

Fundamental of Engineering



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Chapter 1: Engineering Majors

1.1 Introduction

If you're considering engineering as a career, reading through this should be able to inform you a bit more about the different Engineering fields. It will also inform you about searching and applying for jobs and being able to transfer to a four-year university. Afterward, we will show you what a professional engineer is and how to become one.

1.2 Helpful Skills for Engineering

Firstly, engineering as a discipline requires critical thinking skills. This is only natural due to the very nature of engineering itself. It is most helpful in figuring out how well a current system is operating and in coming up with an effective way to keep it operating correctly. Engineering also requires you to stretch your mind in order to come up with a new system to either repair or replace an older system, product, or idea. Being able to both identify when a problem occurs, and quickly and effectively create an efficient solution to that problem will be a priceless asset to you and your employer in the face of any and all potentially failing situations.

1.3 The different Types of engineering

The following will show you some of the specific requirements for several different engineering fields. (Information below acquired from www.mynextmove.org and www.economicmodeling.com)

1.3.1 Civil Engineering

What they do:

Perform engineering duties in planning, designing, and overseeing construction and maintenance of building structures, and facilities, such as roads, railroads, airports, bridges, harbors, channels, dams, irrigation projects, pipelines, power plants, and water and sewage systems. Includes architectural, structural, traffic, ocean, and geo-technical engineers. Excludes "Hydrologists" (19-2043).

On the job, you would:

- Inspect project sites to monitor progress and ensure conformance to design specifications and safety or sanitation standards.
- Compute load and grade requirements, water flow rates, or material stress factors to determine design specifications.

- Provide technical advice to industrial or managerial personnel regarding design, construction, or program modifications or structural repairs.

Summary of Biomedical Engineers

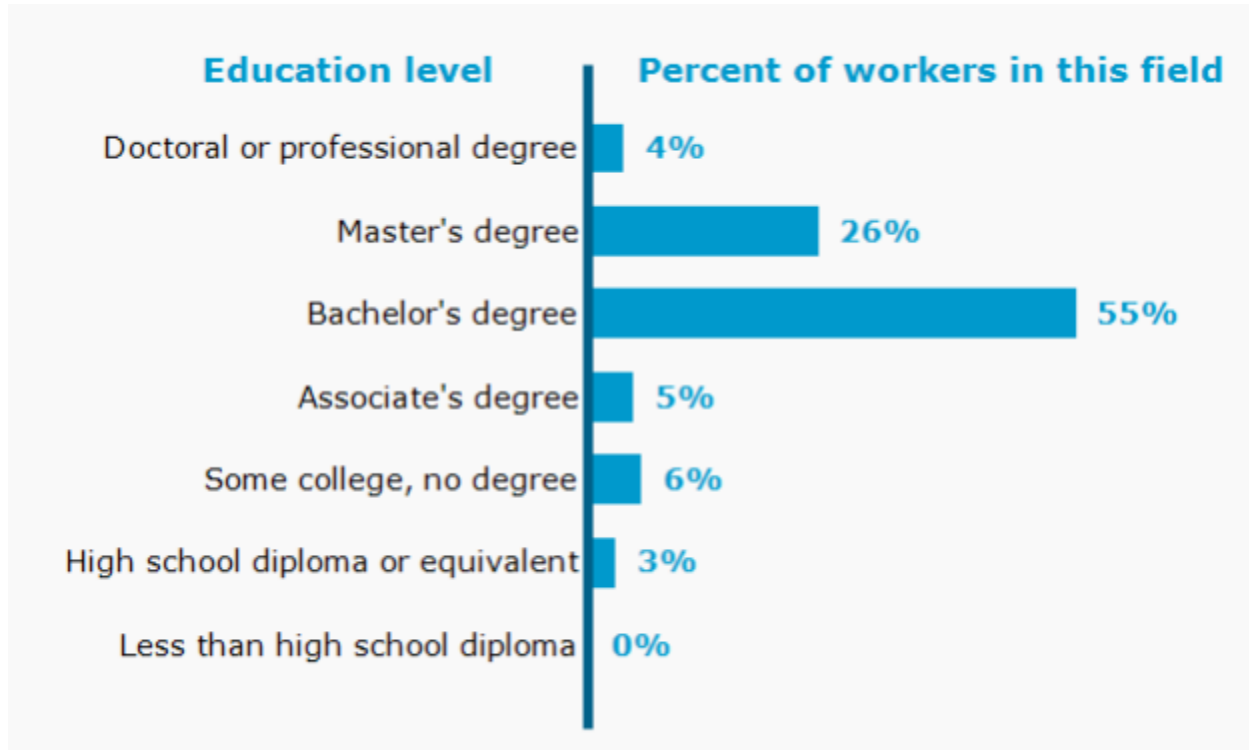
Activities: what you might do in a day

- Inspect facilities or sites to determine if they meet specifications or standards.
- Design systems to reduce harmful emissions.
- Recommend technical design or process changes to improve efficiency, quality, or performance.
- Estimate technical or resource requirements for development or production projects.
- Test characteristics of materials or structures.
- Direct construction activities.
- Survey land or bodies of water to measure or determine features.
- Estimate operational costs.
- Create graphical representations of civil structures.
- Prepare proposal documents.
- Explain project details to the general public.
- Incorporate green features into the design of structures or facilities.
- Develop technical methods or processes.
- Investigate the environmental impact of projects.
- Coordinate safety or regulatory compliance activities.
- Evaluate technical data to determine effect on designs or plans.
- Implement design or process improvements.
- Analyze operational data to evaluate operations, processes or products.

Typical tasks

- Inspect project sites to monitor progress and ensure conformance to design specifications and safety or sanitation standards.
- Design or engineer systems to efficiently dispose of chemical, biological, or other toxic wastes.
- Provide technical advice to industrial or managerial personnel regarding design, construction, or program modifications or structural repairs.
- Compute load and grade requirements, water flow rates, or material stress factors to determine design specifications.
- Test soils or materials to determine the adequacy and strength of foundations, concrete, asphalt, or steel.
- Manage and direct the construction, operations, or maintenance activities at project site.
- Direct or participate in surveying to lay out installations or establish reference points, grades, or elevations to guide construction.
- Estimate quantities and cost of materials, equipment, or labor to determine project feasibility.
- Plan and design transportation or hydraulic systems or structures using computer assisted design or drawing tools.
- Prepare or present public reports on topics such as bid proposals, deeds, environmental impact statements, or property and right-of-way descriptions.
- Design energy efficient or environmentally sound civil structures.
- Identify environmental risks and develop risk management strategies for civil engineering projects.

- Direct engineering activities ensuring compliance with environmental, safety, or other governmental regulations.
- Analyze survey reports, maps, drawings, blueprints, aerial photography, or other topographical or geologic data.
- Develop or implement engineering solutions to clean up industrial accidents or other contaminated sites.



Sample of Reported Job Titles:

Traffic Engineer
 Structural Engineer
 County Engineer
 City Engineer
 Railroad Design Consultant
 Transportation Engineer
 Roadway Engineer
 Traffic Operations Engineer
 Roadway Designer



1.3.2 Biomedical Engineers

What they do:

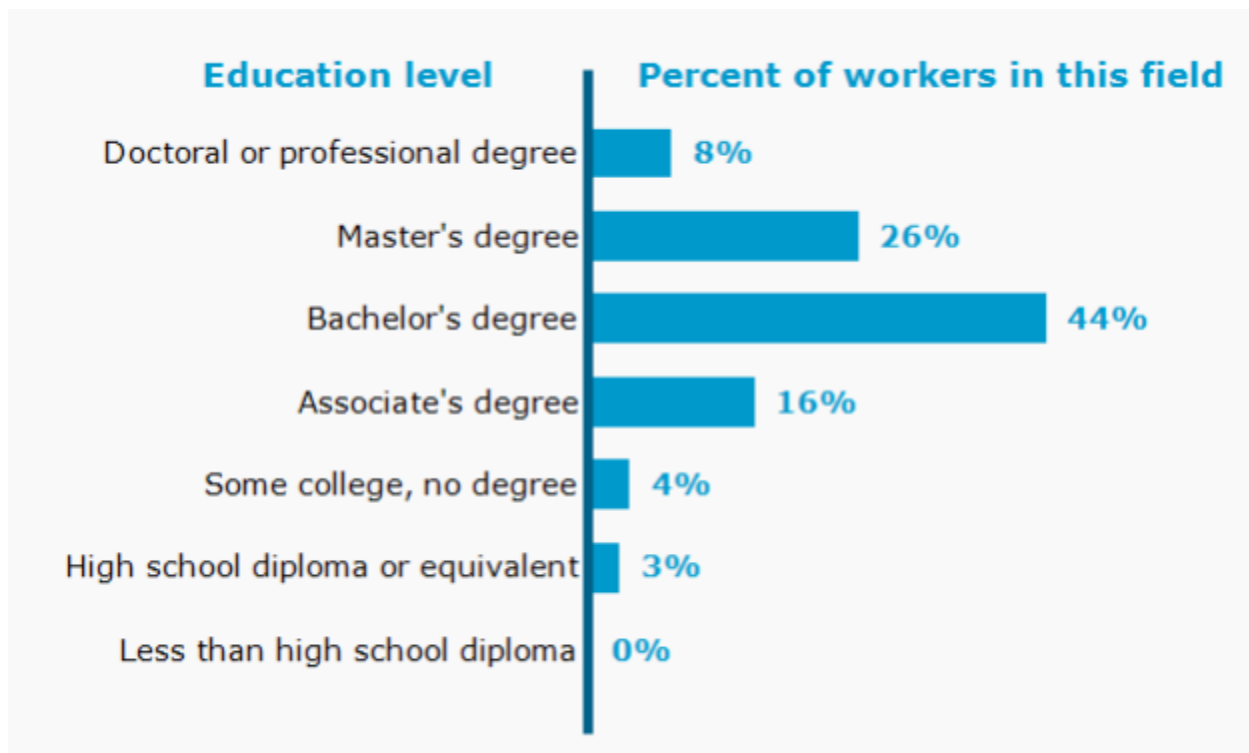
Apply knowledge of engineering, biology, and biomechanical principles to the design, development, and evaluation of biological and health systems and products, such as artificial organs, prostheses, instrumentation, medical information systems, and health management and care delivery systems.

On the job, you would:

- Design and develop medical diagnostic and clinical instrumentation, equipment, and procedures, using the principles of engineering and biobehavioral sciences.
- Conduct research, along with life scientists, chemists, and medical scientists, on the engineering aspects of the biological systems of humans and animals.
- Manage teams of engineers by creating schedules, tracking inventory, creating and using budgets, and overseeing contract obligations and deadlines.

Activities: what you might do in a day

- Design electronic or computer equipment or instrumentation.
- Research engineering aspects of biological or chemical processes.
- Supervise engineering or other technical personnel.
- Develop software or computer applications.
- Evaluate characteristics of equipment or systems.
- Create models of engineering designs or methods.
- Interpret design or operational test results.
- Prepare procedural documents.
- Advise customers on the use of products or services.
- Install instrumentation or electronic equipment or systems.
- Calibrate scientific or technical equipment.
- Train personnel on proper operational procedures.
- Analyze operational data to evaluate operations, processes or products.
- Design alternative energy systems.
- Maintain operational records or records systems.



Sample of Reported Job Titles:

Biomedical Engineer

Engineer

Clinical Engineer

Biomedical Manager

Biomedical Equipment Technician (BMET)

Biomedical Engineering Technician

Biomedical Engineering Director

Biomedical Electronics Technician

Research Engineer

1.3.3 Mechanical Engineering

What they do:

Perform engineering duties in planning and designing tools, engines, machines, and other mechanically functioning equipment. Oversee installation, operation, maintenance, and repair of equipment such as centralized heat, gas, water, and steam systems.

On the job, you would:

- Read and interpret blueprints, technical drawings, schematics, or computer-generated reports.
- Research, design, evaluate, install, operate, or maintain mechanical products, equipment, systems or processes to meet requirements.
- Confer with engineers or other personnel to implement operating procedures, resolve system malfunctions, or provide technical information.

Sample of Reported Job Titles:

Mechanical Design Engineer

Equipment Engineer

Design Engineer

Senior Stack Engineer

Senior Scientist

Technical Specialist

Technical Services Manager

Senior

Project

Engineer

1.3.4 Chemical Engineering

What they do:

Design chemical plant equipment and devise processes for manufacturing chemicals and products, such as gasoline, synthetic rubber, plastics, detergents, cement, paper, and pulp, by applying principles and technology of chemistry, physics, and engineering.

On the job, you would:

- Monitor and analyze data from processes and experiments.
- Develop safety procedures to be employed by workers operating equipment or working in close proximity to ongoing chemical reactions.
- Develop processes to separate components of liquids or gases or generate electrical currents, using controlled chemical processes.

Sample of Reported Job Titles:

Process Engineer

Development Engineer

Refinery Process Engineer

Scientist

Research Chemical Engineer

Project Engineer

Process Control Engineer

Engineering Scientist

Engineer

Chemical Engineer

1.3.5 Electrical Engineering

What they do:

Research, design, develop, test, or supervise the manufacturing and installation of electrical equipment, components, or systems for commercial, industrial, military, or scientific use.

On the job, you would:

- Operate computer-assisted engineering or design software or equipment to perform engineering tasks.
- Prepare technical drawings, specifications of electrical systems, or topographical maps to ensure that installation and operations conform to standards and customer requirements.
- Confer with engineers, customers, or others to discuss existing or potential engineering projects or products.

1.3.6 Industrial Engineering

What they do:

Design, develop, test, and evaluate integrated systems for managing industrial production processes, including human work factors, quality control, inventory control, logistics and material flow, cost analysis, and production coordination.

On the job, you would:

- Plan and establish sequence of operations to fabricate and assemble parts or products and to promote efficient utilization.
- Review production schedules, engineering specifications, orders, and related information to obtain knowledge of manufacturing methods, procedures, and activities.
- Estimate production costs, cost saving methods, and the effects of product design changes on expenditures for management review, action, and control.

Sample of Reported Job Titles:

Production Engineer

Process Engineer

Plant Engineer

Manufacturing Specialist

Manufacturing Engineer

Human Factors Engineer

User Experience Team Lead

Senior Research Associate

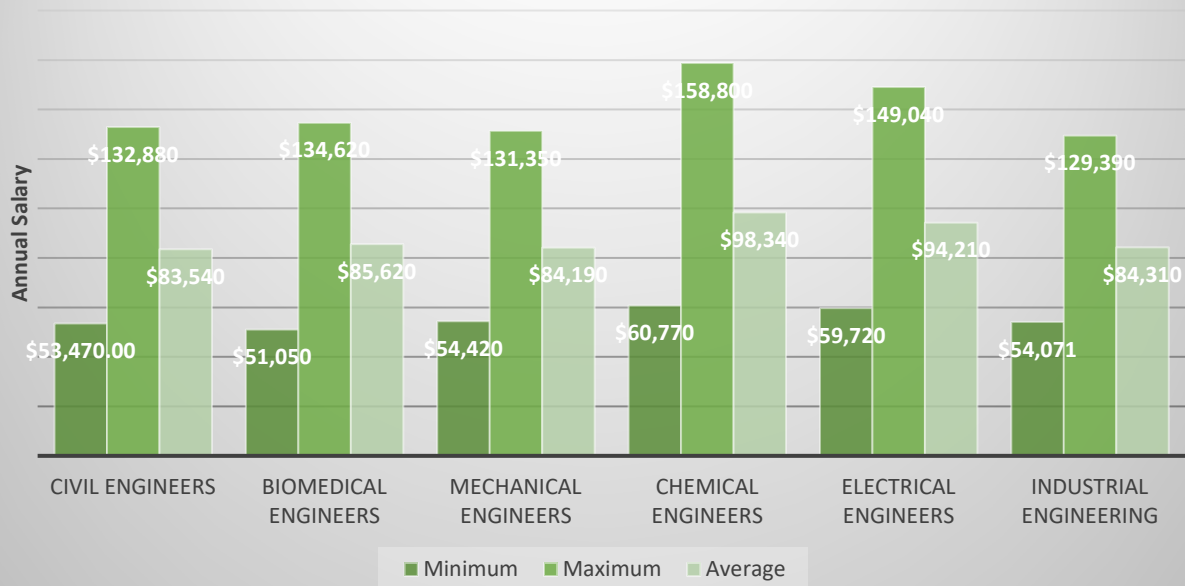
Principal Engineer

President Ergonomic Consulting

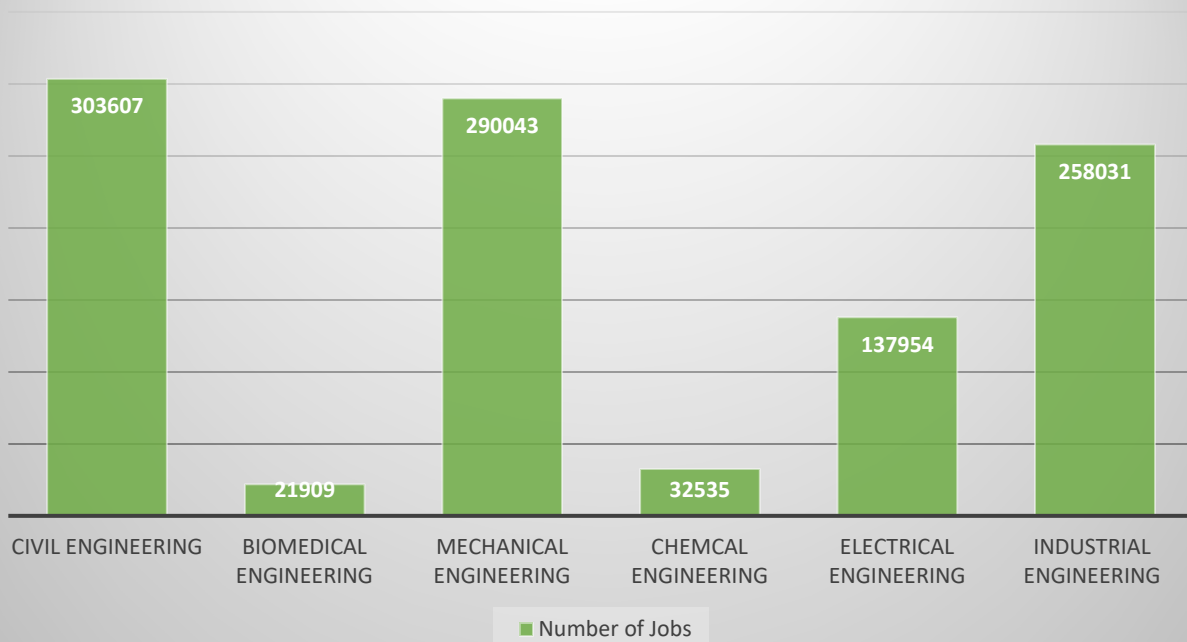
1.4 Comparisons between engineering majors

The following information was attained from www.economicmodeling.com.

Income Comparison Between Different Engineering Fields (2017)



Number of Jobs (2017 Nationally)



1.5 Engineering versus Engineering Technology:

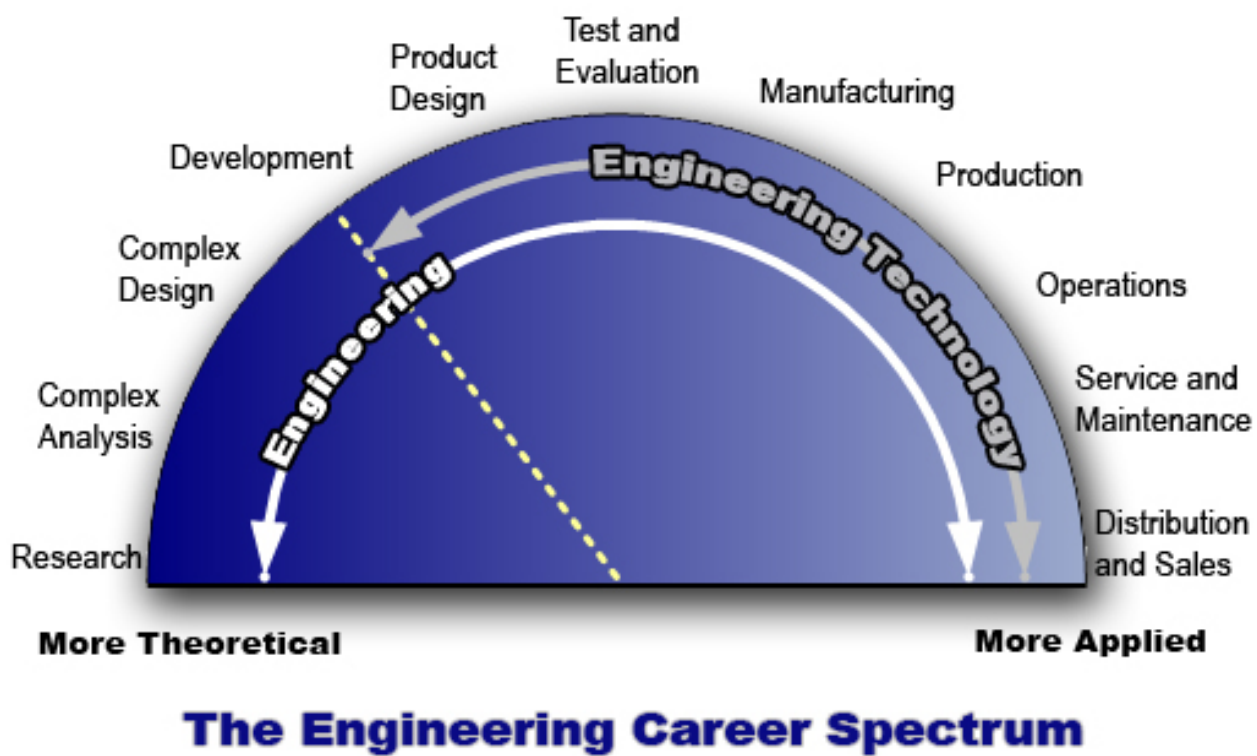
Engineering

- Knowledge required to meet the **needs of the future**

- Foundation is **calculus-based**
- Theory
- Research

Engineering Technology

- Knowledge required to **apply** state of the art techniques and design
- **Algebra-based**- applied calculus is required
- Application
- More Hands-on





- More Hands-on
- Less Math Requirements

4-Year Universities

Bachelor in Engineering Technology in two years



Bachelor in Engineering in two years



80-90 Credits to WSU

Transfer to an Engineering School

63-72 Credits to UM-Dearborn

Descent Career

Associate degree in Engineering Technology



Associate degree in Pre-Engineering

Who is Engineer?

- Apply knowledge **of math and science**
(Preparatory College Path)
- Conduct design and analysis
- Solve problems
- Develop
 - devices
 - processes
 - structures
 - systems



Engineering Technology?

Engineer Technologist is the same as Engineer, but
more hands-on and less analytical.

Less mathematics

More Practical



Chapter 2: How to Apply for a Job

Popular Sites

<http://careers.hfcc.edu/>

www.linkedin.com/

www.indeed.com/

www.symbaloo.com/profile/cs_o

www.simplyhired.com/

www.idealists.org/

www.glassdoor.com/index.htm

www.internships.com/

www.dice.com/

www.allstarjobs.com

www.beyond.com

www.careerexposure.com

www.career.com

www.careerage.com

www.careerbuilder.com

www.careeronestop.org

www.careersite.com

www.cjhunter.com

www.careerkey.org

Health Care/Medical Sites

www.healthcareers.com

www.medzilla.com

Human Resources Sites

www.hrconnections.com

www.hrhub.com

International Sites

www.escapeartist.com

www.internationaljobs.org

www.latpro.com

www.overseasjobs.com

www.wowjobs.ca

General Sites

2.1 Tips from Hiring Employers

The best job-search advice comes from the employers that are hiring. If you take the time to follow this advice, you'll be better prepared than your competition for your application and interview.

Here are some things you can do to aid in your job-search success:

Research the Company

- What products or services does the company produce and sell?
- Where is it located?
- How well did the company do last year?
- What activities by this company have been in the news lately?

Learn something about the company with which you want to interview. Read its website and its annual report. Search for news stories mentioning the company. Use this information to customize your resume and cover letter for the position you want. Impress the interviewer by knowing something about the company.

Perfect Your Qualifications

A high GPA is important. It means you know the subject matter. However, employers are looking for people with "soft skills," too—skills you can learn through extracurricular activities such as leading a team, taking part in a group task, or organizing a volunteer project. Employers want to find communication skills, a strong work ethic, teamwork skills, initiative, the ability to relate to co-workers and customers, problem-solving skills, and analytical skills.

Get Experience

Year after year, the majority of employers taking part in a survey conducted by the National Association of Colleges and Employers (NACE) say they prefer to hire job candidates who have pertinent experience. For college students, typically, relevant experience is gained through an internship.

An internship can be the "foot in the door" to a job with many employers: NACE surveys show that newly hired employees often come from the organization's internship program.

Build a Network

Whether you get the job you want—or even hear about the job opportunity you want—could easily depend on who you know.

Here's where you will find people to build your professional network:

Business and professional social networking sites

Professional associations (online and in-person)

Career fairs

Company information sessions

Your school's alumni network

An internship or co-op program

A student professional organization

2.2 The Cover Letter

Why a Cover letter?

The cover letter; never emphasized as much as it should be, could easily be just as important as your resume. The primary purpose of the cover letter is to give your potential employer a personalized, direct, and explanatory request for the position at hand. It is also there to show them that you have confidence in your abilities and qualifications to fill the position that you are applying for. Letting them know that you know you are up for the job and that your presence in the company will be of great benefit to them will strengthen your chance of "landing the job". The following page shows an example of a cover letter along with some suggestions on what to do, and what not to do.

