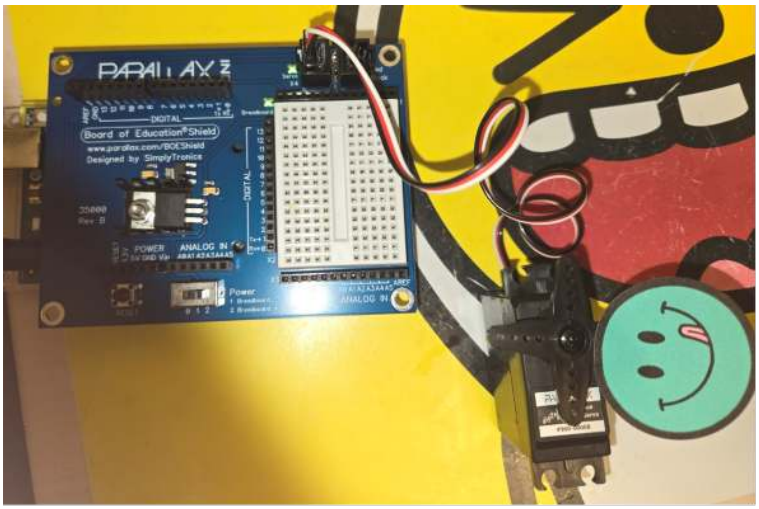




Figure *Chapter*5.4: Servo Motor Pin Board.

We are connecting these motors to Pin 12 and 13 here and we will have to do the following steps

• Include Servo Library

• Declare the Servo Motor

• Attach the Servo Motor to pin 12 or 13

• writeMicroseconds a value of 1500 will stay still, 1300 will go clockwise, and 1700 will go counter-clockwise

It is important that you may have to use a screwdriver to adjust the servomotor to ensure they do not turn when at a value of 1500. We can make the motors turn CW, CCW, pause, and then alternate as seen in Fig.5.

Servo_115 | Arduino IDE 2.3.2

File Edit Sketch Tools Help

Arduino Uno

Servo_115.ino

```
# include <Servo.h>
Servo leftMotor;
Servo rightMotor;

void setup() {
  rightMotor.attach(12);
  leftMotor.attach(13);
  }

void loop() {
  // put your main code here, to run repeatedly:
  rightMotor.writeMicroseconds(1300);
  leftMotor.writeMicroseconds(1300);
  delay(3000);
  rightMotor.writeMicroseconds(1700);
  leftMotor.writeMicroseconds(1700);
  delay(3000);
  rightMotor.writeMicroseconds(1500);
  leftMotor.writeMicroseconds(1500);
  delay(3000);
  rightMotor.writeMicroseconds(1700);
  leftMotor.writeMicroseconds(1300);
  delay(3000);
  rightMotor.writeMicroseconds(1300);
  leftMotor.writeMicroseconds(1700);
  delay(3000);
  rightMotor.writeMicroseconds(1500);
  leftMotor.writeMicroseconds(1500);
  delay(3000);
}
```

Figure $Chapter5.5$: Servo Motor Sketch.

Bot Navigation

Now that we have done our initial testing we can build our robot!! Be sure to follow the steps in our video and it should look like Fig.6.

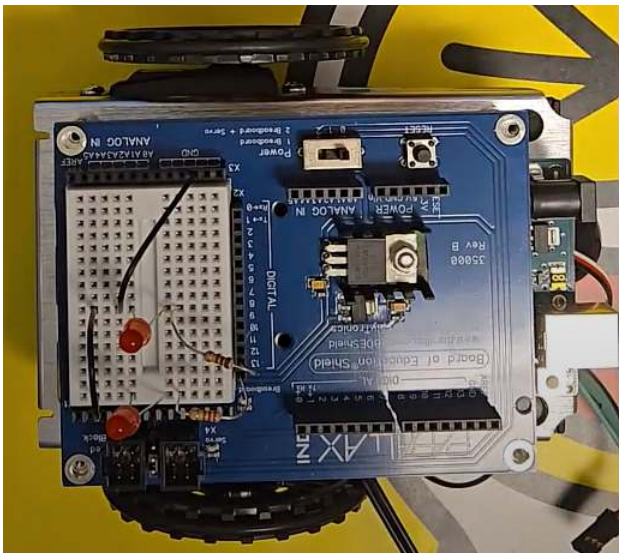


Figure $Chapter5.6$: Robot Image.