Cover Letter Example

Robert Fictional

3333 Imaginary Rd. Empty Township, MI 48888

Home (555) 555-5555 / Cell (555) 777-7777

example@example.com

September 10, 2016

Mr. John Smith **(Contact's name – if name not available, use Human Resources Director)**

Hiring Manager **(Contact's title or position)**

Notreal Electronics **(Company's name)**

555 Some Road **(Company's mailing address)**

Some City, Michigan 48555

Dear Mr. Smith, **(Dear Mr./Ms. or if name not available, Dear Sir or Madam)**

First Paragraph: Tell them who you are and the position for which you are applying. Explain where you saw the position or how you found out about it. Tell them you believe/know/feel that you are a good fit for the position

My name is Robert Fictional and I am writing you this letter to express my interest in applying for the Assistant Manager position with Notreal Electronics. I learned about this position through the Office of Career Services at Henry Ford Community College. Based on my qualifications and your needs I believe I am a good fit for this position.

Second Paragraph: Tell them why you are the best person for this position. Match your skills and abilities with what they have stated in the job description that they are looking for. Tell them about your abilities, experiences, qualifications, skills, and how you can add value to the organization. Give three to four examples of how you fit the job requirements. Then give one example of how you would fit in with the company culture or how your values match the company's

In your job description for the Assistant Manager position you state that you are looking for someone that has experience with customer service and strong organizational skills. In my previous position as a clerk at ABC Dollar Store I had to deal with customers on a daily basis and I had to organize and schedule deliveries from vendors regularly. You also state you are looking for someone that has computer skills. I have used computers in both school and in the workplace and am very familiar with most software programs that Notreal Electronics would use and would like to bring these skills to work for you. Additionally, I know that you are looking for someone that can help you improve your regional sales numbers. I have helped increase sales by 38% in my current position over the last 2 years. Clearly your needs and my abilities would be a good match. After reviewing your company mission statement and core values I know that you also value someone that is goal oriented and driven. I have held down a full time job while completing my education at HFC and I always follow through with all of my commitments. I think that I would do well in the Assistant Manager position with Notreal Electronics

Third Paragraph: Thank them for reading your cover letter and resume. Tell them you want an opportunity to interview for the position. Provide your contact information.

Thank you for taking the time to review my cover letter and resume. I would greatly appreciate the opportunity to discuss my qualifications with you in more detail. I can be reached at 555-555-5555 or example @example.com. I look forward to your call.

Sincerely

Robert Fictional

2.3 The Resume

Why a Resume?

Having a well written, well-presented resume will help make the crucial first impression with your future potential employer that could make or break your opportunity to work for them. Presenting them with a neat, clearly defined, organized, and understandable document of your previous achievements and accomplishments will help them critically analyze your abilities and experience, and compare that to what will be required for the position they are trying to fill. An illustration comprising of the “do’s and don’ts” in a resume can be found at the end of the next section.

Action Words for Your Resume

Describe your accomplishments using brief statements. Each statement should include action words. **Example:** “HTML Programming experience.” say “Created client websites using HTML programming.” Always be sure to maintain the proper tense when describing past and present jobs.

Abstracted	Communicated	Directed	Fixed
Accepted	Compiled	Discovered	Formulated
Achieved	Composed	Displayed	Gathered
Acquired	Computed	Drew	Generated
Acted	Conceptualized	Earned	Greet
Adapted	Conducted	Edit	Greeted
Addressed	Confronted	Edited	Grossed
Administered	Consolidated	Eliminated	Group
Advised	Constructed	Empower	Facilitate
Allocated	Consulted	Empowered	Guided
Analyzed	Cooperated	Endure	Handled
Anticipated	Coordinated	Enforced	Hire/Fire
Applied	Corresponded	Entertain	Hired/Fired
Appraised	Counseled	Entertained	Hypothesized
Arranged	Counted	Established	Identified
Assembled	Created	Estimate	Illustrate
Assert	Critiqued	Estimated	Illustrated
Assessed	Enter	Evaluated	Implemented
Assisted	Decided	Evaluating	Improved
Attained	Decorated	Examine	Increased
Audited	Defined	Examine	Initiate
Budgeted	Delegated	Examined	Initiated
Built	Designed	Expanded	Inspect
Calculated	Detected	Experimented	Inspected
Classified	Determined	Explain	Install
Coached	Developed	Explained	Installed
Collected	Devised	Financed	Instituted
	Diagnosed		Instructed

Interpret	Network	Purchased	Sketch
Interpreted	Observe	Question	Sorted
Interview	Obtain	Read	Speak
Interviewed	Operate	Reason	Studied
Invent	Operated	Recommended	Styled
Invented	Ordered	Reconciled	Summarized
Inventory	Organized	Record	Supervise
Investigate	Oversaw	Recorded	Supervised
Investigated	Persuade	Recruit	Support
Lectured	Persuaded	Referred	Surveyed
Listened	Photographed	Refined	Teach
Locate	Plan	Rehabilitate	Test
Located	Planned	Remember	Tested
Maintain	Prepare	Repaired	Train
Maintained	Prepared	Represented	Trained
Managed	Preserve	Researched	Transcribed
Manipulate	Printed	Resolved	Traveled
Marketed	Prioritize	Responded	Troubleshoot
Mediate	Processed	Retrieved	Tutored
Modeled	Produced	Review	Upgraded
Monitored	Projected	Run	Utilized
Motivated	Proofread	Scheduled	Wrote
Negotiate	Provided	Selected	
Negotiated	Publicized	Sell	


Resume Example

**** The following page is an approved format for preparing your resume. Upload your finished product to your HFC Job Leads account at: careers.hfcc.edu ****

Robert Fictional

3333 Imaginary Rd. Empty Township, MI 48888
Home (555) 555-5555 / Cell (555) 777-7777
example@example.com

Objective Seeking the position of _____ *[Put actual job title in if known]* with _____ *[Put in actual company name if known]* where valuable experience can be gained and education can be utilized to benefit your company.
[Keep your objective as specific as possible and to the point.]

Education  Henry Ford College, Dearborn, MI May 2016
Associate in Applied Science Degree GPA 3.5
Electrical Technology
[Highlight things such as your degree and job titles by bolding or italicizing]

Experience

Clerk May 2014 - Present
ABC Dollar Store, Some City, MI

- **Prepare** store for opening and closing
- **Market** store products and services to customers
- **Coordinate and schedule** deliveries with various vendors
- **Collaborate** on projects with other staff members
- **Organize and input** daily sales totals into company computer system

[Notice the use of verbs to begin every line. Always start off work descriptions with an action verb i.e. something that you actually DO]

Ride Coordinator May 2013 - Sep 2014
AB Funrides, Anywhere, MI

- **Research**ed and responded to customer concerns
- **Ensured** customer safety
- **Processed** monetary transactions

[Notice verbs are now put in past tense. This is a very common mistake. Past jobs that are no longer current need to be put in past tense.]

Junior Varsity Lacrosse Coach Aug 2012 - Dec 2012
Notreal High School, Somewhere, MI

- **Managed** a team of 16-18 players
- **Devised** and taught strategic goals and concepts

[Don't worry if you don't always have a lot to put down for a job but make sure what you do put down is RELEVANT to the job you want. Don't put down job activities that will not help you get the job your objective is crafted for]

Sales Counselor May 2012 - Oct 2012
Sample Store, This Place, MI

- **Tabulated** worked hours and salary
- ~~**Marketed** company's services and product to customers~~
- **Established** sales goals and sold product to consumers

[Second bullet is removed because the same experience is highlighted in the first job, second bullet. Do not repeat experiences.]

Honors & Activities

Coach- Fictional Youth Baseball Team Sep 2013 - Present
Recipient- Sales Team Excellence Award, ABC Dollar Store May & Jun 2014
Volunteer- Mountain City Nursing Home May 2013

President- Baking Club, Henry Ford College

May 2015- Present

Computer Skills

Microsoft Office- Word, Excel, PowerPoint
Google Analytics

2.4 Page for Reference

Why a Page for Reference?

A page for reference will give the one hiring you a useful list of individuals to contact to show them your previous work performance. This should not be overlooked in the preparation for an interview or application.

Please note, that you should only submit a reference sheet to employers at the conclusion of an interview, or if an employer formally requests references as part of the application process. **Do not** submit them voluntarily as part of a resume/cover letter.

Remember, never “burn bridges” when you are leaving your current occupation because the person you are working, for now, can also play a pivotal role in whether or not you get the job that you are aiming for.

Robert Fictional

3333 Imaginary Rd. Empty Township, MI 48888
Home (555) 555-5555 / Cell (555) 777-7777
example@example.com

Charles Carmichael
Regional Manager
CJ Funrides Inc.
Dearborn, MI
Former Supervisor
555-555-9999
example@example.com

*[Make sure that anyone you put on a
sheet KNOWS that they are going to be a
reference for you]*

Desmond Hume
Store Manager
Viscount Electronics
Warren, MI
Former Co-worker
555-555-7777
example@example.com

*[Supervisors aren't the only people that
can be a reference for you. Also consider
former co-workers, co-workers, teachers,
former teachers, and anyone else that can
speak to your professional abilities]*

Dr. B. F. Pierce
Professor of Management
Henry Ford Community College
Dearborn, MI
Current Instructor
555-555-7777
example@example.com

*[Though you may have worked for family
members in the past it is inappropriate and
ineffective to list them on your reference
sheet. Employers place little weight in the
words of a family member. This should
be avoided.]*

The above contacts represent a standard reference sheet for a job seeker.

Employers just need the basics: Who they are, what their job title is, who they work for, their relationship to you, and how to contact them.

Chapter 3: Transferring to a University

Transferring from Henry Ford College to a University to finish a four-year degree requires you to take several courses specific to your Major along with most, or all, of the general education courses defined by the MTA (Michigan Transfer Agreement). The specific courses and general classes that will transfer is ultimately up to the University you plan on transferring too. Following a transfer guide and/or communicating with your educational advisor will be your safest option. Doing so will help you to both maximize your transferable credits, and help you avoid taking any unnecessary classes that won't count towards your degree.

3.1 MTA (Michigan Transfer Agreement)

What is it?

“The Michigan Transfer Agreement (MTA) was designed to facilitate the transfer of general education requirements from one institution to another. Students may complete the Michigan Transfer Agreement as part of an associate's degree or as a stand-alone package at a Michigan community college”. (www.macrao.org)

What courses will transfer from Henry Ford College?

The following is a guideline and overview of what courses transfer, and how many transfer to most universities participating in the MTA. Keep in mind that different paths of study and different Universities have different requirements and it is highly recommended that you check with your specific educational course and/or advisor to verify which of the following applies to you.

Category One: 1 course in English Composition

Category Two: 1 course in English Composition or Communications

Category Three: 1 course in Mathematics

Category Four: 2 courses in Social Sciences (One has to be Macro or Micro Economics)

Category Five: 2 courses in Humanities and Fine Arts

Category Six: 2 courses in Natural Sciences (Engineering Physics and General Chemistry)

Note: A minimum of 30 credit hours are required to satisfy the MTA requirements.

3.2 Transferring from the Pre-Engineering Program

Requirements for different fields of engineering and schools vary. Students must consult with the Engineering Faculty Advisor to plan an appropriate course of study for the area of engineering and the college or university to which they intend to transfer. Students are encouraged to take advantage of this by completing as many courses at HFC as possible that will eventually transfer to another academic institution.

Chapter 4: Professional Engineers and Codes of Ethics

4.1 How to Become a Professional Engineer in Michigan

What is a Professional Engineer?

(i) “Professional engineer” means a person who, by reason of the knowledge of mathematics, the physical sciences, and the principles of engineering, acquired by professional education and practical experience, is qualified to engage in the practice of professional engineering.

(MCL 339.2001 Definitions)

What does a Professional Engineer do?

(g) “Practice of professional engineering” means professional services, such as consultation, investigation, evaluation, planning, design, or review of material and completed phases of work in construction, alteration, or repair in connection with a public or private utility, structure, building, machine, equipment, process, work, or project, if the professional service requires the application of engineering principles or data. (MCL 339.2001 Definitions)

How to Become a Professional Engineer?

ELIGIBILITY FOR LICENSING

- Possess a bachelor’s or master’s degree from a school and program accredited by the Engineering Accreditation Commission/Accreditation Board of Engineering and Technology (EAC/ABET) or Canadian Engineering Accreditation Board (CEAB).
- Possess at least 4 years of acceptable engineering work experience obtained after having received an acceptable bachelor’s degree.
 - Experience must be verified by at least one individual familiar with the nature of work performed by the applicant.
- Pass the Fundamentals of Engineering (FE) examination administered through the National Council of Examiners for Engineering and Surveying (NCEES). The cost of the examination is \$225. For additional information, please visit www.ncees.org.
- Pass the Principles and Practice of Engineering (PE) examination administered through NCEES. The cost of the examination is \$350.
- Submit an online application at www.michigan.gov/mylicense.
 - Applicants must be of good moral character. The fee due at the time of application is \$75.

(www.michigan.gov)

4.2 NSPE Code of Ethics for Engineers

(Source: <https://www.nspe.org/resources/ethics/code-ethics>)

Preamble

Engineering is an important and learned profession. As members of this profession, engineers are expected to exhibit the highest standards of honesty and integrity. Engineering has a direct and vital impact on the quality of life for all people. Accordingly, the services provided by engineers require honesty, impartiality, fairness, and equity, and must be dedicated to the protection of the public health, safety, and welfare. Engineers must perform under a standard of professional behavior that requires adherence to the highest principles of ethical conduct.

I. Fundamental Canons

- Engineers, in the fulfillment of their professional duties, shall:
- Hold paramount the safety, health, and welfare of the public.
- Perform services only in areas of their competence.
- Issue public statements only in an objective and truthful manner.
- Act for each employer or client as faithful agents or trustees.
- Avoid deceptive acts.
- Conduct themselves honorably, responsibly, ethically, and lawfully so as to enhance the honor, reputation, and usefulness of the profession.

II. Rules of Practice

1. Engineers shall hold paramount the safety, health, and welfare of the public.
 - a. If engineers' judgment is overruled under circumstances that endanger life or property, they shall notify their employer or client and such other authority as may be appropriate.
 - b. Engineers shall approve only those engineering documents that are in conformity with applicable standards.
 - c. Engineers shall not reveal facts, data, or information without the prior consent of the client or employer except as authorized or required by law or this Code.
 - d. Engineers shall not permit the use of their name or associate in business ventures with any person or firm that they believe is engaged in fraudulent or dishonest enterprise.
 - e. Engineers shall not aid or abet the unlawful practice of engineering by a person or firm.
 - f. Engineers having knowledge of any alleged violation of this Code shall report thereon to appropriate professional bodies and, when relevant, also to public authorities, and cooperate with the proper authorities in furnishing such information or assistance as may be required.
2. Engineers shall perform services only in the areas of their competence.
 - . Engineers shall undertake assignments only when qualified by education or experience in the specific technical fields involved.

a. Engineers shall not affix their signatures to any plans or documents dealing with subject matter in which they lack competence, nor to any plan or document not prepared under their direction and control.

b. Engineers may accept assignments and assume responsibility for coordination of an entire project and sign and seal the engineering documents for the entire project, provided that each technical segment is signed and sealed only by the qualified engineers who prepared the segment.

3. Engineers shall issue public statements only in an objective and truthful manner.

. Engineers shall be objective and truthful in professional reports, statements, or testimony. They shall include all relevant and pertinent information in such reports, statements, or testimony, which should bear the date indicating when it was current.

a. Engineers may express publicly technical opinions that are founded upon knowledge of the facts and competence in the subject matter.

b. Engineers shall issue no statements, criticisms, or arguments on technical matters that are inspired or paid for by interested parties, unless they have prefaced their comments by explicitly identifying the interested parties on whose behalf they are speaking, and by revealing the existence of any interest the engineers may have in the matters.

4. Engineers shall act for each employer or client as faithful agents or trustees.

. Engineers shall disclose all known or potential conflicts of interest that could influence or appear to influence their judgment or the quality of their services.

a. Engineers shall not accept compensation, financial or otherwise, from more than one party for services on the same project, or for services pertaining to the same project, unless the circumstances are fully disclosed and agreed to by all interested parties.

b. Engineers shall not solicit or accept financial or other valuable consideration, directly or indirectly, from outside agents in connection with the work for which they are responsible.

c. Engineers in public service as members, advisors, or employees of a governmental or quasi-governmental body or department shall not participate in decisions with respect to services solicited or provided by them or their organizations in private or public engineering practice.

d. Engineers shall not solicit or accept a contract from a governmental body on which a principal or officer of their organization serves as a member.

5. Engineers shall avoid deceptive acts.

. Engineers shall not falsify their qualifications or permit misrepresentation of their or their associates' qualifications. They shall not misrepresent or exaggerate their responsibility in or for the subject matter of prior assignments. Brochures or other presentations incident to the solicitation of employment shall not misrepresent pertinent facts concerning employers, employees, associates, joint venturers, or past accomplishments.

a. Engineers shall not offer, give, solicit, or receive, either directly or indirectly, any contribution to influence the award of a contract by public authority, or which may be reasonably construed by the public as having the effect or intent of influencing the awarding of a contract. They shall not offer any gift or other valuable consideration in order to secure work. They shall not pay a commission, percentage, or brokerage fee

in order to secure work, except to a bona fide employee or bona fide established commercial or marketing agencies retained by them.

III. Professional Obligations

1. Engineers shall be guided in all their relations by the highest standards of honesty and integrity.

- a. Engineers shall acknowledge their errors and shall not distort or alter the facts.
- b. Engineers shall advise their clients or employers when they believe a project will not be successful.
- c. Engineers shall not accept outside employment to the detriment of their regular work or interest. Before accepting any outside engineering employment, they will notify their employers.
- d. Engineers shall not attempt to attract an engineer from another employer by false or misleading pretenses.
- e. Engineers shall not promote their own interest at the expense of the dignity and integrity of the profession.

2. Engineers shall at all times strive to serve the public interest.

. Engineers are encouraged to participate in civic affairs; career guidance for youths; and work for the advancement of the safety, health, and well-being of their community.

- a. Engineers shall not complete, sign, or seal plans and/or specifications that are not in conformity with applicable engineering standards. If the client or employer insists on such unprofessional conduct, they shall notify the proper authorities and withdraw from further service on the project.
- b. Engineers are encouraged to extend public knowledge and appreciation of engineering and its achievements.
- c. Engineers are encouraged to adhere to the principles of sustainable development¹ in order to protect the environment for future generations.
- d. Engineers shall continue their professional development throughout their careers and should keep current in their specialty fields by engaging in professional practice, participating in continuing education courses, reading in the technical literature, and attending professional meetings and seminars.

3. Engineers shall avoid all conduct or practice that deceives the public.

. Engineers shall avoid the use of statements containing a material misrepresentation of fact or omitting a material fact.

- a. Consistent with the foregoing, engineers may advertise for recruitment of personnel.
- b. Consistent with the foregoing, engineers may prepare articles for the lay or technical press, but such articles shall not imply credit to the author for work performed by others.

4. Engineers shall not disclose, without consent, confidential information concerning the business affairs or technical processes of any present or former client or employer, or public body on which they serve.

. Engineers shall not, without the consent of all interested parties, promote or arrange for new employment or practice in connection with a specific project for which the engineer has gained particular and specialized knowledge.

a. Engineers shall not, without the consent of all interested parties, participate in or represent an adversary interest in connection with a specific project or proceeding in which the engineer has gained particular specialized knowledge on behalf of a former client or employer.

5. Engineers shall not be influenced in their professional duties by conflicting interests.

. Engineers shall not accept financial or other considerations, including free engineering designs, from material or equipment suppliers for specifying their product.

a. Engineers shall not accept commissions or allowances, directly or indirectly, from contractors or other parties dealing with clients or employers of the engineer in connection with work for which the engineer is responsible.

6. Engineers shall not attempt to obtain employment or advancement or professional engagements by untruthfully criticizing other engineers, or by other improper or questionable methods.

. Engineers shall not request, propose, or accept a commission on a contingent basis under circumstances in which their judgment may be compromised.

a. Engineers in salaried positions shall accept part-time engineering work only to the extent consistent with policies of the employer and in accordance with ethical considerations.

b. Engineers shall not, without consent, use equipment, supplies, laboratory, or office facilities of an employer to carry on outside private practice.

7. Engineers shall not attempt to injure, maliciously or falsely, directly or indirectly, the professional reputation, prospects, practice, or employment of other engineers. Engineers who believe others are guilty of unethical or illegal practice shall present such information to the proper authority for action.

. Engineers in private practice shall not review the work of another engineer for the same client, except with the knowledge of such engineer, or unless the connection of such engineer with the work has been terminated.

a. Engineers in governmental, industrial, or educational employ are entitled to review and evaluate the work of other engineers when so required by their employment duties.

b. Engineers in sales or industrial employ are entitled to make engineering comparisons of represented products with products of other suppliers.

8. Engineers shall accept personal responsibility for their professional activities, provided, however, that engineers may seek indemnification for services arising out of their practice for other than gross negligence, where the engineer's interests cannot otherwise be protected.

. Engineers shall conform with state registration laws in the practice of engineering.

a. Engineers shall not use association with a nonengineer, a corporation, or partnership as a "cloak" for unethical acts.

9. Engineers shall give credit for engineering work to those to whom credit is due, and will recognize the proprietary interests of others.

. Engineers shall, whenever possible, name the person or persons who may be individually responsible for designs, inventions, writings, or other accomplishments.

a. Engineers using designs supplied by a client recognize that the designs remain the property of the client and may not be duplicated by the engineer for others without express permission.

b. Engineers, before undertaking work for others in connection with which the engineer may make improvements, plans, designs, inventions, or other records that may justify copyrights or patents, should enter into a positive agreement regarding ownership.

c. Engineers' designs, data, records, and notes referring exclusively to an employer's work are the employer's property. The employer should indemnify the engineer for use of the information for any purpose other than the original purpose.

Chapter 5: Engineering Extracurricular Activities

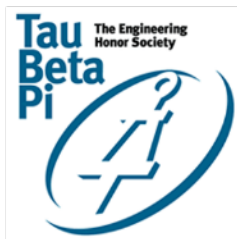
5.1 Student Chapters of engineering organizations



To promote and enhance the technical competency and professional well being of our members, and through quality programs and activities in mechanical engineering.



SME promotes advanced manufacturing technology and develops a skilled workforce.



The Society of Women Engineers supports and encourages women in pursuit of their engineering degree.



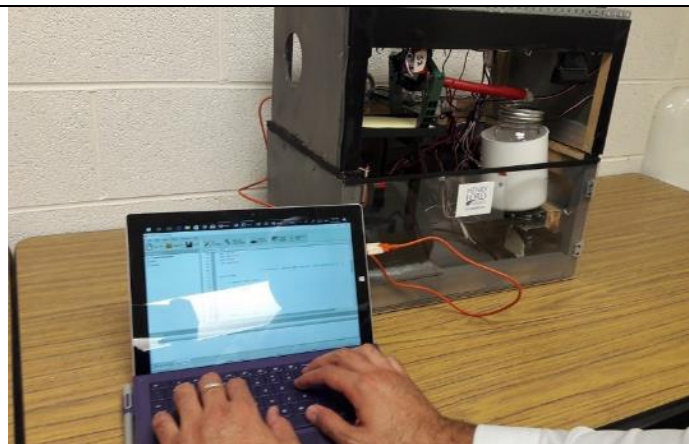
The IEEE Student Branch strives to enhance the student's academic goals in the field of electrical and computer engineering

The mission of the Michigan Epsilon Chapter of The Tau Beta Pi Association is to honor both students and professionals, in the field of engineering, who demonstrate distinguished scholarship and exemplary character.



Joining the ASCE student chapter will allow you to meet fellow civil students and faculty members, and to network with those in industry

5.2 Henry Ford College Engineering Club



The Engineering Club encourages students to explore careers in the field of engineering and provides a forum for the exchange of ideas and activities related to the field of engineering. The club strives to develop future leaders through teamwork and opportunities for professional growth and development.

Learn amazing stuff

- Program a robot controller.
- Design a 3D object and make it with a 3D printer.

- Come up with an amazing idea and learn how to make a reality.

Contact engineering@hfcc.edu for more information.

<http://facebook.com/hfceng>

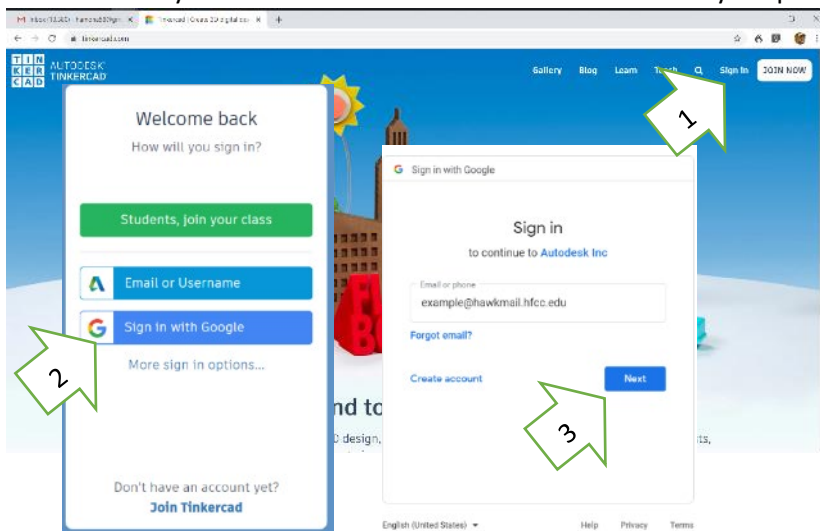
Chapter 6: Arduino Tutorial

6.1 Arduino Circuit Simulation in TinkerCAD

How to use Tinker CAD

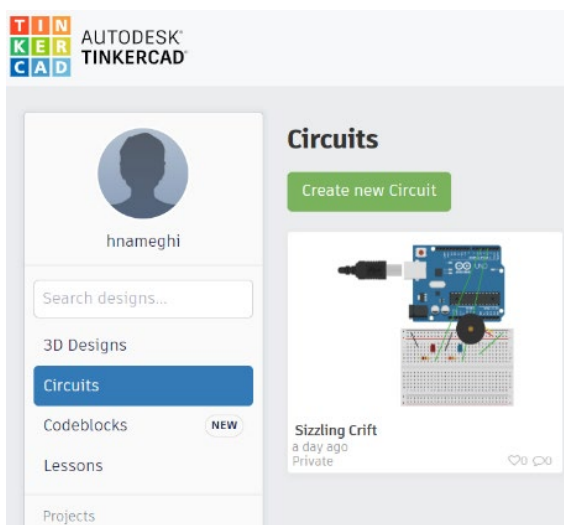
Open a browser, and type in www.tinkercad.com

- 1- On the right-top of the screen click on “Sign In”
- 2- Click on “Sign In with Google”
- 3- Enter your Hawkmail and click Next and then enter your password.

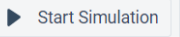


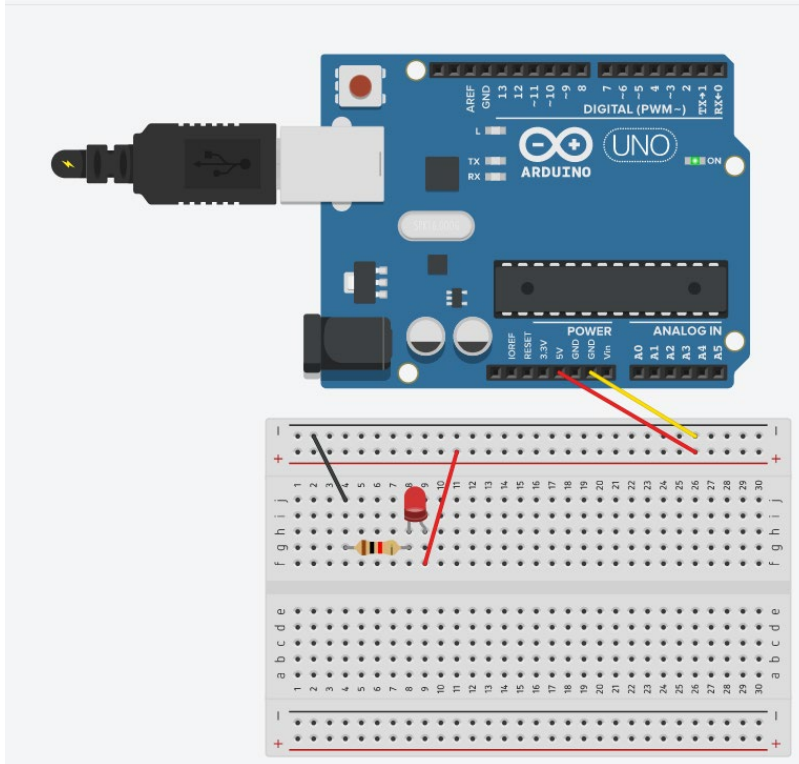
Circuits in TinkerCAD

- Make sure “Circuits” is selected on the left tab
- Click “create new Circuit”



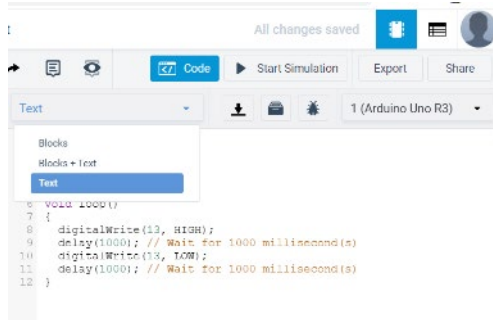
Example 1: Simple Circuit (just to turn on an LED light)

- 1- Click on Components, Basic, select Arduino, Drag the Arduino a Breadboard to the page
- 2- For this experiment, we need a resistor and an LED light. Drag the components and build the circuits as below.
- 3- Click on the resistor, and change the resistance to 100 Ω
- 4- Remember that breadboard rows are connect underneath. Therefore, if two wires are inserted in the same row, they will be connected.
- 5- Click on  "Start Simulation" on the top, your LED should light up.



Example 2: Circuit for a blinking LED light

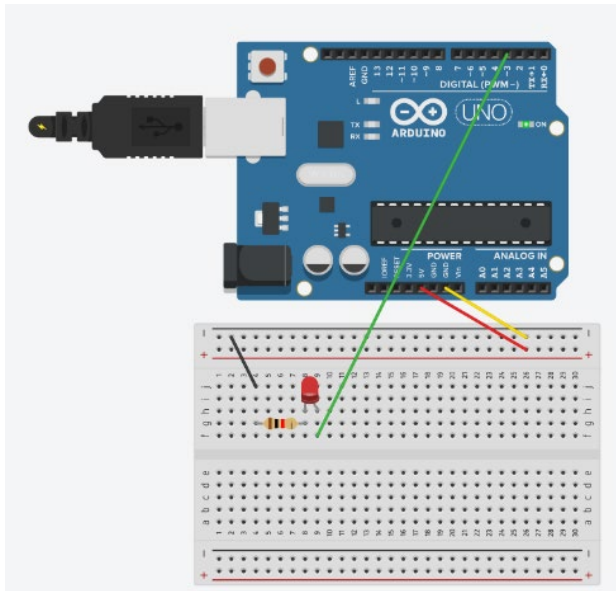
- 1- Click on Code, on the top, then select “Text”, and copy-paste the following code.



```
void setup()
{
  pinMode(3, OUTPUT);
}

void loop()
{
  // turn the LED on
  digitalWrite(3, HIGH);
  delay(1000); // Wait for 10000 millisecond(s)
  // turn the LED off
  digitalWrite(3, LOW);
  delay(1000); // Wait for 10000 millisecond(s)
}
```

- 2- Setup your circuit as shown below, and click on “Start Simulation”, and LED light should start blinking



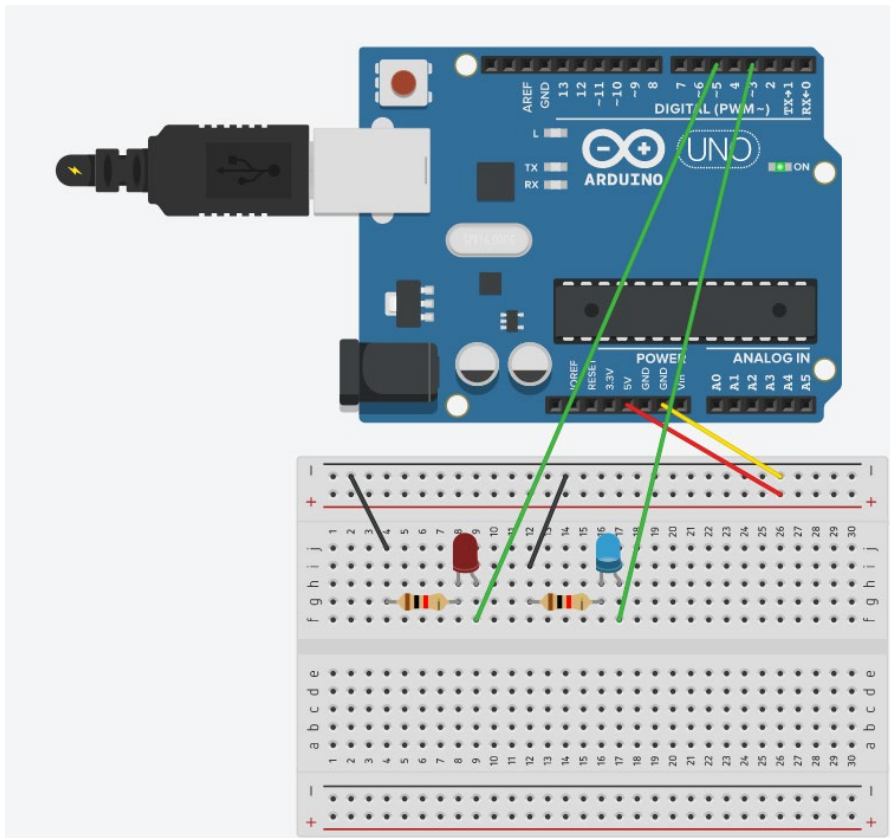
Example 3: Circuit for two blinking LED lights

1- Click on “Code”, on the top, then select “Text”, and copy-paste the following code.

```
void setup()
{
  pinMode(3, OUTPUT);
  pinMode(5, OUTPUT);
}
void loop()
{
  digitalWrite(3, HIGH);
  digitalWrite(5, LOW);
  delay(1000); // Wait for 10000 millisecond(s)
  digitalWrite(3, LOW);
  digitalWrite(5, HIGH);

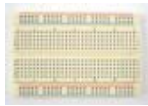



  delay(1000); // Wait for 10000 millisecond(s)
}
```

2- Setup your circuit as shown below, and click on “Start Simulation”, and LED lights should start blinking.

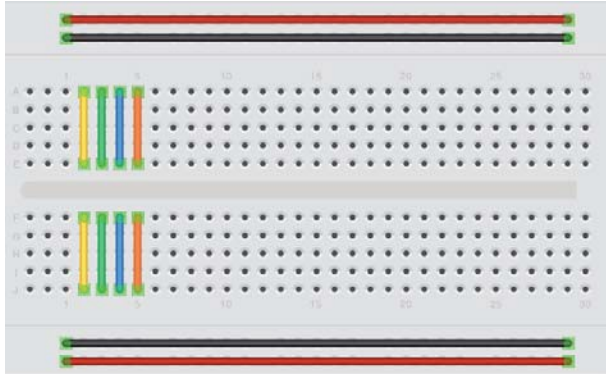


6.2 Hardware Overview (Source: www.EarthshineDesign.co.uk)

The hardware used for this project was:-

Breadboard	
Red LED	
150Ω Resistor	
Jumper Wires	

The breadboard is a reusable solderless device used generally to prototype an electronic circuit or for experimenting with circuit designs. The board consists of a series of holes in a grid and underneath the board these holes are connected by a strip of conductive metal. The way those strips are laid out is typically something like this:-



The strips along the top and bottom run parallel to the board and are design to carry your power rail and your ground rail. The components in the middle of the board can then conveniently connect to either 5v (or whatever voltage you are using) and Ground. Some breadboards have a red and a black line running parallel to these holes to show which power (Red) is and which is Ground (Black). On larger breadboards the power rail sometimes has a split, indicated by a break in the red line. This is in case you want different voltages to go to different parts of your board. If you are using just one voltage a short piece of jumper wire can be placed across this gap to make sure that the same voltage is applied along the whole length of the rail

The strips in the centre run at 90 degrees to the power and ground rails in short lengths and there is a gap in the middle to allow you to put Integrated Circuits across the gap and Have each pin of the chip go to a different set of holes and therefore a different rail.



The next component we have is a [Resistor](#). A resistor is a device designed to cause 'resistance' to an electric current and therefore cause a drop in voltage across it's terminals. If you imagine a resistor to be like a water pipe that is a lot thinner than the pipe connected to it. As the water (the electric current) comes into the resistor, the pipe gets thinner and the current coming out of the other end is therefore reduced. We use resistors to decrease voltage or current to other devices. The value of resistance is known as an Ohm and it's symbol is a Greek Omega symbol Ω .

In this case Digital Pin 10 is outputting 5 volts DC at (according to the Atmega datasheet) 40mA (milliamps) and our LED's require (according to their datasheet) a voltage of 2v and a current of 20mA. We therefore need to put in a resistor that will reduce the 5v to 2v and the current from 40mA to 20mA if we want to display the LED at it's maximum brightness. If we want the LED to be dimmer we could use a higher value of resistance.

To work out what resistor we need to do this we use what is called [Ohm's law](#) which is $I = V/R$ where I is current, V is voltage and R is resistance. So to work out the resistance we arrange the formula to be $R = V/I$ which is $R = 3/0.02$ which is 100 Ohms. V is 3 because we need the Voltage Drop, which is the supply voltage (5v) minus the Forward Voltage (2v) of the LED (found in the LED datasheet) which is 3v. We therefore need to find a 150Ω resistor. So how do we do that?

A resistor is too small to put writing onto that could be readable by most people so instead resistors use a colour code. Around the resistor you will typically find 4 coloured bands and by using the colour code in the chart on the next page you can find out the value of a resistor or what colour codes a particular resistance will be.

WARNING:

Always put a resistor (commonly known as a current limiting resistor) in series with an LED. If you fail to do this you will supply too much current to the LED and it

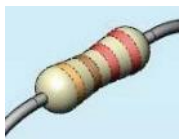
Colour	1 st Band	2 nd Band	3 rd Band (multiplier)	4 th Band (tolerance)
Black	0	0	$\times 10^0$	
Brown	1	1	$\times 10^1$	$\pm 1\%$
Red	2	2	$\times 10^2$	$\pm 2\%$
Orange	3	3	$\times 10^3$	
Yellow	4	4	$\times 10^4$	
Green	5	5	$\times 10^5$	$\pm 0.5\%$
Blue	6	6	$\times 10^6$	$\pm 0.25\%$
Violet	7	7	$\times 10^7$	$\pm 0.1\%$
Grey	8	8	$\times 10^8$	$\pm 0.05\%$
White	9	9	$\times 10^9$	
Gold			$\times 10^{-1}$	$\pm 5\%$
Silver			$\times 10^{-2}$	$\pm 10\%$
None				$\pm 20\%$

We need a 150 Ω resistor, so if we look at the colour table we see that we need 1 in the first band, which is Brown, followed by a 5 in the next band which is Green and we then need to multiply this by 10^1 (in other words add 1 zero) which is Brown in the 3rd band. The final band is irrelevant for our purposes as this is the tolerance. Our resistor has a gold band and therefore has a tolerance of $\pm 5\%$ which means the actual value of the resistor can vary between 142.5 Ω and 157.5 Ω . We therefore need a resistor with a Brown, Green, Brown, Gold colour band combination which looks like this:-

If we needed a 1K (or 1 kilo-ohm) resistor we would need a Brown, Black, Red combination (1, 0, +2 zeros). If we needed a 570K resistor the colours would be Green, Violet and Yellow.



In the same way, if you found a resistor and wanted to know what value it is you would do the same in



reverse. So if you found this resistor and wanted to find out what value it was so you could store it away in your nicely labelled resistor storage box, we could look at the table to see it has a value of 220 Ω .

Our final component is an LED (I'm sure you can figure out what the jumper wires do for yourself), which stands for Light Emitting Diode. A [Diode](#) is a device that permits current to flow in only one direction. So, it is just like a valve in a water system, but in this case it is letting electrical current to go in one direction, but if the current tried to reverse and go back in the opposite direction the diode would stop it from doing so. Diodes can be useful to prevent someone from accidentally connecting the Power and Ground to the wrong terminals in a circuit and damaging the components.

An [LED](#) is the same thing, but it also emits light. LED's come in all kinds of different colours and brightnesses and can also emit light in the ultraviolet and infrared part of the spectrum (like in the LED's in your TV remote control).

If you look carefully at the LED you will notice two things. One is that the legs are of different lengths and also that on one side of the LED, instead of it being cylindrical, it is flattened. These are indicators to show you which leg is the Anode (Positive) and which is the Cathode (Negative). The longer leg gets connected to the Positive Supply (5v) and the leg with the flattened side goes to Ground.

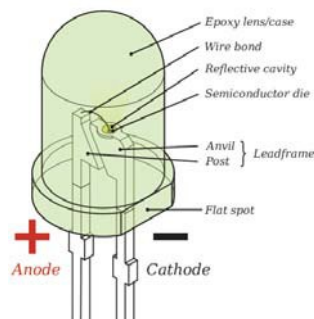
If you connect the LED the wrong way, it will not damage it (unless you put very high currents through it) and indeed you can make use of that 'feature' as we will see later on.

It is essential that you always put a resistor in series with the LED to ensure that the correct current gets to the LED. You can permanently damage the LED if you fail to do this.

As well as single colour resistors you can also obtain bi-colour and tri-colour LED's. These will have several legs coming out of them with one of them being common (i.e. Common anode or common cathode).

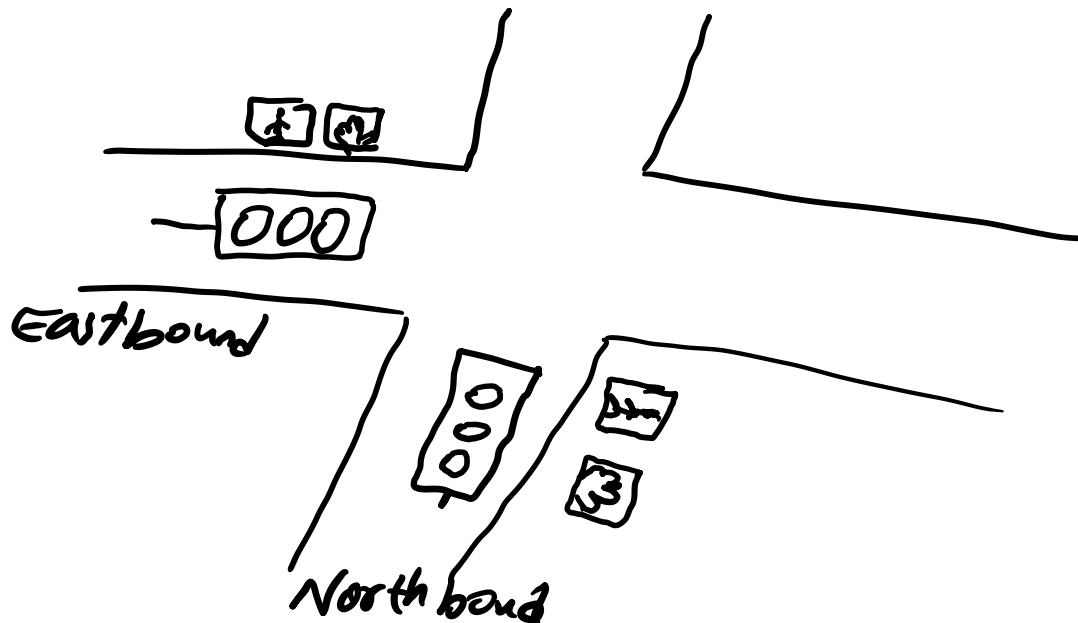
Supplied with your kit is an RGB LED, which is 3 LED's in a single package. An RGB LED has a Red, Green and a Blue (hence RGB) LED in one package. The LED has 4 legs, one will be a common anode or cathode, common to all 3 LED's and the other 3 will then go to the anode or cathode of the individual Red, Green and Blue LED's. By adjusting the brightness values of the R, G and B channels of the RGB LED you can get any colour you want. The same effect can be obtained if you used 3 separate red, green and blue LED's.

Now that you know how the components work and how the code in this project works, let's try something a bit more interesting.



6.3 Traffic Signal Arduino Challenge Project

Problem statement: You need to design and time traffic lights in a two-way street: Northbound and East Bound. There are also two pedestrian lights.



Parts needed: LEDs (3 Red, 2 Yellow, 2 Green, and 2 White)

Task 1 (20 points)

Wire three LEDs representing the traffic light on the northbound side and time them according to the timing shown in Figure 1.

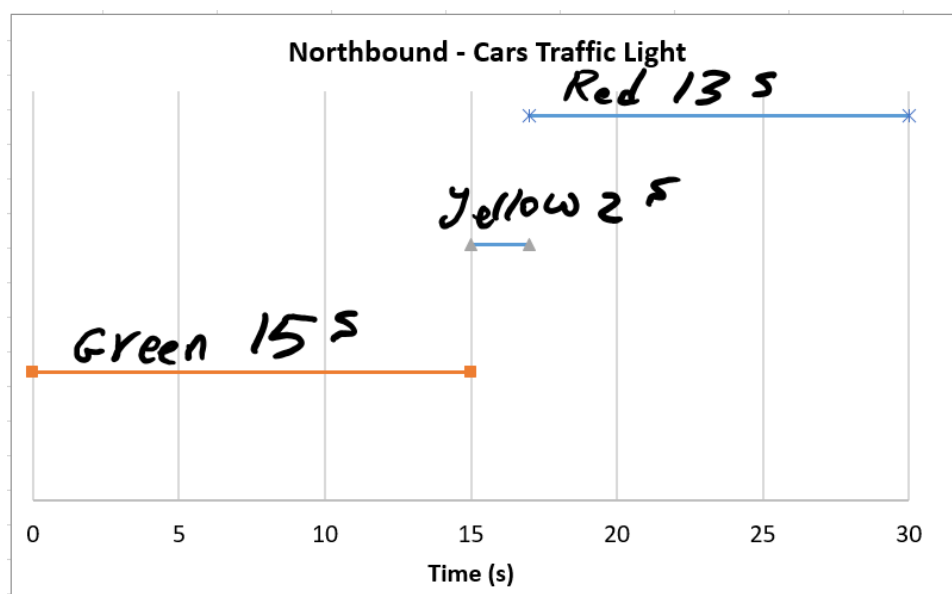


Figure 1: Timing of traffic light on Northbound

Task 2 (20 points)

Wire two extra LEDs representing the pedestrian light on the Northbound side. Following the timing shown in Figure 2. Remember that traffic light and pedestrian light should be synchronized

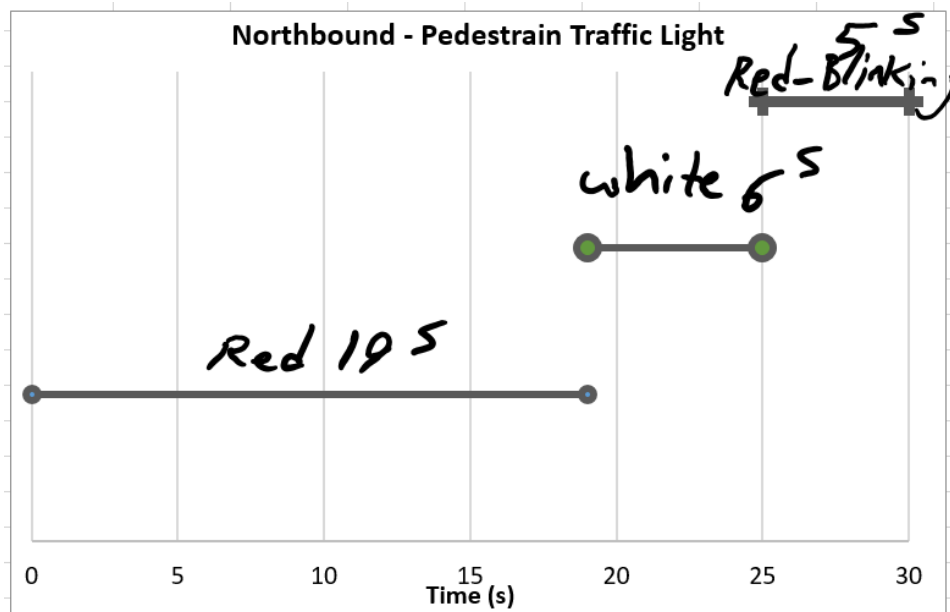


Figure 2: Timing of pedestrian light on Northbound

Task 3 (20 points)

Wire three LEDs representing the traffic light on the Eastbound side and time them according to the timing shown in Figure 3. Remember that both traffic lights should be synchronized.

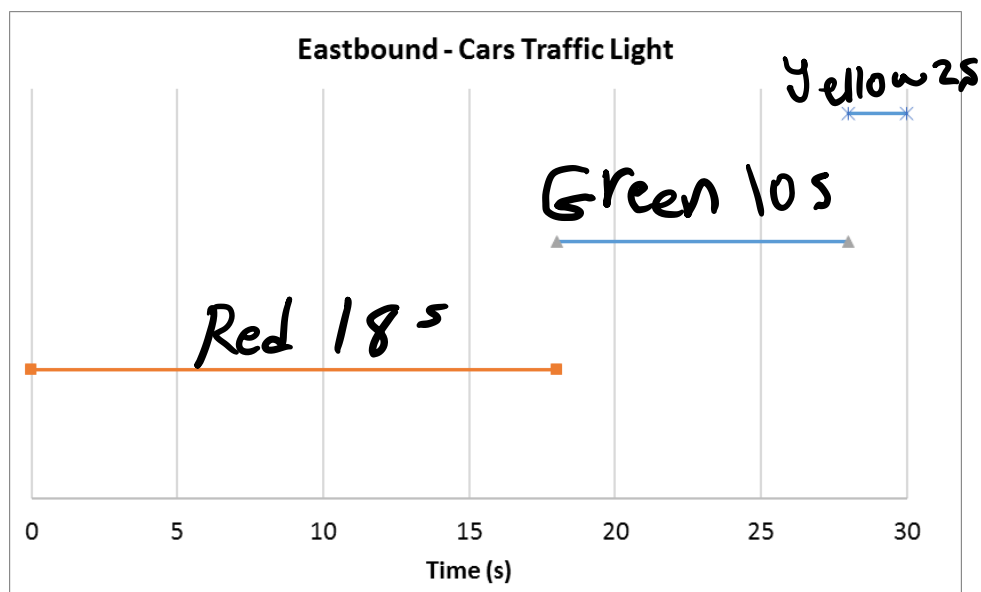


Figure 3: Timing of traffic light on Northbound

Task 4 (20 points)

Wire two extra LEDs representing the pedestrian light on the Eastbound side following the timing shown in Figure 4. Remember that traffic light and pedestrian light should be synchronized

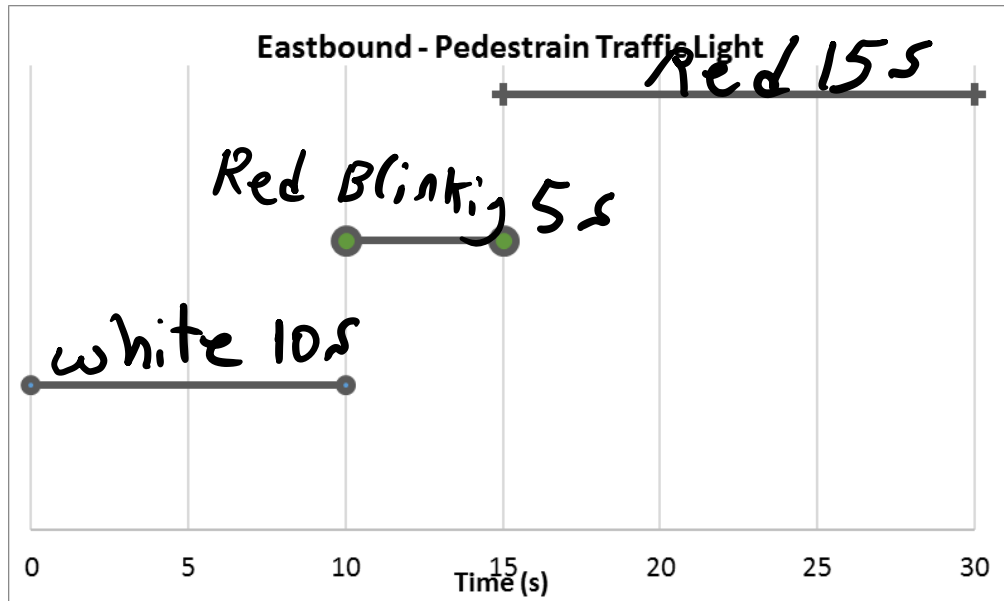


Figure 4: Timing of pedestrian light on Eastbound

Some Hints:

- For every LED, there should be one resistor. The power should go through the resistor in to LEDS
- The longer leg of LED is the positive one
- It is easier to complete the task in the order they are given
- Read the problem completely before you start with hands-on activities

Chapter 7: Engineering Design

7.1 Orthographic Projections:

Objectives

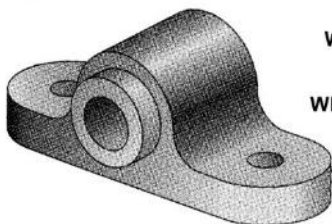
Isometric and Orthographic Projections

- Understanding Graphic representations as a communication tool.
- Projections
 - Orthographic.
 - Isometric.
 - Lines and elements.