We can drive the robot using the same functions that we worked with previously to drive the robot forward, backward, turn right, turn left, pivot right, and pivot left in Fig.7.

forward_back_turn_pivot.ino

```
# include <Servo.h>
Servo leftMotor;
Servo rightMotor;
void setup() {
  // put your setup code here, to run once:
  rightMotor.attach(12);
  leftMotor.attach(13);
}

void loop() {
  // Move Forward
  rightMotor.writeMicroseconds(1700);
  leftMotor.writeMicroseconds(1300);
  delay(3000);
  // Turn Right
  rightMotor.writeMicroseconds(1700);
  leftMotor.writeMicroseconds(1700);
  delay(300);
  // Move Backward
  rightMotor.writeMicroseconds(1300);
  leftMotor.writeMicroseconds(1700);
  delay(3000);
  // Turn Left
  rightMotor.writeMicroseconds(1300);
  leftMotor.writeMicroseconds(1300);
  delay(300);
  // Pivot Forward Right
  rightMotor.writeMicroseconds(1700);
  leftMotor.writeMicroseconds(1500);
  delay(3000);
  // Pivot Forward Left
  rightMotor.writeMicroseconds(1500);
  leftMotor.writeMicroseconds(1300);
  delay(3000);
}

```

Figure *Chapter*5.7: Drive Robot Sketch.

We can also use a for loop to ramp up the speed the robot as seen in Fig.8

forward_back_turn_pivot_ramp.ino

```
# include <Servo.h>
Servo leftMotor;
Servo rightMotor;
void setup() {
  // put your setup code here, to run once:
  rightMotor.attach(12);
  leftMotor.attach(13);
  for(int speed = 0; speed<=200; speed+=1)
  {rightMotor.writeMicroseconds(1500+speed);
  leftMotor.writeMicroseconds(1500-speed);
  delay(20);}
}

void loop() {

}

```

Figure *Chapter*5.8: Ramp Up Robot Speed Sketch.

Whisker Navigation

We can now begin to program and combine some more complex navigation protocols to our robot but we also want our robot to navigate **autonomously**. However to do that we will have to add some additional **sensors** to provide feedback to guide navigation there are a number of sensors that we can choose from but we will illustrate a **whisker** navigation technique as well as a **light sensitive** navigation technique.

The whiskers work by either applying a 5V or if they are pressed and touch our 3 pin headers then the circuit applies 0 V. So we can utilize this digital readout that occurs if the whiskers physically run into something to change the direction of our robot. We can see our fully built robot here in Fig.9

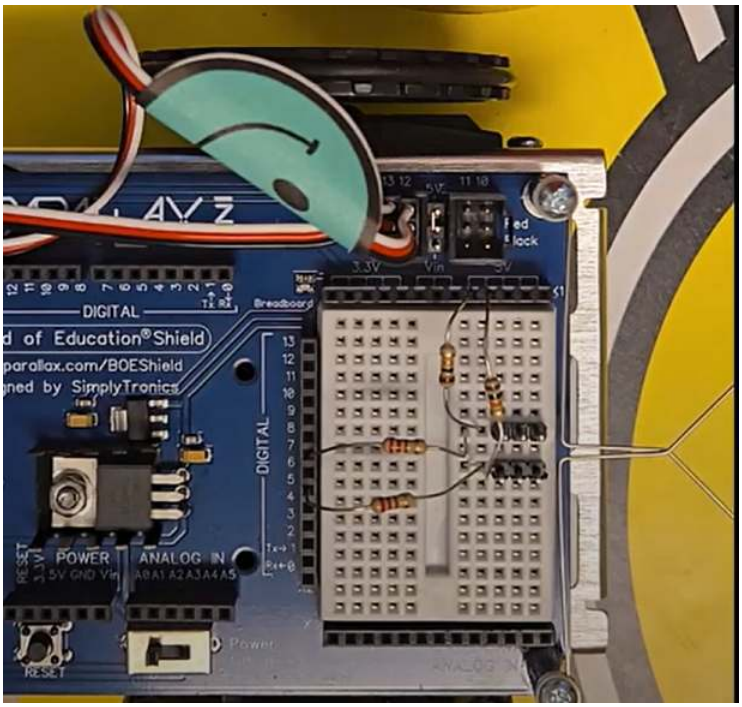


Figure *Chapter*5.9: Whisker Robot.

We can utilize **if** and **else if** function logic to navigate the robot here and we can demo this in class and in our videos.

Light Sensitive Navigation

We can also use a light sensor on our robot as seen here in Fig.10 and some of the same protocols we developed previously to move either toward or away from light.