Source:
<http://misskiley.pbworks.com/>

What can you learn about this object from this drawing?

Could you build an accurate model only using this drawing?



What is its size?

What is it made of?

What does the other side of it look like?

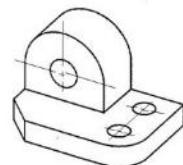
Are there any moving parts?

What is missing that you might need?

Source:
<http://misskiley.pbworks.com/>

Three Basic Types of Technical Drawings

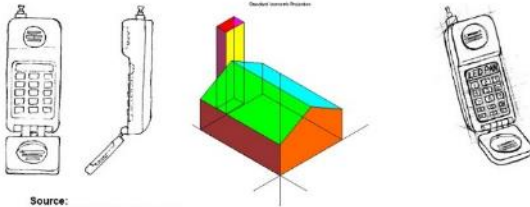
- Freehand sketches
- Instrument drawings
- Computer drawings and models



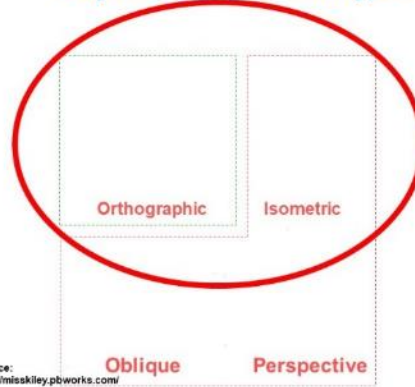
Source:
<http://misskiley.pbworks.com/>

Introduction to Projections

- Two Basic Categories
 - Presenting objects with 2-D media in 2-D or 3-D
- Orthographic and Isometric Pictorial

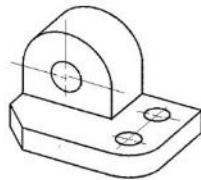


Projections: Four Basic Types

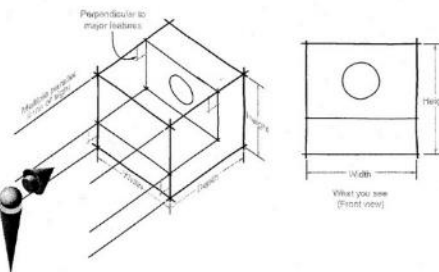


Orthographic Projections

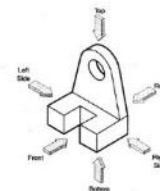
- The purpose of orthographic projections is to accurately represent object.
- Accurately, means to make a drawing from which it is possible to manufacture or reproduce the object only using the drawing as a guide.



Orthographic Projection



Defining the Principal Views or Orthographic Views



The Six Principal Views or Orthographic Views

Source:
<http://misskiley.pbworks.com/>

Source:
<http://misskiley.pbworks.com/>

Which Views to Present?

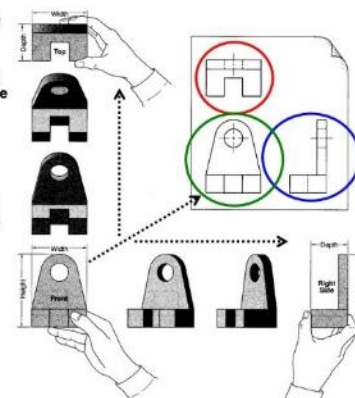
General Guidelines

- The Front View that is which is the most descriptive of object.
 - Has normally the longest dimension as the width (or length).
 - Most common combination of views is to use: Front, Top, and Side View, Which ever gives all information you need to understand the object.
 - Views other than the Principal Views are called Auxiliary Views.
- Source:
<http://misskiley.pbworks.com/>

Normally we use the front top or right side view only.

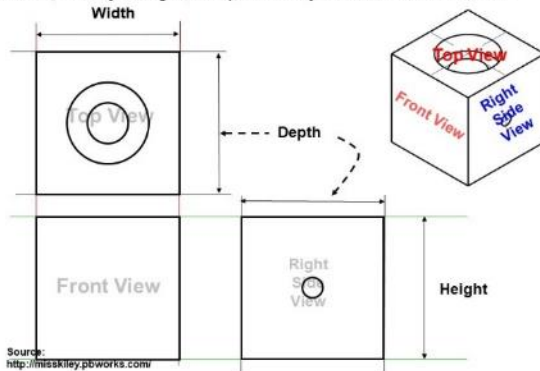
The 4 other views only repeat what we already can see in the these views.

These views can be seen by either physically or mentally rotating the object into the appropriate position to show the detail of the object visible form that view.



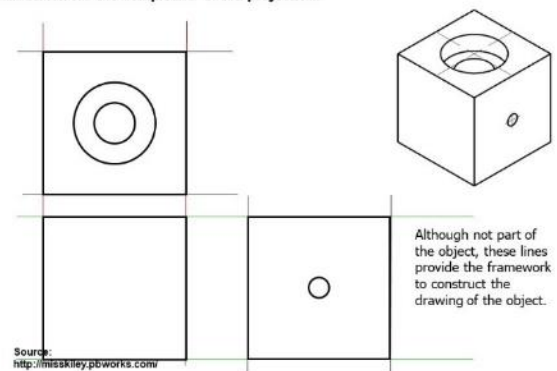
Conventional Orthographic Views

Each view is constructed so that information (dimensions, and object edges, etc ...), are clearly related to the other views.



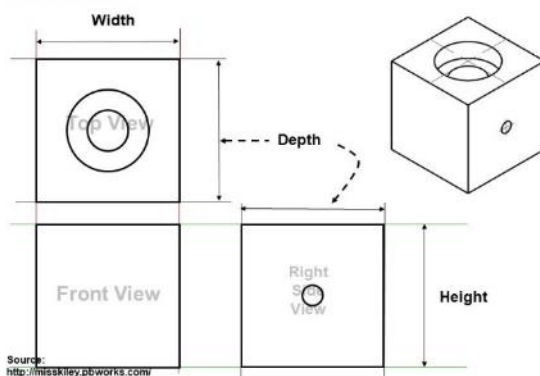
Construction Lines

Construction lines When a drawing is rendered, basic faint lines are drawn to provide a framework for the completion of the projection.



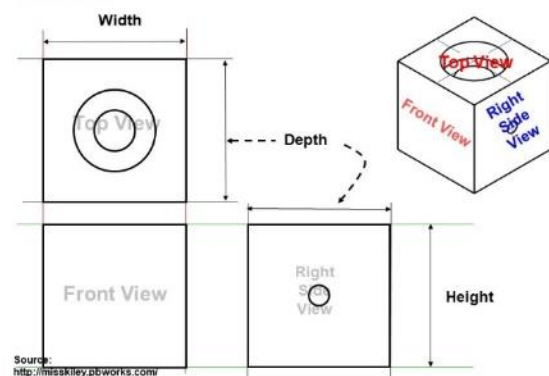
Dimension Lines

Dimension Lines display precise information about the size of the object.



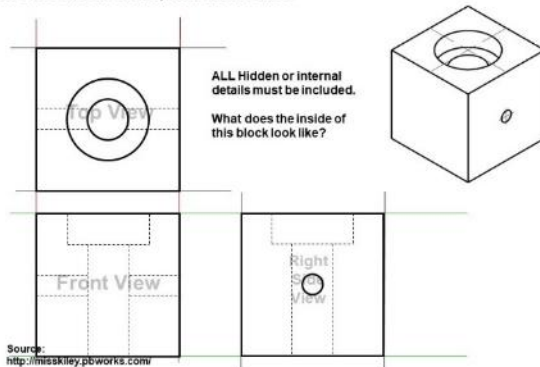
Object Lines

Object Lines Represent features that are only visible in the current view.



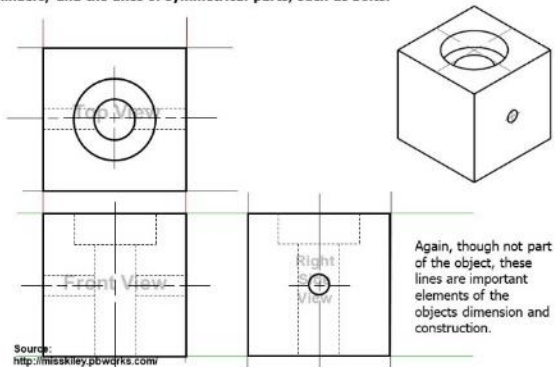
Hidden lines

Hidden Lines represent features that cannot be seen in the current view. We show these unseen details, with dashed lines.

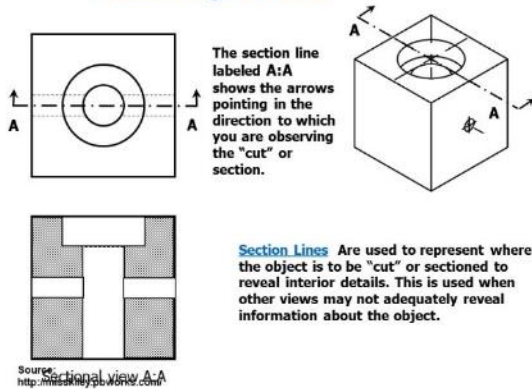


Center Lines

Center lines represent symmetry and mark the center of circles, the axes of cylinders, and the axes of symmetrical parts, such as bolts.

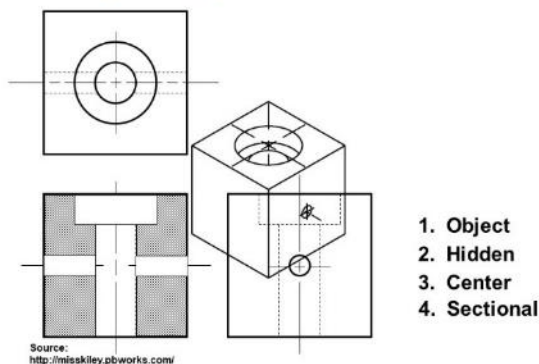


Sectioning of a view



Review: Major views used in orthographic projections.

Isometric View



Types of Lines in Orthographic Projections

Construction lines - Basic faint lines which are drawn to provide a framework for the completion of the projection.

Dimension Lines display precise information about the size of the object.

10cm

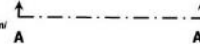
Object Lines - represent visible features for an object. They are the darkest and most present.

Hidden Lines - represent features that cannot be seen in the current view. They are as dark as the object lines.

Center lines - represent symmetry and mark the center of circles, the axes of cylinders, and the axes of symmetrical parts, such as bolts

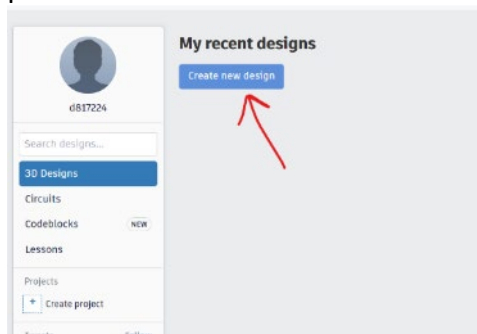
Section Lines Are used to represent where the object is to be "cut" or sectioned to reveal interior details. This is used when other views may not adequately reveal information about the object.

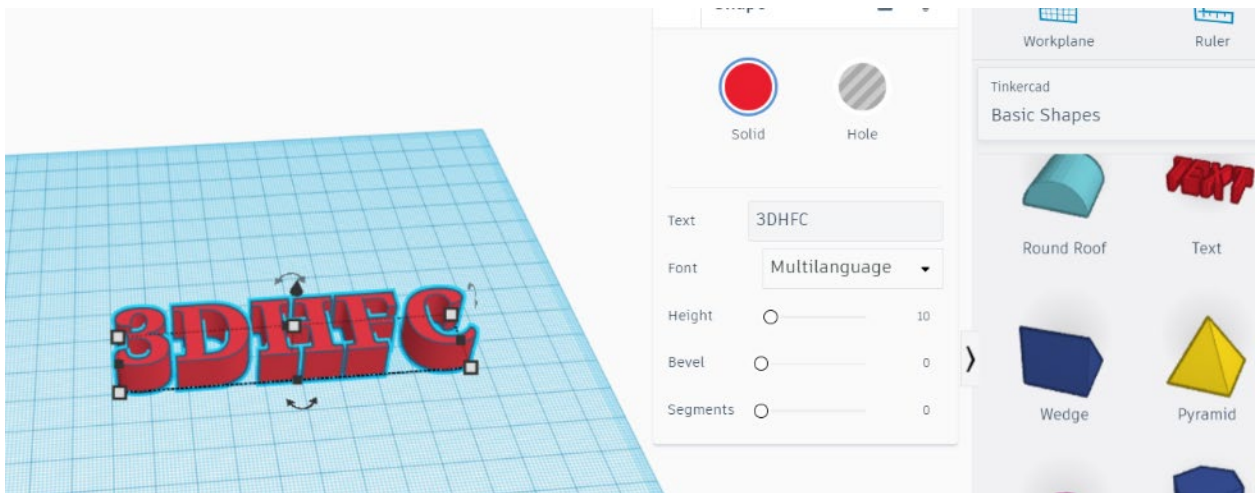
Source: <http://misskiley.pbworks.com/>



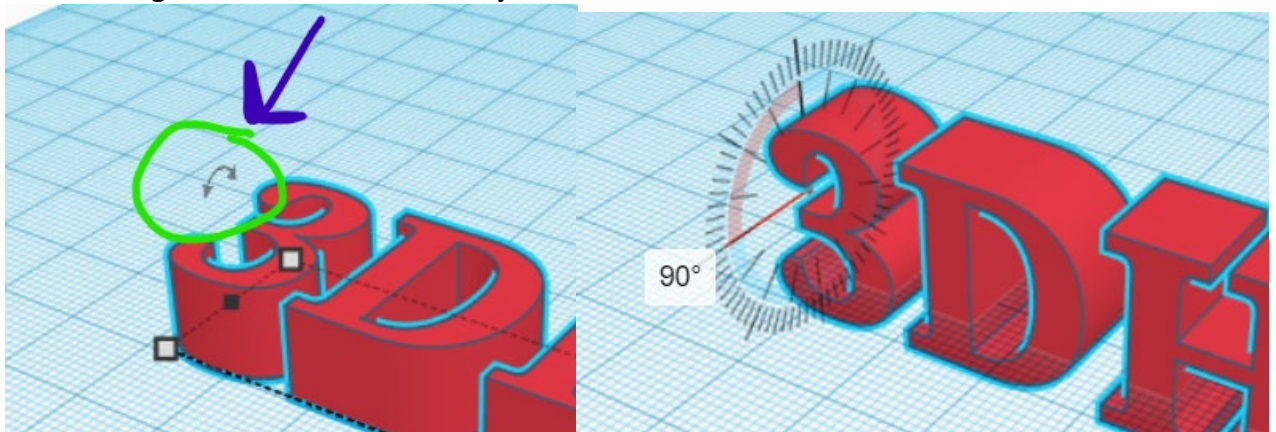
7.2 Design with Tinkercad

- Go to www.tinkercad.com
- Create an account
- Make sure "3D Designs" is selected on the left tab
- Click "create new design" next to the left menu
- Now we see the work plane appears Infront of us, the left mouse button allows you to select and control objects, while the right mouse button allows you to rotate the work plane

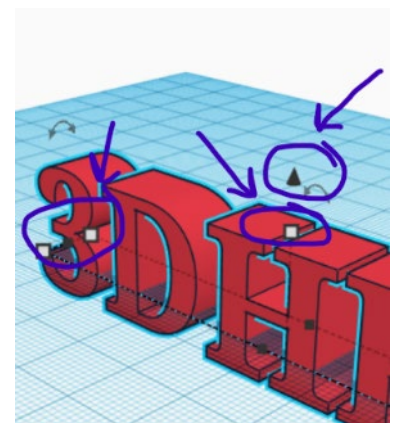




- On the right-side menu, click on “text” then click on the work plane to place the text object (or drag and drop)
- Now a drop-down menu appears on the top right, Edit the text in the text field to say for example “3D HFC”
- Now you can see the text object has changed to whatever text you inputted in the previous step, so adjust the display by rotating it 90 degrees towards you by clicking and rotating the rotate icon on the object



- Now using the black up-arrow icon on the object, click and drag upwards to move the object 5mm above, now the object is leveled with the plane
- Now using the white squares on the object, adjust the height, width and length to 30mm, 100mm, and 10mm respectively (measurements vary depending on your text)
- Now in the same menu that you found the text in, add the box object to the work-plane
- Then adjust the height, width and length of the box to 2mm, 110mm, and 15mm respectively (measurements vary depending on your text)
- Now click and drag on the box to move it under the text, align it under the text



- Finally, click on export on the very top right, and make sure “Everything in the Design” is selected then select “.stl” to save your file

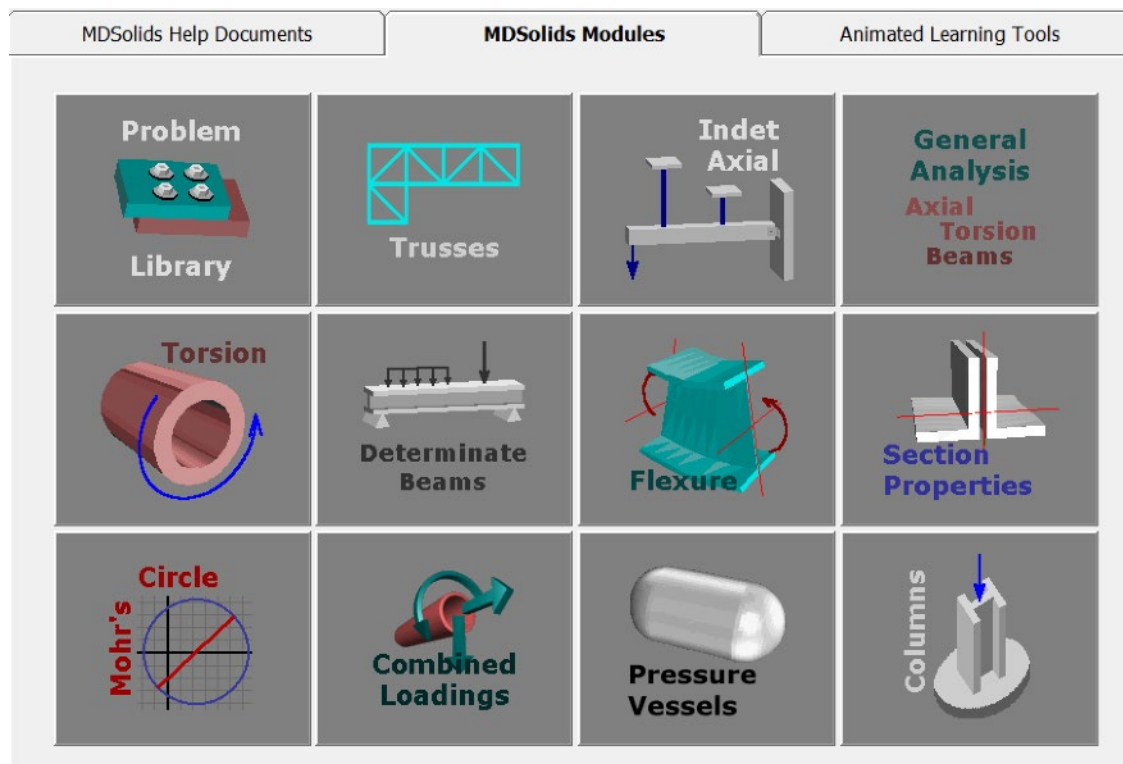
Chapter 8: MDSolids Tutorial for Truss Analysis (Mechanical Engineering)

You can practice mechanics of materials using simulations by MDSolids software package, available from <http://web.mst.edu/~mdsolids/download.htm>

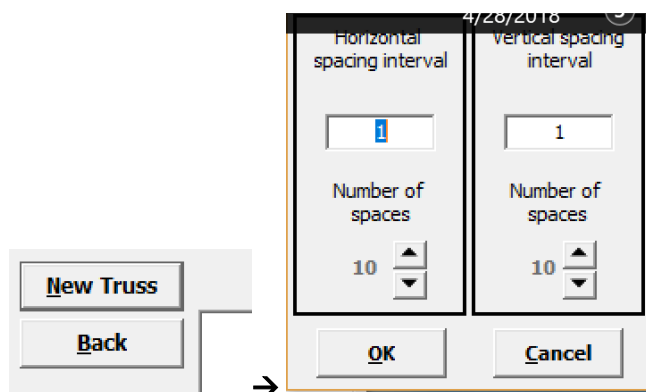
MDSolids runs in Windows 10, Windows 8, Windows 7, and all prior version Windows. Download MDSolids and give it a try.

Follow the tutorial below for truss analysis and calculation of forces.

Step 1: Open MDSolids

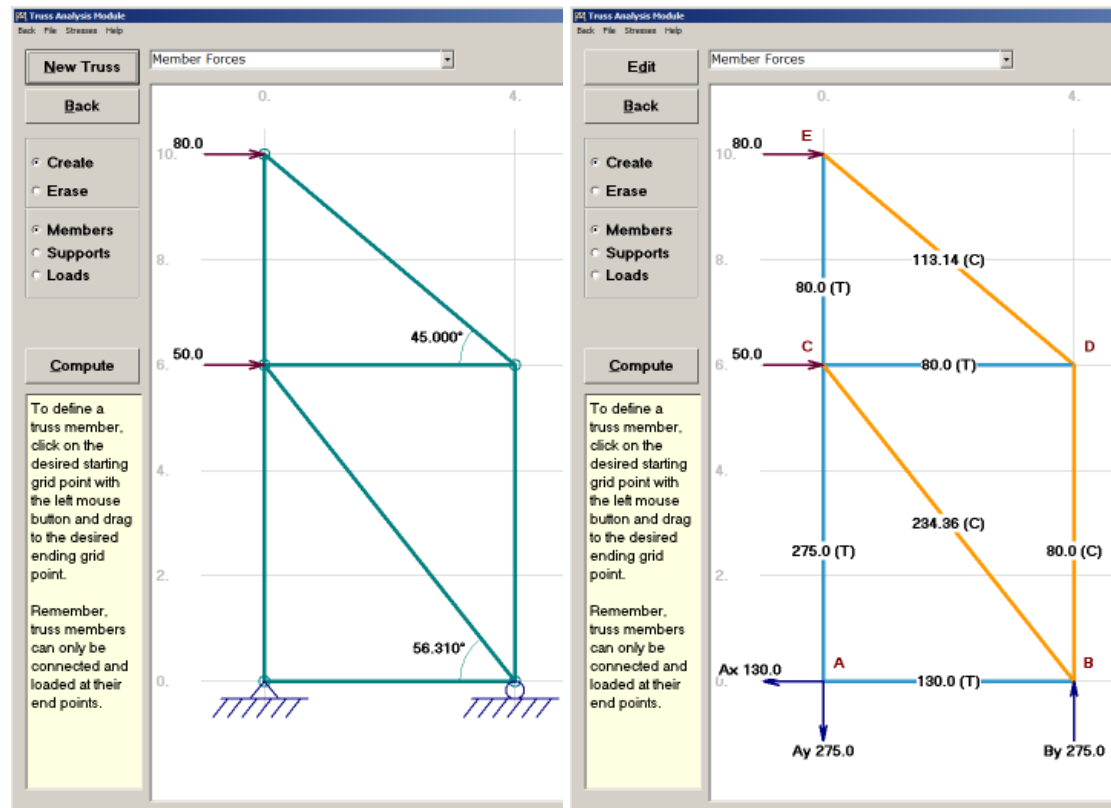


Step 2: Click on the Trusses and set the intervals and spaces as shown below:



Step 3: Create a sample truss as it is done below (more detailed explanation is provided in solution to Problem 1)

Step 4: Press compute to calculate forces in each member



Truss Design Hints:

- The overall dimensions of the truss are established by creating a user-defined grid of joints.
- Truss members are defined by using a mouse to draw lines connecting the desired joints. The software checks the members as they are defined to ensure that the truss idealization assumptions are satisfied (i.e., members connected only at the joints)
- Supports and loads are also defined with mouse movements. The software checks to allow at least three support constraints and to accept loads only at the joints.
- Labeling of joints is performed automatically. Angles of truss members are computed and displayed as the truss is created.
- The analysis results are shown on the truss. Tension members, compression members, and zero force members are each indicated by a different color.
- Optionally, normal stresses can be computed for the truss members, or given a stress limit, the required area for each member can be computed from the results of the truss analysis.

Strain- Stress Diagram:

If we place a metal rod in a tension testing machine, we can observe the relationship between applied force and elongation of the metal rod. To find a relationship independent of the diameter and length of specimen, we use a concept called Stress-Strain. Stress is defined as the amount of force over the cross-sectional area, and strain means the amount of elongation over the initial length of specimen.

$$\sigma = \frac{F}{A}$$

where:

σ : Stress

F: Force

A: Cross-sectional area

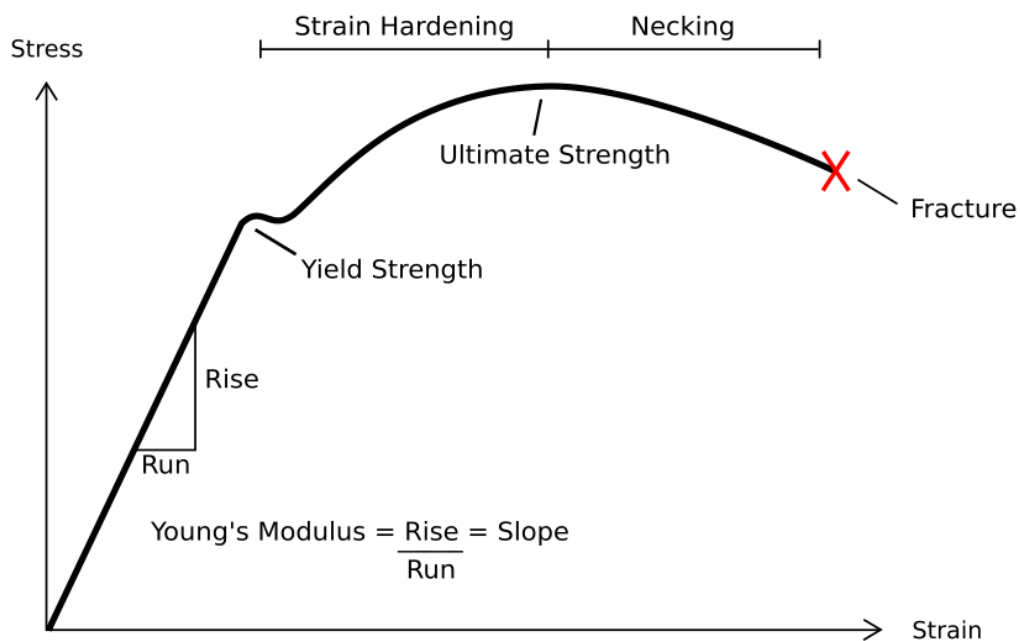
$$\varepsilon = \frac{\Delta L}{L_0}$$

where:

ε : Strain

ΔL : Elongation, change in length of specimen

L_0 : Initial length of specimen



Stress-strain diagram of a medium-carbon structural steel
(https://commons.wikimedia.org/wiki/File:Stress_Strain_Ductile_Material.png)

Proportional Limit (Hooke's Law)

From the origin to the point called proportional limit, the stress-strain curve is a straight line. This linear relation between elongation and the axial force causing was first noticed by Sir Robert Hooke in 1678 and is called Hooke's Law that within the proportional limit, the stress is directly proportional to strain or

$$\sigma \propto \epsilon \quad \text{or} \quad \sigma = k\epsilon$$

The constant of proportionality is called the Modulus of Elasticity E or Young's Modulus and is equal to the slope of the stress-strain diagram from O to P. Then

$$\sigma = E\epsilon$$

Elastic Limit

The elastic limit is the limit beyond which the material will no longer go back to its original shape when the load is removed, or it is the maximum stress that may be developed such that there is no permanent or residual deformation when the load is entirely removed.

Yield Point

Yield point is the point at which the material will have an appreciable elongation or yielding without any increase in load.

Ultimate Strength

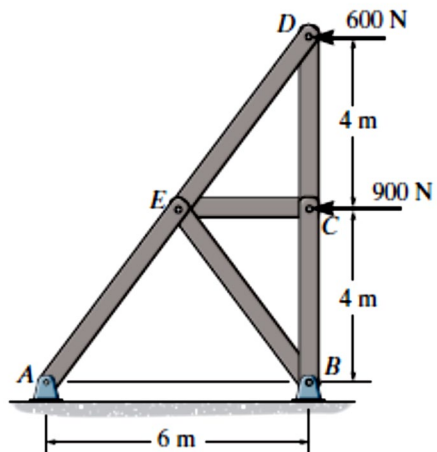
The maximum ordinate in the stress-strain diagram is the ultimate strength or tensile strength.

Truss Sizing

$$\sigma_{yield} = \frac{F}{A} \rightarrow A = \frac{F}{\sigma_{yield}}$$

$$\text{if cross-section is circle, } A = \frac{\pi d^2}{4} \rightarrow d = \sqrt{\frac{4F}{\pi \sigma_{yield}}}$$

Problem 1: Determine the force in each member of the truss, and state if the members are in tension or compression. Calculate the diameter of member DC if it is made of mild steel with yield stress of 100 Mpa.



Draw members. You should draw each member separately. If you wanted to delete a member, check Erase on the right, then select the member from one end to the other end.

Truss Analysis Module

Back File Stresses Help

New Truss

Back

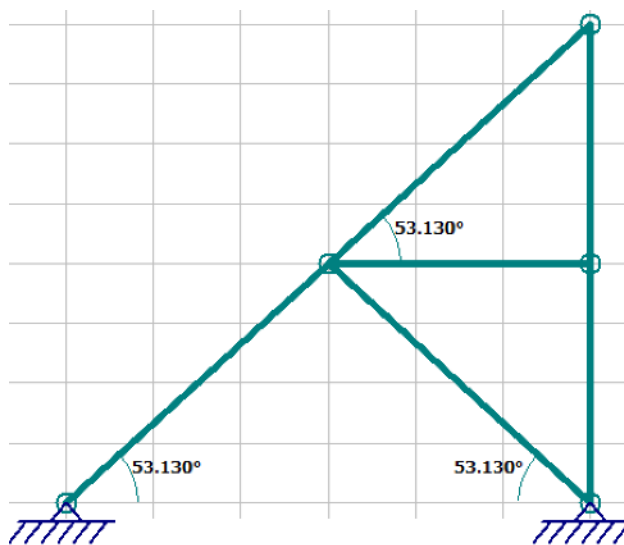
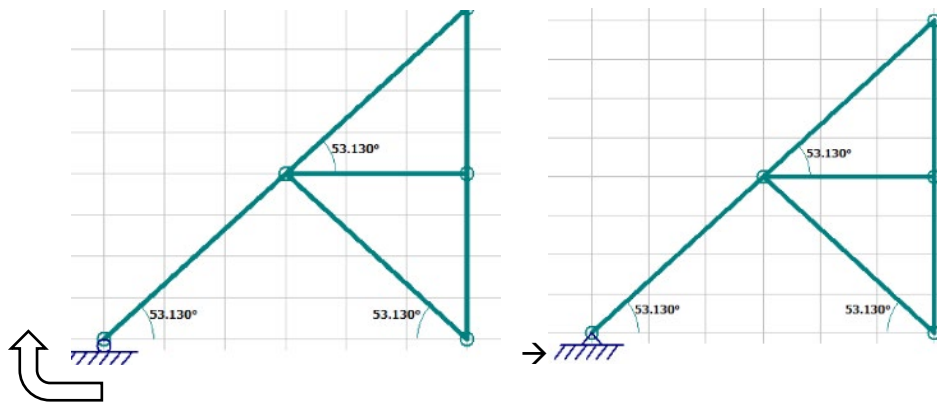
☒ Create
☐ Erase
☒ Members
☐ Supports
☐ Loads

Undo

To define a truss member, click on the desired starting grid point with the left mouse button and drag to the desired ending grid point.

Remember, truss members can only be connected and loaded at their end points.

Create supports:



New Truss

Back

Create

Erase

Members

Supports

Loads

To specify a load, click on the desired truss joint with the left mouse button and drag either up, down, left, or right.

After releasing the mouse button, a box will appear in which the force magnitude is entered.

Define Truss Load

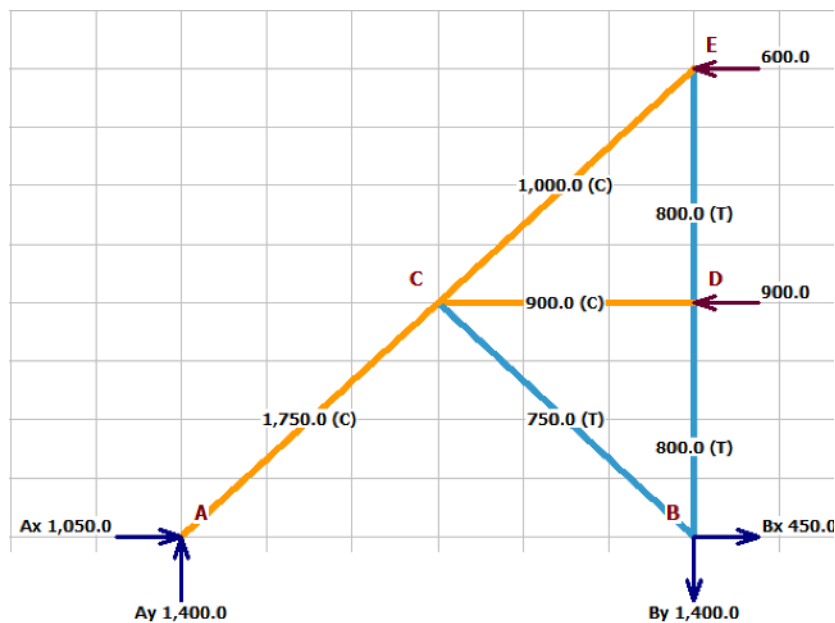
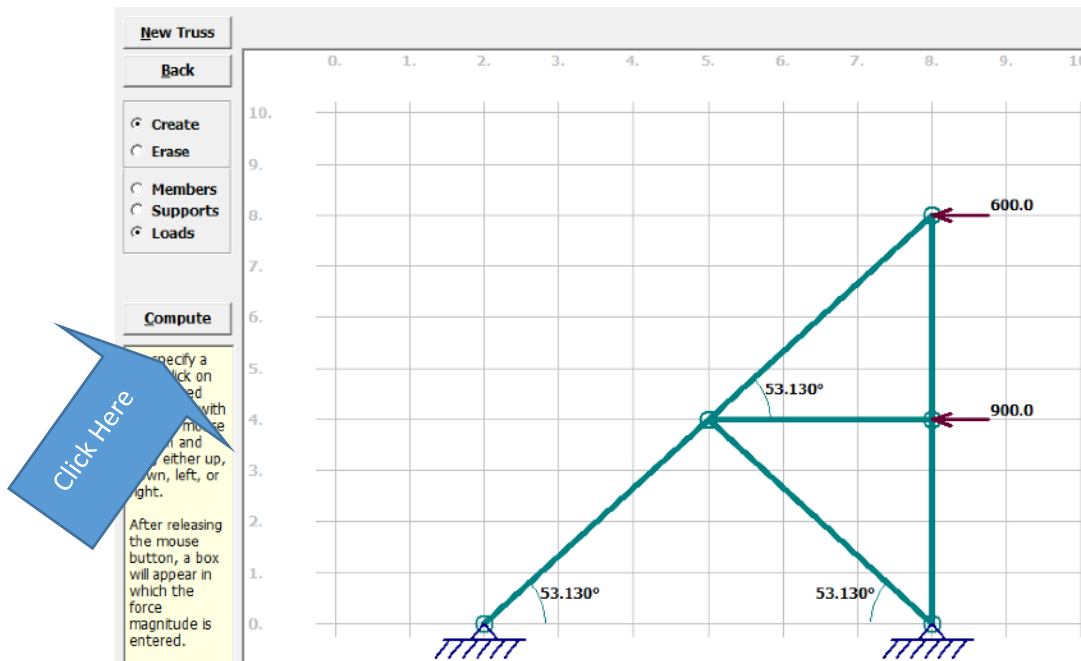
Load Magnitude: 500

(right to left direction)

Enter Load

Cancel

A truss diagram with a pin support at the bottom left and a roller support at the bottom right. The truss has a horizontal member at the top and a diagonal member at the bottom. The angle between the horizontal member and the diagonal member is 53.130° . The angle between the diagonal member and the horizontal member is 53.130° . A horizontal arrow points to the left at the top right joint.

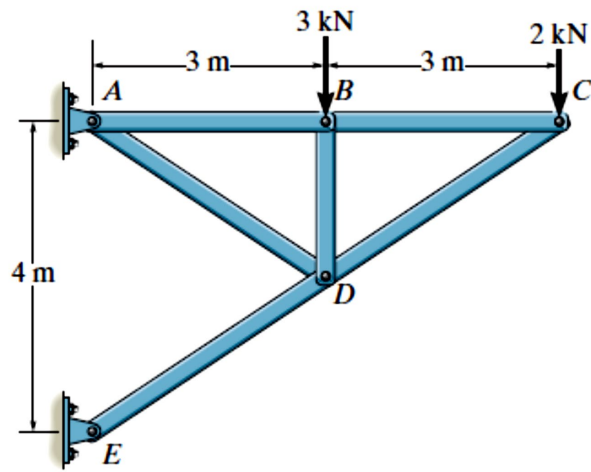


Diameter of Member CD:

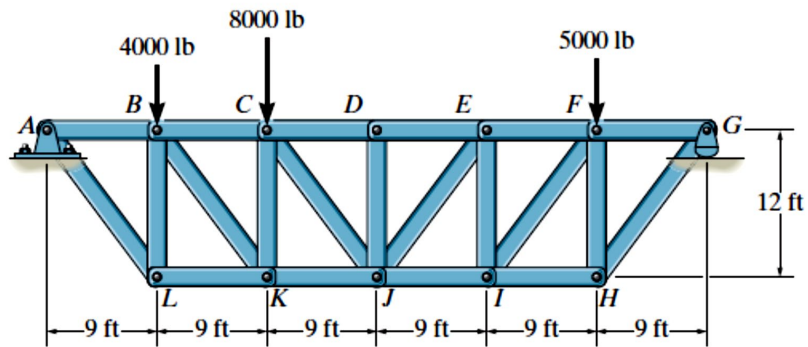
$F_{CD} = 900 \text{ N}$ from MDsolids

$$d = \sqrt{\frac{4F}{\pi \sigma_{yield}}} = \sqrt{\frac{4 \times 900}{\pi 100,000,00}} = 0.00339 \text{ m} \sim 3.4 \text{ mm}$$

Problem 2: Determine the force in each member of the truss and state if the members are in tension or compression. Calculate the diameter of member AD if it is made of mild steel with yield stress of 150 Mpa.



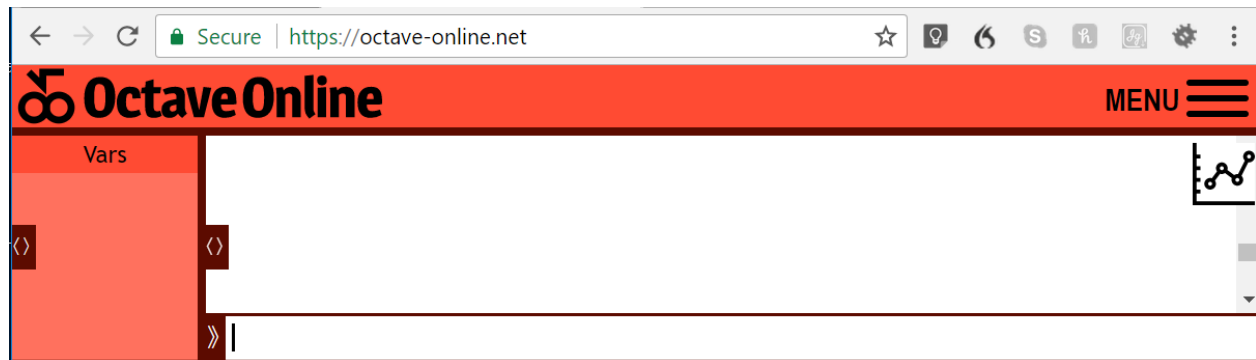
Problem 3: Determine the force in members CD, CJ, KJ, and DJ of the truss which serves to support the deck of a bridge. State if these members are in tension or compression. Calculate the diameter of member CJ and JE if they are made of mild steel with yield stress of 100 Mpa.



Chapter 9: MATLAB Tutorial

Visit: <https://octave-online.net/>

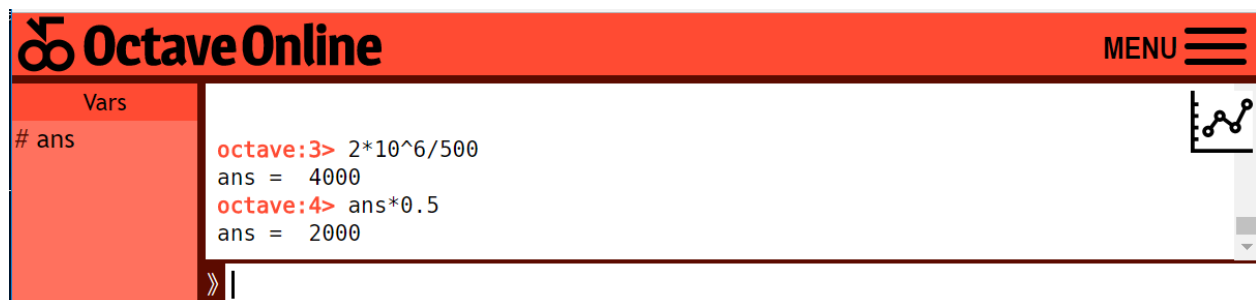
Use MATLAB as a Calculator



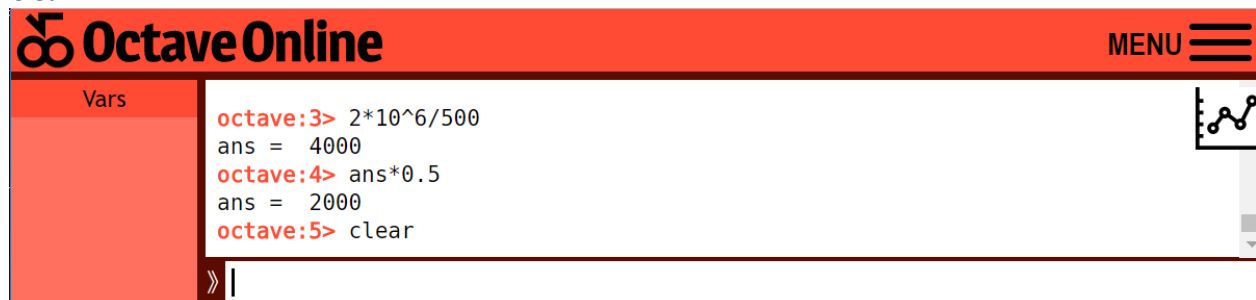
$2 \times 10^6 / 500$



$ans \times 0.5$



Clear:



Some Useful Math Function in Matlab:

cos(x) Cosine	abs(x) Absolute value
sin(x) Sine	sign(x) Signum function
tan(x) Tangent	max(x) Maximum value
acos(x) Arc cosine	min(x) Minimum value
asin(x) Arc sine	ceil(x) Round towards $+\infty$
atan(x) Arc tangent	floor(x) Round towards $-\infty$
exp(x) Exponential	round(x) Round to nearest integer
sqrt(x) Square root	rem(x) Remainder after division
log(x) Natural logarithm	log10(x) Common logarithm

Example:

`x=pi/3, y=tan(x)^2`

OctaveOnline MENU

Vars

x

y

octave:7> x=pi/3, y=tan(x)^2

x = 1.0472

y = 3.0000

Vectors in Matlab

`m = 0:0.1:2`

OctaveOnline MENU

Vars

[1x21] m

x

y

m =

Columns 1 through 7:

0.00000 0.10000 0.20000 0.30000 0.40000 0.50000 0.60000

Columns 8 through 14:

0.70000 0.80000 0.90000 1.00000 1.10000 1.20000 1.30000

Columns 15 through 21:

1.40000 1.50000 1.60000 1.70000 1.80000 1.90000 2.00000

If we use semicolon ";" at the end of a line, MATLAB will not show this in our results.

2D plots

`x = 0:pi/100:2*pi;`

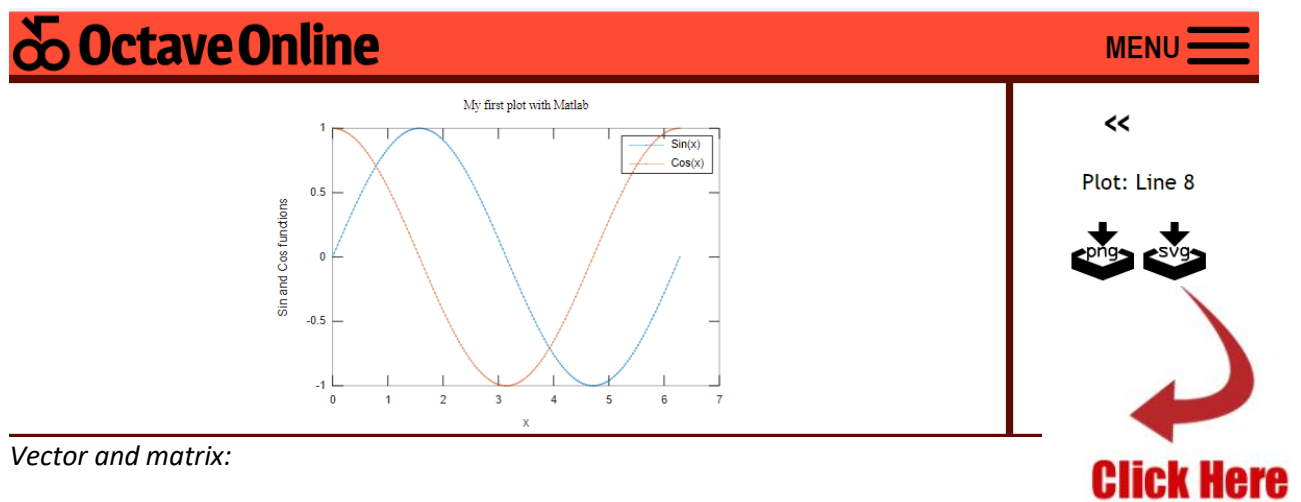
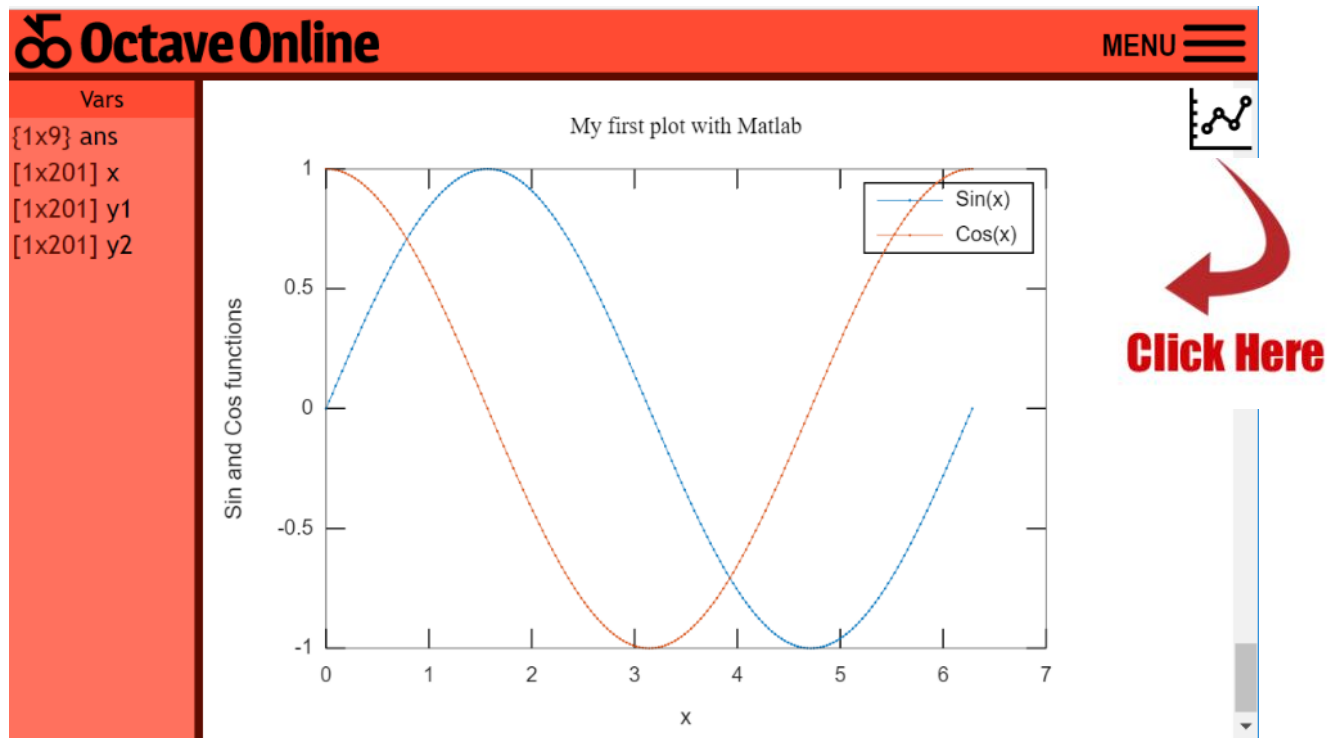
`y1 = sin(x);`

`y2 = cos(x);`


```

plot(x,y1,x,y2)
xlabel('x');
ylabel('Sin and Cos functions');
legend('Sin(x)','Cos(x)');
title('My first plot with Matlab');

```



Vector and matrix:

```

>> v = [12 4 5 23 12]
v =
1 4 7 10 13

```

Column vectors are created in a similar way, however, semicolon (;) must separate the components of a column vector,

```

>> w = [1;4;7;10;13]

```

```
w =  
1  
4  
7  
10  
13
```

```
> w = v'  
w =  
1  
4  
7  
10  
13
```

```
>> A = [1 2 3; 4 5 6; 7 8 9]  
MATLAB then displays the  $3 \times 3$  matrix as follows,  
A =  
1 2 3  
4 5 6  
7 8 9
```

```
>> x = 0:0.1:5;  
Because we used a semicolon “;”, at the end, MATLAB will not display anything
```

Dimension

```
>> size(A)  
ans =  
3 3  
means 3 rows and 3 columns.
```

Or more explicitly with,

```
>> [m,n]=size(A)  
m =  
3  
n =  
3
```

```
>> C = A.*B  
produces another matrix C of the same size with elements  $c_{ij} = a_{ij} b_{ij}$  . For example, using  
Matrix arithmetic operations  
the same  $3 \times 3$  matrices,
```

```
A=  
1 2 3  
4 5 6  
7 8 9
```

```
B =  
10 20 30  
40 50 60  
70 80 90
```

Then, we have

```
>> C = A.*B
C =
10 40 90
160 250 360
490 640 810
```

Solving linear equations

One of the problems encountered most frequently in scientific computation is the solution of systems of simultaneous linear equations. With matrix notation, a system of simultaneous linear equations is written

$$Ax = b$$

where there are as many equations as unknown. A is a given square matrix of order n , b is a given column vector of n components, and x is an unknown column vector of n components. In linear algebra we learn that the solution to $Ax = b$ can be written as $x = A^{-1}b$, where A^{-1} is the inverse of A .