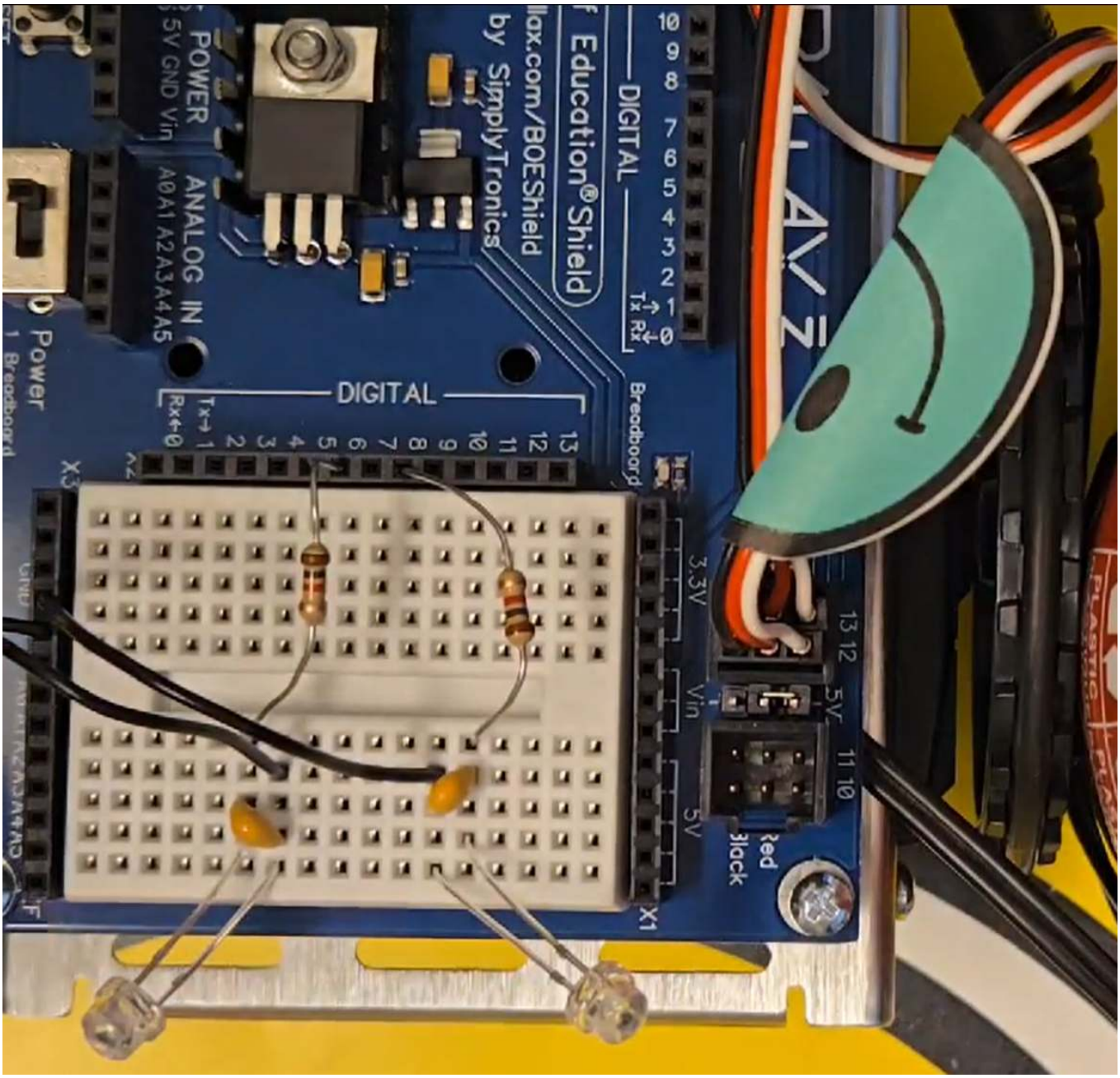


Figure *Chapter*5.10: Light Robot Robot.

We can also navigate our robot with a **camera** as well as **LED sensors** to do things like park, follow lines, or navigate a maze as well.

Chapter 5: Controls and Robotics is shared under a CC BY-NC-ND license and was authored, remixed, and/or curated by LibreTexts.

Introduction to Mechanical Engineering Discipline

TBD

Introduction to Mechanical Engineering Discipline is shared under a CC BY-NC-ND license and was authored, remixed, and/or curated by LibreTexts.

Statics

TBD

Statics is shared under a CC BY-NC-ND license and was authored, remixed, and/or curated by LibreTexts.

Index

D

dire

Glossary

Sample Word 1 | Sample Definition 1

Detailed Licensing

Overview

Title: Introduction to Mechanical Engineering

Webpages: 17

Applicable Restrictions: Noncommercial, No Derivatives

All licenses found:

- CC BY-NC-ND 4.0: 94.1% (16 pages)
- Undeclared: 5.9% (1 page)

By Page

- Introduction to Mechanical Engineering - *CC BY-NC-ND 4.0*
  - Front Matter - *CC BY-NC-ND 4.0*
    - TitlePage - *CC BY-NC-ND 4.0*
    - InfoPage - *CC BY-NC-ND 4.0*
    - Table of Contents - *Undeclared*
    - Licensing - *CC BY-NC-ND 4.0*
  - Chapter 1: Introduction to Mechanical Engineering Discipline - *CC BY-NC-ND 4.0*
  - Chapter 2: Statics - *CC BY-NC-ND 4.0*
  - Chapter 3: Dynamics and Vibrations - *CC BY-NC-ND 4.0*
  - Chapter 4: Materials Science and Engineering - *CC BY-NC-ND 4.0*
  - Chapter 5: Controls and Robotics - *CC BY-NC-ND 4.0*
  - Introduction to Mechanical Engineering Discipline - *CC BY-NC-ND 4.0*
    - Statics - *CC BY-NC-ND 4.0*
  - Back Matter - *CC BY-NC-ND 4.0*
    - Index - *CC BY-NC-ND 4.0*
    - Glossary - *CC BY-NC-ND 4.0*
    - Detailed Licensing - *CC BY-NC-ND 4.0*