For example, consider the following system of linear equations

$$\begin{aligned}x + 2y + 3z &= 1 \\4x + 5y + 6z &= 1 \\7x + 8y &= 1\end{aligned}$$

The coefficient matrix A is

$$A = \begin{bmatrix} 1 & 2 & 3 \\ 4 & 5 & 6 \\ 7 & 8 & 9 \end{bmatrix}$$

and the vector

$$b = \begin{bmatrix} 1 \\ 1 \\ 1 \end{bmatrix}$$

With matrix notation, a system of simultaneous linear equations is written

$$Ax = b$$

This equation can be solved for x using linear algebra. The result is

$$x = A^{-1}b.$$

There are typically two ways to solve for x in MATLAB:

1. The first one is to use the matrix inverse, `inv`.

```
>> A = [1 2 3; 4 5 6; 7 8 0];
>> b = [1; 1; 1];
>> x = inv(A)*b
```

```
x =
-1.0000
1.0000
-0.0000
```

2. The second one is to use the backslash (`\`) operator. The numerical algorithm behind

this operator is computationally efficient. This is a numerically reliable way of solving system of linear equations by using a well-known process of Gaussian elimination.

```
>> A = [1 2 3; 4 5 6; 7 8 0];
```

```
>> b = [1; 1; 1];
```

```
>> x = A\b
```

```
x =
```

```
-1.0000
```

```
1.0000
```

```
-0.0000
```

The “for...end” loop

In the for ... end loop, the execution of a command is repeated at a fixed and predetermined number of times. The syntax is

```
for variable = expression
```

```
statements
```

```
end
```

Usually, expression is a vector of the form i:s:j. A simple example of for loop is

```
for ii=1:5
```

```
    x=ii*ii
```

```
end
```

```
x = 1
```

```
x = 4
```

```
x = 9
```

```
x = 16
```

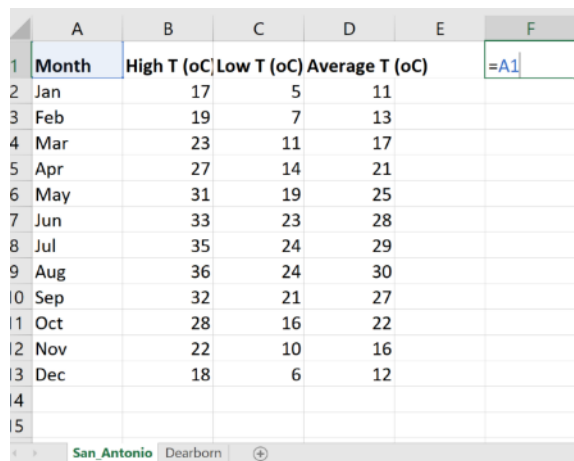
```
x = 25
```

We offer a course called Introduction to Engineering Computation (ENGR-125) at HFC. This course covers Excel spreadsheets, MATLAB, and Data Analysis with Python.

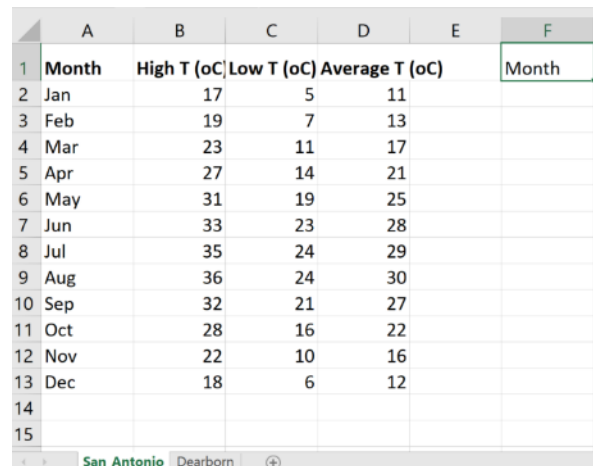
Chapter 10: Excel Tutorial

Monthly average temperature

Month	San Antonio			Dearborn		
	High	Low	Average	High	Low	Average
Jan	1	-8	-3	17	5	11
Feb	2	-7	-2	19	7	13
Mar	8	-3	3	23	11	17
Apr	16	3	9	27	14	21
May	22	9	16	31	19	25
Jun	27	14	21	33	23	28
Jul	29	17	23	35	24	29
Aug	28	16	22	36	24	30
Sep	24	12	18	32	21	27
Oct	17	6	12	28	16	22
Nov	10	1	6	22	10	16
Dec	3	-5	-1	18	6	12

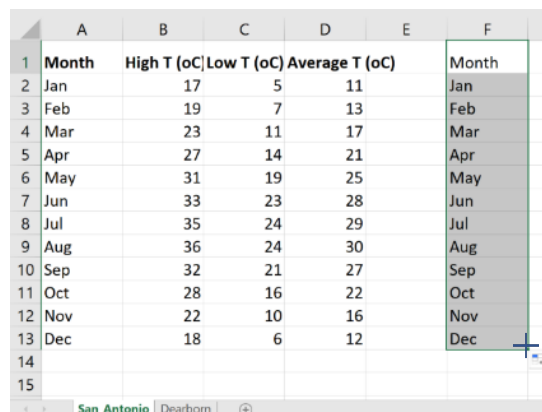


Month	High T (oC)	Low T (oC)	Average T (oC)
Jan	17	5	11
Feb	19	7	13
Mar	23	11	17
Apr	27	14	21
May	31	19	25
Jun	33	23	28
Jul	35	24	29
Aug	36	24	30
Sep	32	21	27
Oct	28	16	22
Nov	22	10	16
Dec	18	6	12

Month	High T (oC)	Low T (oC)	Average T (oC)
Jan	17	5	11
Feb	19	7	13
Mar	23	11	17
Apr	27	14	21
May	31	19	25
Jun	33	23	28
Jul	35	24	29
Aug	36	24	30
Sep	32	21	27
Oct	28	16	22
Nov	22	10	16
Dec	18	6	12

To populate the function for the rest of cells drag the content of cell F1 down. Move the cursor of the mouse to the right bottom of cell F1. A solid plus sign like this⁺ should appear at right bottom corner of the cell. Then drag the mouse down to populate for the rest



Month	High T (oC)	Low T (oC)	Average T (oC)
Jan	17	5	11
Feb	19	7	13
Mar	23	11	17
Apr	27	14	21
May	31	19	25
Jun	33	23	28
Jul	35	24	29
Aug	36	24	30
Sep	32	21	27
Oct	28	16	22
Nov	22	10	16
Dec	18	6	12

$$F = 9/5 * C + 32$$

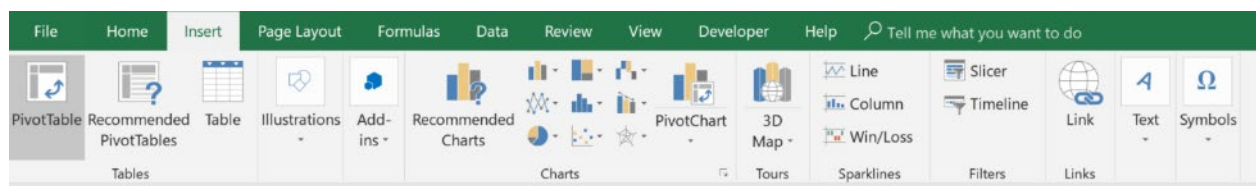
	A	B	C	D	E	F	G	H	I
1	Month	High T (oC)	Low T (oC)	Average T (oC)		Month	High T (oF)	Low T (oF)	Average T (oF)
2	Jan	17	5	11		Jan	=9/5*B2+32		
3	Feb	19	7	13		Feb			
4	Mar	23	11	17		Mar			
5	Apr	27	14	21		Apr			
6	May	31	19	25		May			
7	Jun	33	23	28		Jun			
8	Jul	35	24	29		Jul			
9	Aug	36	24	30		Aug			
10	Sep	32	21	27		Sep			
11	Oct	28	16	22		Oct			
12	Nov	22	10	16		Nov			
13	Dec	18	6	12		Dec			
14									
15									

Press enter and drag to the right and drag down

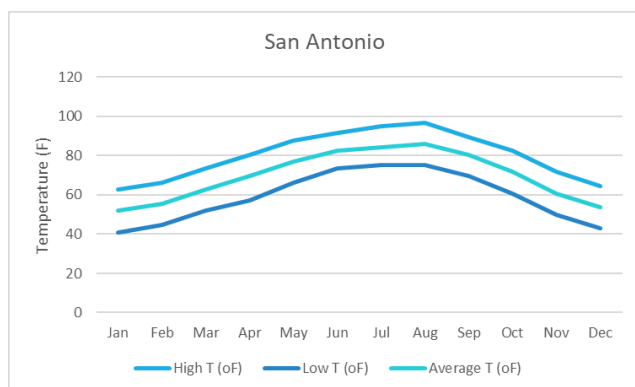
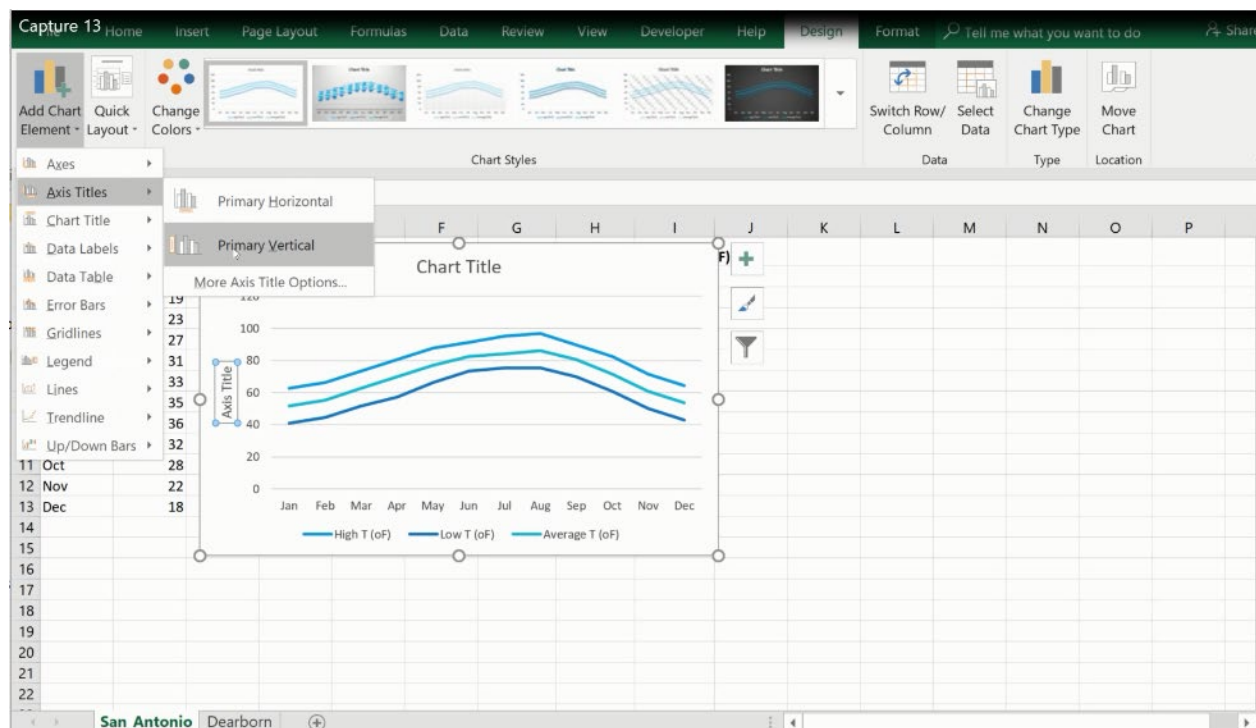
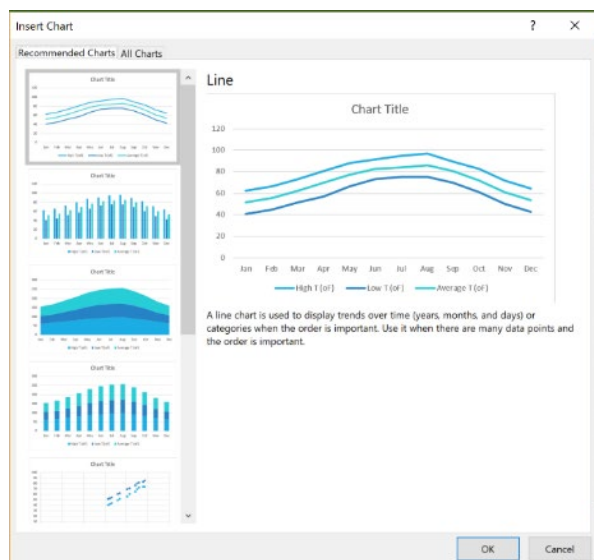
Month	High T (oF)	Low T (oF)	Average T (oF)
Jan	62.6	41	51.8
Feb			

Month	High T (oF)	Low T (oF)	Average T (oF)
Jan	62.6	41	51.8
Feb	66.2	44.6	55.4
Mar	73.4	51.8	62.6
Apr	80.6	57.2	69.8
May	87.8	66.2	77
Jun	91.4	73.4	82.4
Jul	95	75.2	84.2
Aug	96.8	75.2	86
Sep	89.6	69.8	80.6
Oct	82.4	60.8	71.6
Nov	71.6	50	60.8
Dec	64.4	42.8	53.6

Month	High T (oF)	Low T (oF)	Average T (oF)
Jan	62.6	41	51.8
Feb	66.2	44.6	55.4
Mar	73.4	51.8	62.6
Apr	80.6	57.2	69.8
May	87.8	66.2	77
Jun	91.4	73.4	82.4
Jul	95	75.2	84.2
Aug	96.8	75.2	86
Sep	89.6	69.8	80.6
Oct	82.4	60.8	71.6
Nov	71.6	50	60.8
Dec	64.4	42.8	53.6



Select line chart



Chapter 11: Electrical Circuits Tutorial

I. Purpose

This lab is designed to understand the following concepts:

- Ohm's law
- Kirchhoff's laws

Ohm's law:

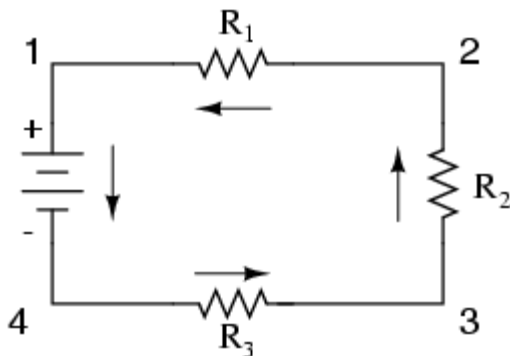
Ohm's law states that the current through a conductor between two points is directly proportional to the voltage across the two points. Introducing the constant of proportionality, the resistance, one arrives at the usual mathematical equation that describes this relationship:

$$I = \frac{V}{R}$$

where I is the current through the conductor in units of amperes, V is the voltage measured across the conductor in units of volts, and R is the resistance of the conductor in units of ohms.



Series Circuit:



In a series circuit, the current is the same for all of the elements.

$$I_{total} = I_1 = I_2 = I_3 = \dots = I_n$$

The total voltage in series is equal to the sum of individual voltages.

$$V_{total} = V_1 + V_2 + V_3 + \dots + V_n$$

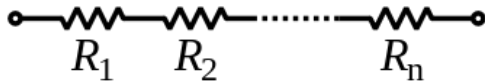
If we rearrange the Ohm's law, we will have $V = IR$.

We will then have $I_{total}R_{total} = I_1R_1 + I_2R_2 + I_3R_3 + \dots + I_nR_n$

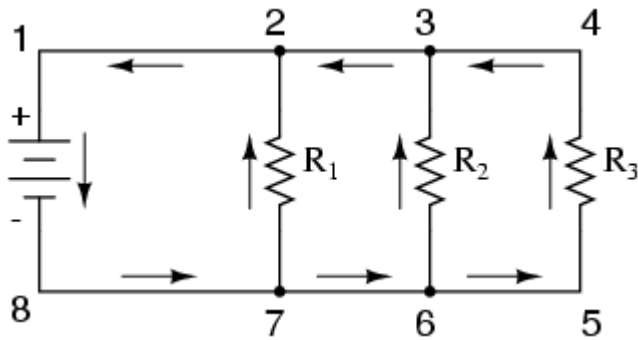
As the value of current is the same for all resistors, it can be crossed off from both sides of the equation. Therefore, we will have:

$$R_{total} = R_1 + R_2 + R_3 + \dots + R_n$$

Conclusion: The total resistance of resistors in series is equal to the sum of their individual resistances.



Parallel Circuit:



In a parallel circuit, the voltage is the same for all of the resistors.

$$V_{total} = V_1 = V_2 = V_3 = \dots = V_n$$

The total current in series is equal to the sum of individual currents.

$$I_{total} = I_1 + I_2 + I_3 + \dots + I_n$$

From the ohm's law, we have $I = \frac{V}{R}$.

We will then have $V_{total}/R_{total} = V_1/R_1 + V_2/R_2 + V_3/R_3 + \dots + V_n/R_n$

As the value of voltage is the same for all resistors, it can be crossed off from both sides of the equation. Therefore, we will have:

$$\frac{1}{R_{total}} = \frac{1}{R_1} + \frac{1}{R_2} + \frac{1}{R_3} + \dots + \frac{1}{R_n}$$

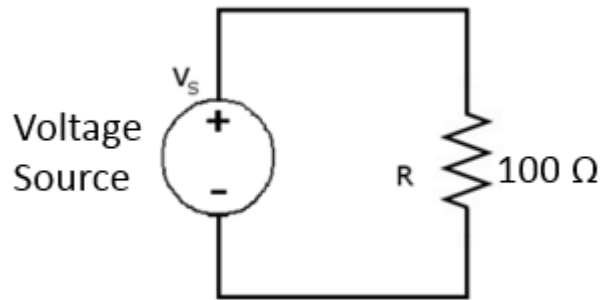
II. Equipment

Breadboard	Power Supply	Multimeter
Multimeter probes	Alligator clips	Wires
Resistances (100 Ω , 3 k Ω , 3.6 k Ω , 10 k Ω)		

III. Experiment

Part 1: Ohm's law

Consider the circuit diagram below:



- i. If the voltage in the circuit is 5V, calculate the current flowing in the circuit. What happens to the current if the voltage in the circuit is doubled and how does this relate to Ohm's law?

- ii. Wire up the circuit shown in the figure on the breadboard.
- iii. Adjust the voltage source in increments of 2V from 2V up to 10V. For each voltage record the current and tabulate the data.

Voltage (V)	Current (A)
2	
4	
6	
8	
10	

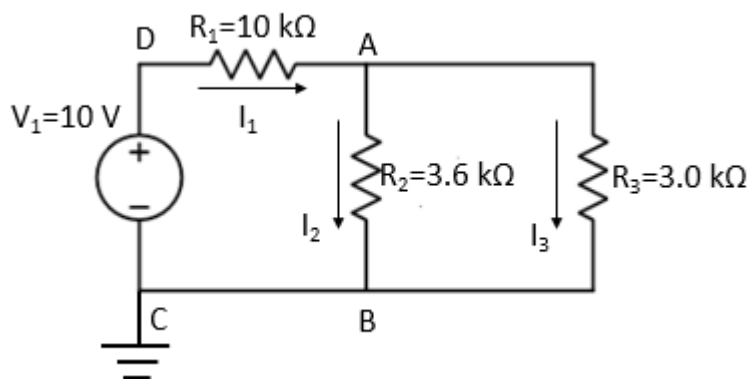
- iv. Repeat the experiment with a 10k Ω resistor.

Voltage (V)	Current (A)
2	
4	
6	
8	
10	

- v. Prepare plots that show voltage (on the x---axis) and current (on the y---axis) for both the resistors.

Part 2: Kirchhoff's Law

In this experiment you will verify both Kirchhoff's laws. Consider the following circuit diagram.



- i. Consider the circuit above. What is the equivalent resistance between D and C?

- ii. What is the power provided by the voltage source? What is the power dissipated by the $3.0\text{ k}\Omega$ resistor?

- iii. Calculate voltages V_{CD} , V_{AB} , V_{DA} and currents I_1 , I_2 , I_3 .

V_{CD}	V_{AB}	V_{DA}	I_1	I_2	I_3

- iv. Wire up the circuit shown above.
 v. Measure the voltages V_{CD} , V_{AB} , V_{DA} using a multimeter. Also measure the currents I_1 , I_2 , I_3 which are the current across resistors R_1 , R_2 , R_3 . Make sure the color coding of the multimeter leads to determine the sign of each voltage and current.

V_{CD}	V_{AB}	V_{DA}	I_1	I_2	I_3

- vi. How does the sum of voltages V_{AB} and V_{DA} relate to V_{CD} ? How can this relationship be explained by Kirchhoff's Voltage Law?

- vii. How does the sum of currents I_2 and I_3 relate to I_1 ? How can this relationship be explained by Kirchhoff's Current Law?

Chapter 12: Dimensions, Units, and Unit Conversion

Prepared by Filiz ALSHANABLEH at Near East University

Learning Objectives

Upon completing this chapter, you should be able to:

- understand the definitions and physical meanings of dimensions and units
- perform operations (*i.e.* addition, subtraction, multiplication, and division) of numbers accompanied by corresponding units
- identify units commonly used in engineering and scientific calculations, including those in cgs, SI, and American Engineering (AE) systems
- convert one set of units (or one unit) associated with numbers (or a number) or in an equation into another equivalent set of units (or another unit), using a given conversion factor
- explain and utilize the concept of dimensional homogeneity (consistency) of equations to identify units of specific numbers in those equations
- appreciate the importance and rationale of dimensionless groups(quantities)

James Clark Maxwell, a Scottish Mathematician and Theoretical Physicist (1831– 1879) expressed the definition of unit that “Every physical quantity can be expressed as a product of a pure number and a unit, where the unit is a selected reference quantity in terms of which all quantities of the same kind can be expressed”.

Physical Quantities

- *Fundamental* quantities
- *Derived* quantities

Fundamental Quantities

- Length
- Mass
- Time
- Temperature
- Amount of substance
- Electric current
- Luminous intensity

Examples of Derived Quantities

- Area [length \times length or (length)²]
- Volume [(length)³]
- Density [mass/volume or mass/(length)³]
- Velocity [length/time]
- Acceleration [velocity/time or length/(time)²]
- Force [mass \times acceleration or (mass \times length)/(time)²]

Dimension

A **property** that can be **measured** directly (*e.g.*, length, mass, temperature) or **calculated**, by multiplying or dividing with other dimensions (*e.g.*, volume, velocity, force)

Unit

A specific numerical value of dimensions.

Systems of Units (*commonly used in engineering and scientific calculations*)

- **cgs** (*centimetre, gram, second*)
- **SI** (*Le Système International d' Unitès*)
- **American Engineering (AE)** (*or fps: foot, pound, second*)

Units & Dimensions of Fundamental Quantities

UNIT SYSTEM	QUANTITY			DIMENSION
	<u>cgs</u>	<u>SI</u>	<u>AE</u>	
• Length	cm	m	ft	L
• Mass	g	kg	lb _m	M
• Time	s	s	s	t or θ
• Temperature	°C	K	°F	T
• Amount of Substance	—	mol	—	N
• Electric current	A	A	A	I
• Luminous intensity	—	Candela	—	

Examples of the Dimensions of Derived Quantities

- Area (A) $[A = L \times L = L^2]$
- Volume (V) $[V = L \times L \times L = L^3]$
- Density (ρ) $[\rho = M / V = M / L^3]$
- Velocity (v) $[v = L / t]$
- Acceleration (a) $[a = v / t = (L / t) / (t) = L / t^2]$

Example 1.1 Sir Isaac Newton (English physicist, mathematician, astronomer, philosopher, and alchemist: 1643–1727) established a *second law of motion* equation that the force (F) is the product of mass (m) and its acceleration (a), which can be described in the equation form as follows:

$$F = ma$$

What is the dimension of F (force)? From

a previous page, the dimensions of

- mass (m) $\equiv M$
- acceleration (a) $\equiv L / t^2$

The dimension of force (F) can, thus, be expressed by those of fundamental quantities as follows

$$F = ma$$

$$\equiv (M)(L / t^2)$$

$$F \equiv (M)(L) / (t^2)$$

Example From a Physics or Chemistry courses, pressure (P) is defined as “*the amount of force (F) exerted onto the area (A) perpendicular to the force*”

What is the dimension of P ?

- Dimension of force $F \equiv (M)(L) / (t^2)$
- Dimension of area (A) $\equiv L^2$

Hence, the dimension of pressure is

$$\frac{\text{_____}}{\text{_____}}$$

Dimensions and Units

The “*dimension*” is the *property* that can be *measured experimentally* or *calculated*, and in order to **express** the **physical quantity** of a **dimension**, we use a **pure number** and its corresponding **unit**

For example, a ruler has a dimension of “length” (L), its physical quantity can be expressed as

1 foot (ft)

or 12 inches (in)

or 30.45 centimetres (cm)

Another example, Americans express their *normal freezing point* of water as 32 °F, while Europeans say that the *normal freezing point* of water at 1atm is at 0 °C

We can see that a **physical property** [*e.g.*, length (L) or temperature (T)] **with the same dimension** may be **expressed in different numerical value** if it is accompanied with **different unit**.

Units of Derived Quantities and Alternative Units

The units of fundamental quantities of different unit systems are summarized on Page 3.

What are the units for derived quantities?

We can assign the unit (in any unit system) to each individual derived quantity using its dimension

For instances,

- the unit of **area** (A), in **SI system**, is m^2 , since its dimension is L^2
- the unit of **volume** (V), in **AE system**, is ft^3

Example 1.2. Determine the units of density, in cgs, SI, and AE systems?

Since the dimension of density (ρ) is

— —

its corresponding units in

- cgs unit system is g / cm^3
- SI unit system is kg / m^3
- AE unit system is $\text{lb}_m / \text{ft}^3$

What are “alternative” units?

From our previous example we have learned that the dimension of force (F) is

$$F \equiv (M)(L) / (t^2)$$

Hence, its corresponding units in

- SI system is $(\text{kg})(\text{m}) / (\text{s}^2)$
- AE system is $(\text{lb}_\text{m})(\text{ft}) / (\text{s}^2)$

Have you ever heard that the unit of force (F) is $(\text{kg})(\text{m}) / (\text{s}^2)$?

To honour Sir Isaac Newton (1643-1727), who established the 2nd law of motion, a community of scientists gave the name of the **unit of force** as “**Newton (N)**”, which is defined as

Newton (N) is an example of an *alternative* unit.

Accordingly, instead of expressing the unit of pressure (P), in SI system, as _____

since the dimension of pressure is _____

we can, alternatively, write the unit of pressure, in SI system, as _____

This comes from the fact that _____ and that the units of force (F) and area (A), in SI system, is N and m^2 , respectively.

However, the **unit of pressure** in **SI system** is expressed as “**Pascal (Pa)**”, which is defined as

$1 \text{ Pa} \equiv 1$ _____

(try proving it yourself that $1 \text{ Pa} \equiv 1$ _____)

In AE system, the unit of pressure is expressed as _____ or psi

(note that lb_f is the unit of force in AE system, not a unit of mass, and that “psi” stands for **p**ound force per **s**quared inches”_

$1 \text{ N} \equiv 0.224809 \text{ lb}_\text{f}$

Example 1.3. Work (W) is defined as “*force (F) acting upon an object to cause a displacement (L)*”.

What are the dimension and the corresponding unit of work, in SI system?

- Dimension of force $F \equiv (M)(L) / (t^2)$

- Dimension of a displacement = L

Hence, the dimension of work is $W = FL$

$$\equiv (M)(L^2) / (t^2)$$

Accordingly, the unit of work, in SI system, is _____

Alternatively, the unit of work, in SI system, can be expressed as $W = FL$

$$\equiv (N)(m)$$

Commonly, the unit of work, in SI system is expressed as “Joule (J)”, in which

$$1 \text{ J} \equiv 1 (N)(m)$$

Units of Work, Energy, and Heat

We have just learned that the **unit of work**, in **SI system**, is **J** or **(N)(m)** or _____

and from Physics courses, we learned that *work*, *energy*, and *heat* are in the same unit

Is it true?

From the definition of work: “force acting upon an object to cause a displacement” the unit of work can be expressed as **J** or **(N)(m)** or _____, as mentioned above.

How about the unit of “**Energy**”?

Energy:

- **Potential Energy;** $E_p = mgL$ where g is an acceleration (a) caused by gravitational force

Thus, in SI system, potential energy has the unit of

$$E_p = mgL$$

- _____
- **Kinetic Energy;** $E_k = \frac{1}{2}(m)(V)^2$

Hence, the unit of kinetic energy, in SI system, is $E_k = \frac{1}{2}(m)(V)^2$ _____

It is clear that E_P and E_K are in the same unit, *i.e.* _____

, and we have already got the fact that

$$1 \text{ J} \equiv 1 \text{ (N)(m)} \equiv \text{_____}$$

Accordingly, we can conclude that *work* and *energy* are in the *same unit*. Since, from Physics or Chemistry courses, both work and heat are the form of energy transferring between a system and surroundings, **the unit of heat is as same as that of work.**

Units of Temperature

A unit of temperature used in any calculations must be an ***absolute temperature*** unit

Absolute temperature unit

- SI K (Kelvin)
- AE R (Rankine)

$$T(\text{K}) = T(^{\circ}\text{C}) + 273.15^* \quad (1.1)$$

$$T(\text{R}) = T(^{\circ}\text{F}) + 459.67^{**} \quad (1.2)$$

* For convenience, the value of **273** is used

** For convenience, the value of **460** is used

The Conversion of the Temperature Units between $^{\circ}\text{C}$ and $^{\circ}\text{F}$

Principle

where

T_{nb} = normal boiling point of water

T_{nf} = normal melting/freezing point of water Hence,

$$T(^{\circ}F) = 1.8T(^{\circ}C) + 32$$

(1.3)

Example 1.4. The specific gravity of liquid is normally reported at 60 °F in AE system. What is the equivalent temperature in SI system?

Employing Eq. 1.3 yields

$$T(^{\circ}F) = 1.8T(^{\circ}C) + 32$$

15.6 °C

Temperature Difference (ΔT)

Consider the following example:

$$\Delta T (^{\circ}C) = 15 ^{\circ}C - 10 ^{\circ}C$$

$$= 5 ^{\circ}C$$

$$\Delta T (K) = (273+15) K - (273+10) K$$

$$= 5 K$$

Thus, it can be concluded that

$$\Delta T (^{\circ}C) = \Delta T (K) \quad (1.4)$$

When considering in the same manner for °F and R, we shall obtain the fact that

$$\Delta T (^{\circ}F) = \Delta T (R) \quad (1.5)$$

How about the relationship between ΔT (°C) and ΔT (°F) or between ΔT (K) and ΔT (R)?

The temperatures of 10 and 15 °C are equivalent to the temperatures in AE system of (using Eq. 1.3)

$$T (\text{°F}) = 1.8(T (\text{°C})) + 32$$

$$T (\text{°F}) = 1.8(10) + 32 \quad \text{and} \quad T (\text{°F}) = 1.8(15) + 32 \quad \text{respectively}$$

Hence, the *temperature difference* between 15 and 10 °C, in AE system, is

$$[1.8(15) + 32] - [1.8(10) + 32] = [1.8(5)] \text{°F}$$

Accordingly, the relationship between ΔT (°F) and ΔT (°C) can be written in a general form as follows

$$\Delta T (\text{°F}) = 1.8 \Delta T (\text{°C}) \quad (1.6)$$

When doing the same for ΔT (R) and ΔT (K), we obtain the following relationship

$$\Delta T (\text{R}) = 1.8 \Delta T (\text{K}) \quad (1.7)$$

Units of Pressure

In addition to **Pa** and **psi**, pressure can be presented in the unit of, *e.g.*,

- atm
- bar
- mm Hg
- in H₂O

As same as temperature, the unit of pressure used in any calculations must be an ***absolute pressure*** unit.

Operations with Units

What is the correct answer for 9+5?

- Is 14 the *only* correct answer?
- Could 9 + 5 be 2?

It is certain that 9 apples + 5 apples = 14 apples

9 oranges + 5 oranges = 14 oranges

but 9 oranges + 5 apples = ?

A fruit salad!!

Can $1 + 1$ be 13 or $1 - 1 = 99$?

These are some examples of confusion caused by writing numbers **without units**.

Some other worse examples

Consider the following news

“A Chinese air-traffic controller at Shanghai international airport directed the pilots of a Korean Airlines plane to take the plane to the altitude of 1,500 meters (the plane was at the altitude of ~1,000 meters at the time), but the pilots thought that it was 1,500 feet, which is equivalent to 455 meters. So, instead of climbing up, the pilots lowered the altitude of the plane. This misunderstanding in “unit” caused the plane to crash, which killed all crewmembers and another five people on the ground”

(Modified from *Wall Street Journal*, June 6th, 2001, Page A22)

“In 1999, the Mars Climate Orbiter was crashed to the Martian surface, because engineers forgot to convert units in SI system to AE one. This damage cost ~US\$ 125 million!”

(Modified from *Basic Principles and Calculations in Chemical Engineering* (7th ed.), Page 15)

By **attaching units to all numbers** when performing any calculations, you can get the following benefits:

- reduce/diminish the possibility of errors in your calculations
- a logical approach to solve the problem rather than remembering a formula
- easy interpretation of the physical meaning of the number you are dealing with

Example 1.5. You want to calculate the mass (m) of substance A, when you are given a volume (V) and a density (ρ) of 0.2 m^3 and $1,250 \text{ kg/m}^3$, respectively, but you **totally forgot** the relationship between m , V , and ρ . How would you do?

Addition & Subtraction

You **can add** or **subtract** numerical quantities **only** when they are in the **same dimension**. On top of that, to **obtain the correct answer**, the **units** of those numerical values **must be the same**.

For example: You **cannot** carry out the following addition/subtraction;

- $5 \text{ kg} - 3 \text{ N}$ (mass vs force)
- $45 \text{ m}^3/\text{kg} + 250 \text{ m}^3$ (specific volume vs volume)

as the **numbers** in operations are in **different dimensions**.

You, however, can do the following addition/subtraction

- 5 km + 5 mi
- $50 \text{ m}^3/\text{kg} - 12 \text{ ft}^3/\text{lb}_m$

BUT you have to do the UNIT CONVERSION before carrying out an addition/a subtraction (unit conversion will be discussed in the next section)

Multiplication & Division

You can multiply or divide any units, but you **cannot cancel** the units **unless they are identical**

For example:

You can do the followings

- $(15 \text{ kg})(9.81 \text{ —}) = 147.2 \text{ —} \text{ or } 147.2 \text{ N}$
- $\text{—} = 600 \text{ —} \text{ or } 600 \text{ Pa}$
- $\frac{\text{—}}{\text{—}} = 30$

but you **cannot** do the following

- $\text{—} = 30$
- $\text{—} = 4$
- $\text{—} = 2$

since the **units** are ***different***.

Unit Conversion

In engineering calculations, there are TWO commonly used unit systems: **SI** and **American Engineering (AE)**

As a prospective engineer, you must be careful of handling all sorts of unit systems and be able to convert a given unit to another *competently*.

The advantages of SI system over AE one

Consider the unit increment in AE system

Length:

12 inches = 1 foot

3 feet = 1 yard

1,760 yards = 1 mile

Mass:

16 ounces (oz) = 1 pound (lb_m)

14 pounds (lb_m) = 1 stone

It is evident that the **increment in unit** is **NOT systematic**, which usually leads to confusion and errors

On the other hand, the unit increment in the **SI system** is **systematic**

For example

Length:

100 cm = 1 m

1,000 m = 1 km

Mass:

1,000 mg = 1 g

1,000 g = 1 kg

You can see that the **unit increment**, in **SI system**, is in the **power of 10**, and the incremental **patterns** are the **same** for (*almost*) **all kinds of quantities**.

Can you think of any quantity in SI system whose unit increment is NOT in the power of 10?

The power of 10 can be expressed by prefixes, and some commonly used prefixes are

- centi- (c) = 10^{-2}
- milli- (m) = 10^{-3}
- micro- (micro- or μ) = 10^{-6}
- nano- (n) = 10^{-9}
- deci- (d) = 10^{-1}
- kilo- (k) = 10^3
- mega- (M) = 10^6
- giga- (G) = 10^9

Examples

$$1 \text{ GBytes} = 10^9 \text{ Bytes}$$

$$15 \text{ MW} = 15 \times 10^6 \text{ Watts}$$

$$30 \text{ kN} = 30 \times 10^3 \text{ N}$$

$$35 \text{ cm} = 35 \times 10^{-2} \text{ m}$$

Example 1.6. Find the length in **ft** that is equivalent to 47.25 **cm**

$$1 \text{ m} \equiv 100 \text{ cm}$$

$$\text{and } 1 \text{ m} \equiv 3.28084 \text{ ft}$$

Thus,

$$\frac{47.25 \text{ cm}}{100 \text{ cm/m}} \times \frac{1 \text{ m}}{3.28084 \text{ ft/m}} = \frac{47.25}{328.084} \text{ ft}$$

Example 1.7. An example of a nano-sized semiconductor is ZnS (in a semiconductor plant, chemical engineers produce this kind of semiconductor). If its size is 1.8 nanometres (nm), what is the size in inches (in.)

$$\frac{1.8 \text{ nm}}{10^9 \text{ nm/m}} \times \frac{1 \text{ m}}{39.37 \text{ in/m}} = \frac{1.8}{39.37 \times 10^9} \text{ in}$$

Example 1.8 At 4 °C, water has a density of 1 g/cm³. Liquid A has a density at the same temperature of 60 lb_m/ft³. When water is mixed with liquid A, which one is on the upper layer?

$$\frac{1 \text{ g/cm}^3}{1 \text{ g/cm}^3 \times \frac{1 \text{ lb}_m}{4.53592 \text{ g}} \times \frac{1 \text{ ft}^3}{28.3168 \text{ dm}^3}} = \frac{1}{4.53592 \times 28.3168} \text{ lb}_m/\text{ft}^3$$

Can you answer that which substance is on the upper layer?

Example 1.9. Convert the mass flux of $0.04 \text{ g / (min. m}^2\text{)}$ to that in the unit of $\text{lb}_m/(\text{ h.ft}^2)$

Dimensional Consistency (Homogeneity)

As stated previously, the answers of *adding* and/or *subtracting* numerical quantities can be obtained *only* when the *unit* of each quantity is *identical*. This is a basic principle of “**dimension homogeneity (consistency)**”

The basic principle states that, in order **to add, subtract, or equate** any terms, **each term** must be in the **same dimension and unit**.

By employing this principle, it leads to a conclusion that the numerical values in any *non-linear* forms (*e.g., log, exp*) must be *dimensionless* (*i.e. have no unit*)

Example 1.10 What is the unit of R in an ideal-gas equation of state

(EoS)? An ideal-gas equation of state (EoS) can be written as follows

$$PV = nRT \quad (1.8)$$

where

P has a unit of Pa (or N/m^2)

V has a unit of

m^3 n has a unit

of mol T has a

unit of K

From the principle of dimensional homogeneity, it is required that each side of equation (*i.e.* EoS in this case) must be in the same unit

Hence, the unit of R can be calculated by substituting the unit of each quantity into Eq. 1.8 and, then, rearranging the equation, as follows

$$PV = nRT$$

$$(Pa)(m^3) = (mol) R (K)$$

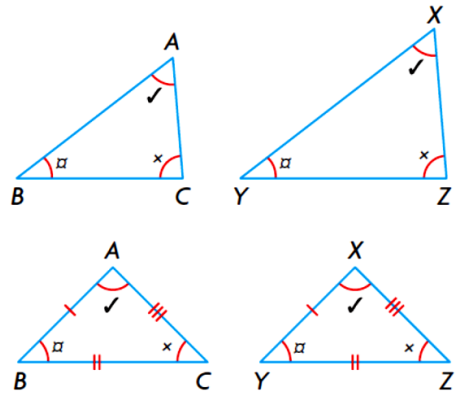
Performing further unit conversions yields

Chapter 13: An overview of trigonometry and vectors

13.1 Similar triangles

Need to Know

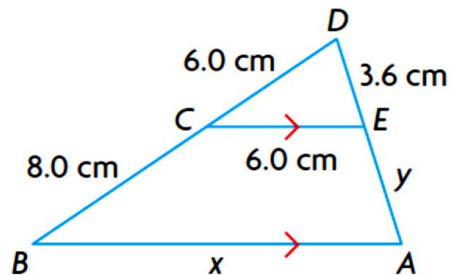
- If $\angle A = \angle X$, $\angle B = \angle Y$, and $\angle C = \angle Z$, then $\triangle ABC \sim \triangle XYZ$ and $\frac{AB}{XY} = \frac{BC}{YZ} = \frac{AC}{XZ}$.
- If $\angle A = \angle X$, $\angle B = \angle Y$, and $\angle C = \angle Z$, and if $AB = XY$ or $BC = YZ$ or $AC = XZ$, then $\triangle ABC \cong \triangle XYZ$.
- When comparing similar triangles, if the scale factor is
 - greater than 1, the larger triangle is an enlargement of the smaller triangle
 - between 0 and 1, the smaller triangle is a reduction of the larger triangle
 - 1, the triangles are congruent



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Example: Similar triangles

Show that the two triangles in this diagram are similar. Then determine the values of x and y .



$$\begin{aligned}\angle BAD &= \angle CED \\ \angle ABD &= \angle ECD \\ \text{So, } \triangle ABD &\sim \triangle ECD.\end{aligned}$$

Since AB and EC are parallel, the corresponding angles in the small and large triangles are equal.

$$\begin{aligned}\frac{BD}{CD} &= \frac{AB}{EC} \\ \frac{14.0}{6.0} &= \frac{x}{6.0} \\ 6.0\left(\frac{14.0}{6.0}\right) &= 6.0\left(\frac{x}{6.0}\right) \\ 14.0 &= x\end{aligned}$$

To calculate x , I set up a proportion using the corresponding sides I knew and the side I needed to determine in the similar triangles. Then I solved for x .

$$\begin{aligned}\frac{AD}{ED} &= \frac{BD}{CD} \\ \frac{y + 3.6}{3.6} &= \frac{14.0}{6.0}\end{aligned}$$

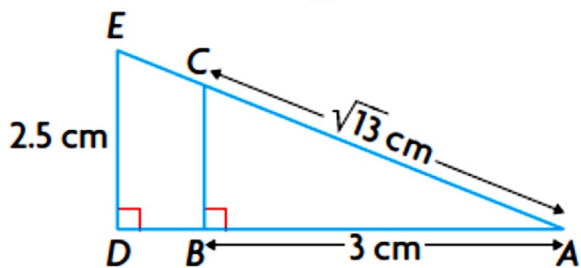
To calculate y , I set up another proportion using the corresponding sides I knew and a side that contains y in the similar triangles. Then I solved for y .

$$\begin{aligned}3.6\left(\frac{y + 3.6}{3.6}\right) &= 3.6\left(\frac{14.0}{6.0}\right) \\ y + 3.6 &= 8.4 \\ y &= 4.8\end{aligned}$$

The value of x is 14.0 cm, and the value of y is 4.8 cm.

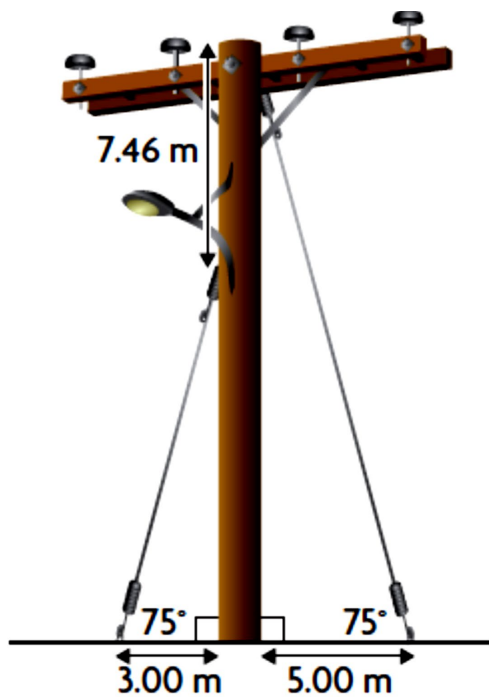
Practice:

1. Determine the length of DB



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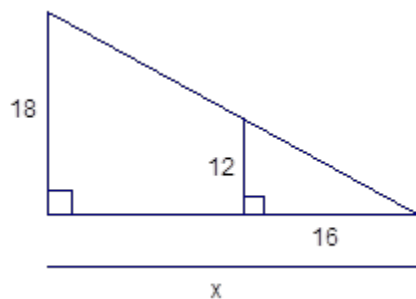
2. In the following figure, determine the height of the pole



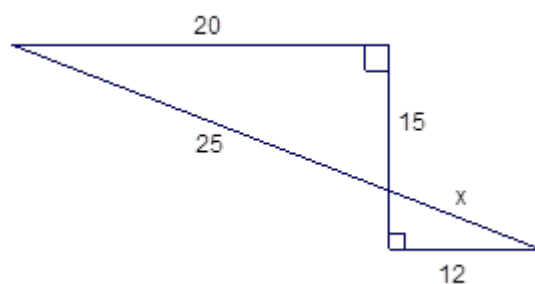
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3. Find side x in each

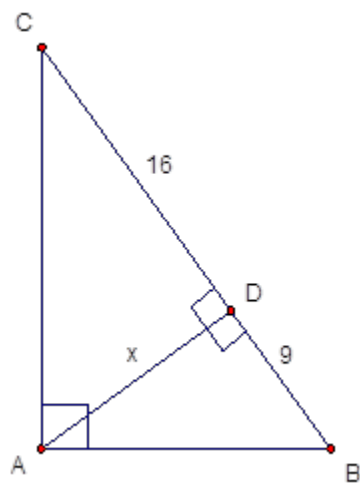
a)



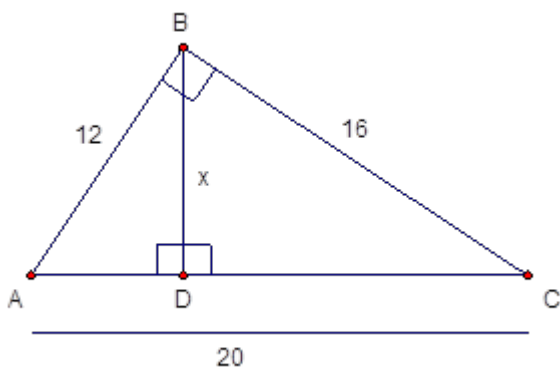
b)



c)



d)



Source: www.harperhighschool.org

13.2 Trigonometry

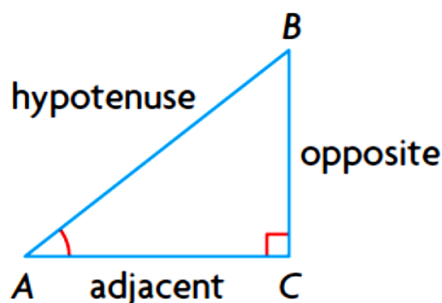
13.2.1 The Primary Trigonometric Ratios

- If $\angle A$ is one of the acute angles in a right triangle, the three primary trigonometric ratios for $\angle A$ can be written as

$$\sin A = \frac{\text{opposite}}{\text{hypotenuse}}$$

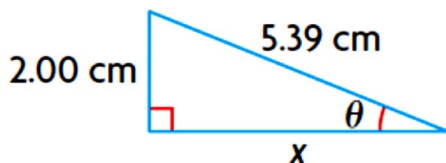
$$\cos A = \frac{\text{adjacent}}{\text{hypotenuse}}$$

$$\tan A = \frac{\text{opposite}}{\text{adjacent}}$$



- Using the Pythagorean theorem, $\text{opposite}^2 + \text{adjacent}^2 = \text{hypotenuse}^2$ in any right triangle.

Example: Determine the measure of θ to the nearest degree and x



$$\sin \theta = \frac{\text{opposite}}{\text{hypotenuse}}$$

$$\sin \theta = \frac{2.00}{5.39}$$

$$\theta = \sin^{-1}\left(\frac{2.00}{5.39}\right)$$

$$\theta \doteq 21.8^\circ$$

$$\theta \doteq 22^\circ$$

$$x^2 + 2.00^2 = 5.39^2$$

$$x^2 + 4.00 = 29.0521$$

$$x^2 = 29.0521 - 4.00$$

$$x^2 = 25.0521$$

$$x = \sqrt{25.0521}$$

$$x \doteq 5.01$$

I started by determining θ using the sine ratio. If I knew the angle, its sine would be $\frac{2.00}{5.39}$.

Since I knew the sine and not the angle, I had to use the **inverse** of sine, which is \sin^{-1} .

Since the tangent and cosine ratios both involve the adjacent side, x , I calculated the length of this side using the Pythagorean theorem.

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Practice:

1. Determine each ratio, and write it as a decimal to four decimal places.

a) $\sin C$

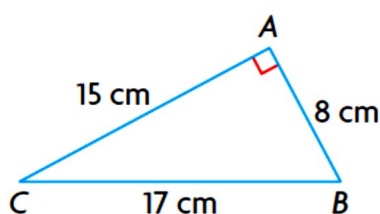
b) $\cos C$

c) $\tan B$

d) $\tan C$

e) $\cos B$

f) $\sin B$



2. Solve for x , and express your answer to one decimal place.

a) $\cos 45^\circ = \frac{x}{6}$

c) $\tan 75^\circ = \frac{x}{20}$

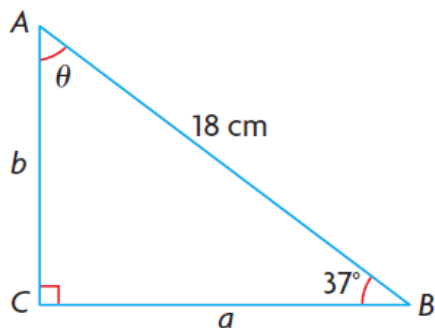
e) $\cos 60^\circ = \frac{15}{x}$

b) $\sin 62^\circ = \frac{x}{14}$

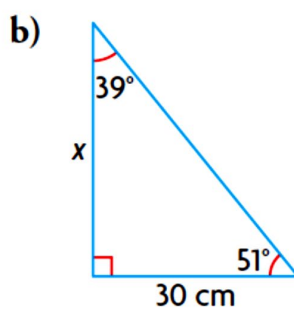
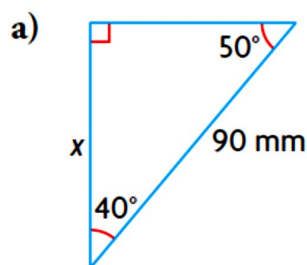
d) $\tan 80^\circ = \frac{12}{x}$

f) $\sin 45^\circ = \frac{10}{x}$

3. Solve $\triangle ABC$.



4. Determine x



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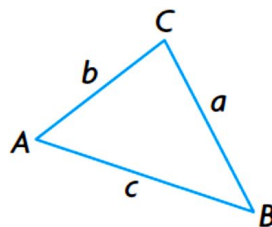
13.2.2 Law of Sine

Need to Know

- In an acute triangle, $\triangle ABC$,

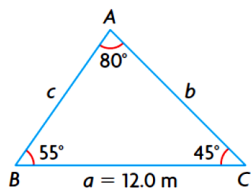
$$\frac{a}{\sin A} = \frac{b}{\sin B} = \frac{c}{\sin C}$$

- This relationship is also true for right triangles.



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Example: Determine the length of AC .



I named the sides of the triangle using lower-case letters that correspond to the opposite angles. Then I identified the measures I didn't know.

Since the triangle does not contain a right angle, I couldn't use the primary trigonometric ratios.

$$\begin{aligned}\frac{a}{\sin A} &= \frac{b}{\sin B} \\ \frac{12.0}{\sin 80^\circ} &= \frac{b}{\sin 55^\circ} \\ \sin 55^\circ \left(\frac{12.0}{\sin 80^\circ} \right) &= \sin 55^\circ \left(\frac{b}{\sin 55^\circ} \right) \\ \sin 55^\circ \left(\frac{12.0}{\sin 80^\circ} \right) &= b \\ 0.8192 \left(\frac{12.0}{0.9848} \right) &\doteq b \\ 9.98 &\doteq b\end{aligned}$$

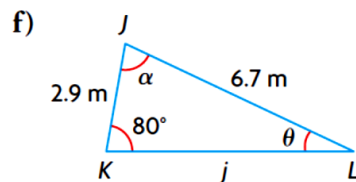
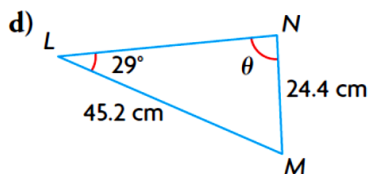
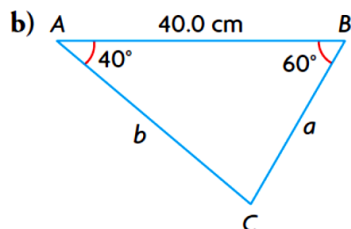
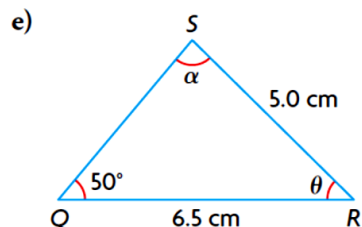
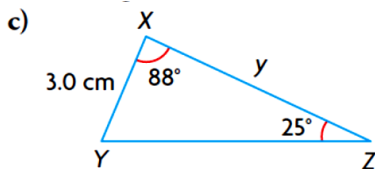
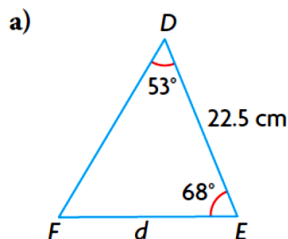
I realized that I could use the sine law if I knew an opposite side-angle pair, plus one more side or angle in the triangle. I knew a and $\angle A$ and I wanted to know b , so I related a , b , $\sin A$, and $\sin B$. I could have used $\frac{\sin A}{a} = \frac{\sin B}{b}$, but I decided to use $\frac{a}{\sin A} = \frac{b}{\sin B}$ since I had to solve for b . This meant that b was the numerator and I could multiply both sides by $\sin 55^\circ$ to solve for b .

The length of AC is about 10.0 m.

It made sense that b is shorter than a , since $\angle B$ is less than $\angle A$.

Practice:

1. Determine the unknown angles and sides



13.2.3 Cosine law

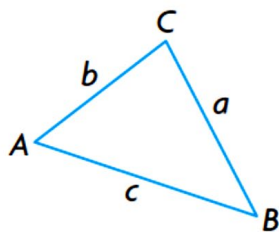
Need to Know

- The cosine law states that for any $\triangle ABC$,

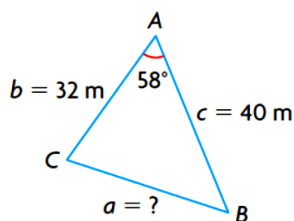
$$a^2 = b^2 + c^2 - 2bc \cos A$$

$$b^2 = a^2 + c^2 - 2ac \cos B$$

$$c^2 = a^2 + b^2 - 2ab \cos C$$



Example: Determine the length of CB .



I copied the triangle and named the sides using lower-case letters. Then I identified the measure that I had to determine. Since the triangle did not contain a right angle, I couldn't use primary trigonometric ratios. I couldn't use the sine law either, because I didn't know a side length and the measure of its opposite angle.

$$a^2 = b^2 + c^2 - 2bc \cos A$$

$$a^2 = 32^2 + 40^2 - 2(32)(40)\cos 58^\circ$$

I knew two sides (b and c) and the angle between these sides ($\angle A$). I had to determine side a , which is opposite $\angle A$. The cosine law relates these four measurements, so I substituted the values I knew into the cosine law.

$$a^2 = 1024 + 1600 - 2560 \cos 58^\circ$$

$$a^2 = 2624 - 2560 \cos 58^\circ$$

$$a^2 = 1267.41$$

$$a = \sqrt{1267.41}$$

$$a \doteq 35.6$$

I evaluated the right side. Then I calculated the square root.

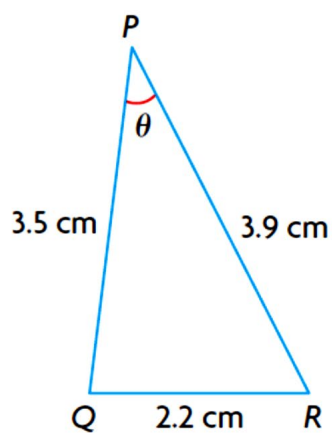
CB is about 36 m.

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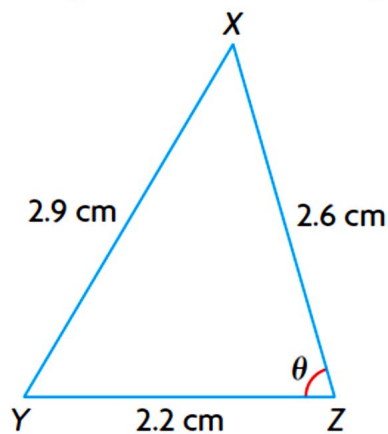
Practice:

- Determine angle θ

a)

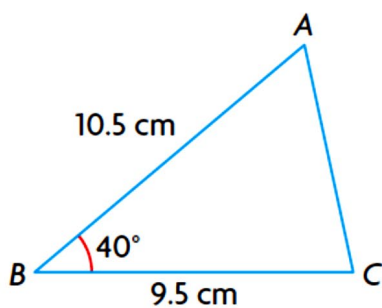


b)

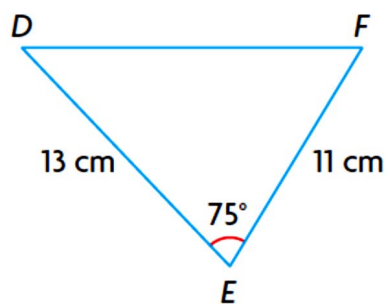


2. Determine the unknown side length

a)

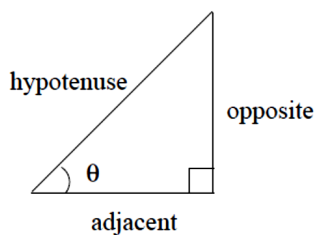


b)



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13.2.4 Trigonometry of right triangles

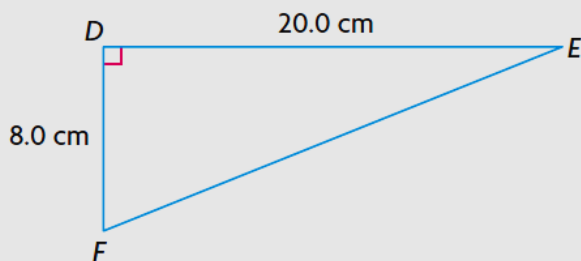


This gives

$$\sin \theta = \frac{\text{opposite}}{\text{hypotenuse}} \quad \cos \theta = \frac{\text{adjacent}}{\text{hypotenuse}} \quad \tan \theta = \frac{\text{opposite}}{\text{adjacent}}$$

Example: Solve the following question

- a) Determine EF in $\triangle DEF$ to the nearest tenth of a centimetre.
- b) Express one unknown angle in terms of a primary trigonometric ratio and the other angle in terms of a reciprocal ratio. Then calculate the unknown angles to the nearest degree.



a) $EF^2 = (8.0)^2 + (20.0)^2$

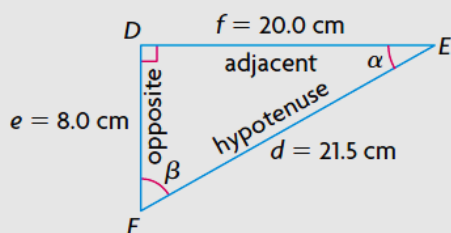
$EF^2 = 464.0 \text{ cm}^2$

$EF = \sqrt{464.0}$

$EF \doteq 21.5 \text{ cm}$

Since $\triangle DEF$ is a right triangle, I used the Pythagorean theorem to calculate the length of EF .

b)



I labelled $\angle E$ as α . Side e is opposite α and f is adjacent to α . So I expressed α in terms of the primary trigonometric ratio $\tan \alpha$.

I labelled $\angle F$ as β . Side d is the hypotenuse and e is adjacent to β .

$\tan \alpha = \frac{\text{opposite}}{\text{adjacent}}$

$= \frac{e}{f}$

$= \frac{8.0}{20.0}$

$= 0.40$

$\alpha = \tan^{-1}(0.40)$

$\alpha \doteq 22^\circ$

$\sec \beta = \frac{\text{hypotenuse}}{\text{adjacent}}$

$= \frac{d}{e}$

$= \frac{21.5}{8.0}$

$\doteq 2.69$

$\sec \beta \doteq 2.69$

I expressed β in terms of the reciprocal trigonometric ratio $\sec \beta$.

To determine angle α , I used my calculator to evaluate $\tan^{-1}(0.40)$ directly.

$\alpha = \tan^{-1}(0.40)$
 $\alpha \doteq 22^\circ$

$\sec \beta \doteq 2.69$

$\cos \beta \doteq \frac{1}{2.69}$

$\beta \doteq \cos^{-1}\left(\frac{1}{2.69}\right)$

$\beta \doteq 68^\circ$

EF is about 21.5 cm long, and $\angle E$ and $\angle F$ are about 22° and 68° , respectively.

To determine angle α , I used my calculator to evaluate $\tan^{-1}(0.40)$ directly.

Since my calculator doesn't have a \sec^{-1} key, I wrote $\sec \beta$ in terms of the primary trigonometric ratio $\cos \beta$ before determining β .

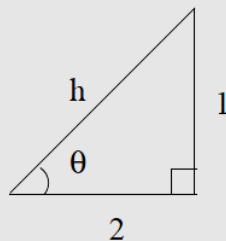
I determined angle β directly by evaluating $\cos^{-1}\left(\frac{1}{2.69}\right)$ with my calculator.

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Example 2: Given that $\cot \theta = 2$ in the third quadrant, find the other trigonometric ratios.

$$\cot \theta = \frac{1}{\tan \theta} = \frac{\text{adj}}{\text{opp}} = \frac{2}{1}$$

We then have the following triangle.



$$1^2 + 2^2 = h^2$$

$$h = \sqrt{5}$$

Next note that θ is in Quad III. Thus

$$\cos \theta = -\frac{\text{adj}}{\text{hyp}} = -\frac{2}{\sqrt{5}} \qquad \sec \theta = \frac{1}{\cos \theta} = -\frac{\sqrt{5}}{2}$$

$$\sin \theta = -\frac{\text{opp}}{\text{hyp}} = -\frac{1}{\sqrt{5}} \qquad \csc \theta = \frac{1}{\sin \theta} = -\sqrt{5}$$

Source: <http://www.math.vanderbilt.edu/~pscrooke/calculus/AT1.pdf>

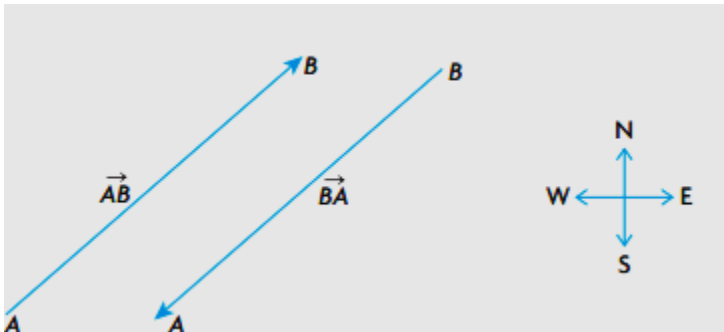
13.3 Vectors

Each vector has two properties

- 1- Direction: where it is going to
- 2- Magnitude: how much is that

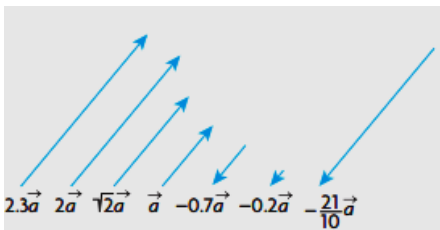
Example:

A boat is traveling at 10 km/h toward the north-east.



Nelson: Calculus and Vectors

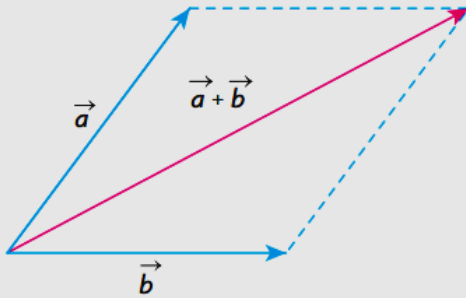
If you multiply a vector by a number, the result is a vector. The direction will be opposite if the number is negative as shown.



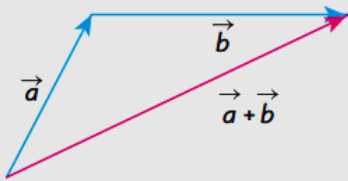
Nelson: Calculus and Vectors

13.3.1 Addition of vectors

- To determine the sum of any two vectors \vec{a} and \vec{b} , arranged tail-to-tail, complete the parallelogram formed by the two vectors. Their sum is the vector that is the diagonal of the constructed parallelogram.



- The sum of the vectors \vec{a} and \vec{b} is also found by translating the tail of vector \vec{b} to the head of vector \vec{a} . The resultant is the vector from the tail of \vec{a} to the head of \vec{b} .



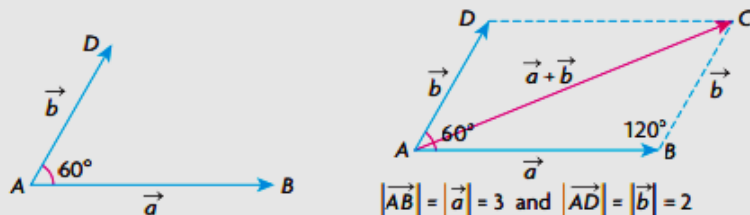
Nelson: Calculus and Vectors

Example: Addition of two vectors

Given vectors \vec{a} and \vec{b} such that the angle between the two vectors is 60° , $|\vec{a}| = 3$, and $|\vec{b}| = 2$, determine $|\vec{a} + \vec{b}|$.

Solution

If it is stated that the angle between the vectors is θ , this means that the vectors are placed tail to tail and the angle between the vectors is θ . In this problem, the angle between the vectors is given to be 60° , so the vectors are placed tail to tail as shown.



To calculate the value of $|\vec{a} + \vec{b}|$, draw the diagonal of the related parallelogram. From the diagram, $\vec{AB} + \vec{BC} = \vec{a} + \vec{b} = \vec{AC}$. Note that the angle between \vec{AB} and \vec{BC} is 120° , the supplement of 60° .

$$\text{Now, } |\vec{a} + \vec{b}|^2 = |\vec{a}|^2 + |\vec{b}|^2 - 2|\vec{a}||\vec{b}|\cos(\angle ABC) \quad (\text{Cosine law})$$

$$|\vec{a} + \vec{b}|^2 = 3^2 + 2^2 - 2(3)(2)\cos 120^\circ \quad (\text{Substitution})$$

$$|\vec{a} + \vec{b}|^2 = 13 - 2(3)(2)\left(\frac{-1}{2}\right)$$

$$|\vec{a} + \vec{b}|^2 = 19$$

$$\text{Therefore, } |\vec{a} + \vec{b}| = \sqrt{19} \approx 4.36.$$

Nelson: Calculus and Vectors

Properties of Vector Addition

1. Commutative Property of Addition: $\vec{a} + \vec{b} = \vec{b} + \vec{a}$
2. Associative Property of Addition: $(\vec{a} + \vec{b}) + \vec{c} = \vec{a} + (\vec{b} + \vec{c})$
3. Distributive Property of Addition: $k(\vec{a} + \vec{b}) = k\vec{a} + k\vec{b}$, $k \in \mathbf{R}$

Nelson: Calculus and Vectors

Example 2: Create new vectors

If $\vec{x} = 3\vec{i} - 4\vec{j} + \vec{k}$, $\vec{y} = \vec{j} - 5\vec{k}$, and $\vec{z} = -\vec{i} - \vec{j} + 4\vec{k}$, determine each of the following in terms of \vec{i} , \vec{j} , and \vec{k} .

a. $\vec{x} + \vec{y}$

b. $\vec{x} - \vec{y}$

c. $\vec{x} - 2\vec{y} + 3\vec{z}$

Solution

$$\begin{aligned}\text{a. } \vec{x} + \vec{y} &= (3\vec{i} - 4\vec{j} + \vec{k}) + (\vec{j} - 5\vec{k}) \\ &= 3\vec{i} - 4\vec{j} + \vec{j} + \vec{k} - 5\vec{k} \\ &= 3\vec{i} - 3\vec{j} - 4\vec{k}\end{aligned}$$

$$\begin{aligned}\text{b. } \vec{x} - \vec{y} &= (3\vec{i} - 4\vec{j} + \vec{k}) - (\vec{j} - 5\vec{k}) \\ &= 3\vec{i} - 4\vec{j} - \vec{j} + \vec{k} + 5\vec{k} \\ &= 3\vec{i} - 5\vec{j} + 6\vec{k}\end{aligned}$$

$$\begin{aligned}\text{c. } \vec{x} - 2\vec{y} + 3\vec{z} &= (3\vec{i} - 4\vec{j} + \vec{k}) - 2(\vec{j} - 5\vec{k}) + 3(-\vec{i} - \vec{j} + 4\vec{k}) \\ &= 3\vec{i} - 4\vec{j} + \vec{k} - 2\vec{j} + 10\vec{k} - 3\vec{i} - 3\vec{j} + 12\vec{k} \\ &= -9\vec{j} + 23\vec{k}\end{aligned}$$

Nelson: Calculus and Vectors

Practice:

1.

If $\vec{a} = 3\vec{i} - 4\vec{j} + \vec{k}$ and $\vec{b} = -2\vec{i} + 3\vec{j} - \vec{k}$, express each of the following in terms of \vec{i} , \vec{j} , and \vec{k} .

a. $2\vec{a} - 3\vec{b}$

b. $\vec{a} + 5\vec{b}$

c. $2(\vec{a} - 3\vec{b}) - 3(-2\vec{a} - 7\vec{b})$

2.

Two vectors, \vec{a} and \vec{b} , have a common starting point with an angle of 120° between them. The vectors are such that $|\vec{a}| = 3$ and $|\vec{b}| = 4$.

a. Calculate $|\vec{a} + \vec{b}|$.

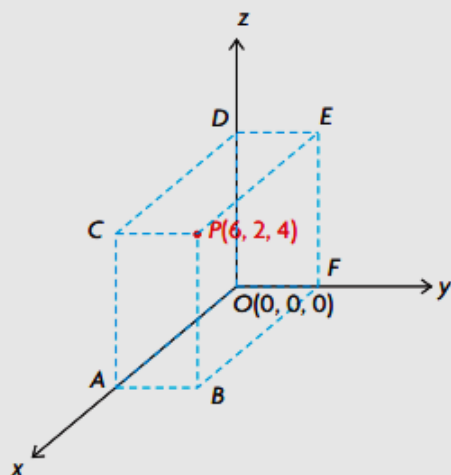
b. Calculate the angle between \vec{a} and $\vec{a} + \vec{b}$.

Nelson: Calculus and Vectors

13.3.2 Coordinates in R^3 (3D)

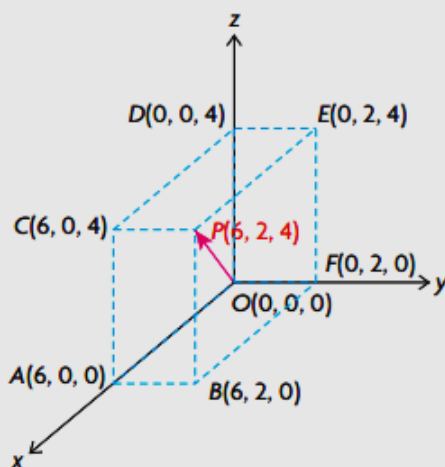
Example:

- In the following diagram, the point $P(6, 2, 4)$ is located in R^3 . What are the coordinates of A , B , C , D , E , and F ?
- Draw the vector \overrightarrow{OP} .



Solution

- a. $A(6, 0, 0)$ is a point on the positive x -axis, $B(6, 2, 0)$ is a point on the xy -plane, $C(6, 0, 4)$ is a point on the xz -plane, $D(0, 0, 4)$ is a point on the positive z -axis, $E(0, 2, 4)$ is a point on the yz -plane, and $F(0, 2, 0)$ is a point on the positive y -axis.
- b. The vector \overrightarrow{OP} is the vector associated with the point $P(a, b, c)$. It is the vector with its tail at the origin and its head at $P(6, 2, 4)$ and is named $\overrightarrow{OP} = (6, 2, 4)$.



Nelson: Calculus and Vectors

Practice:

1.

Draw a set of x -, y -, and z -axes and plot the following points:

- | | | |
|------------------|------------------|-----------------|
| a. $A(1, 0, 0)$ | c. $C(0, 0, -3)$ | e. $E(2, 0, 3)$ |
| b. $B(0, -2, 0)$ | d. $D(2, 3, 0)$ | f. $F(0, 2, 3)$ |

2.

Plot the following points in R^3 , using a rectangular prism to illustrate each coordinate.

- | | | |
|------------------|------------------|-------------------|
| a. $A(1, 2, 3)$ | c. $C(1, -2, 1)$ | e. $E(1, -1, 1)$ |
| b. $B(-2, 1, 1)$ | d. $D(1, 1, 1)$ | f. $F(1, -1, -1)$ |

3.

Draw a diagram on the appropriate coordinate system for each of the following vectors:

- a. $\overrightarrow{OP} = (4, -2)$ c. $\overrightarrow{OC} = (2, 4, 5)$ e. $\overrightarrow{OF} = (0, 0, 5)$
b. $\overrightarrow{OD} = (-3, 4)$ d. $\overrightarrow{OM} = (-1, 3, -2)$ f. $\overrightarrow{OJ} = (-2, -2, 0)$

Nelson: Calculus and Vectors

Chapter 14: Engineering Design Process

14.1 Project description

Engineering teams are required to develop an original solution to a valid, open-ended, technical problem by applying the engineering design process (Figure 1). First, you should conduct research to choose, validate, and justify a technical problem. Students should choose their projects from the list. After carefully defining the problem, teams of students will design, build, and test their solution. Finally, student teams will present and defend their original solution to an outside panel. Students will be supervised step-by-step to make their prototype.

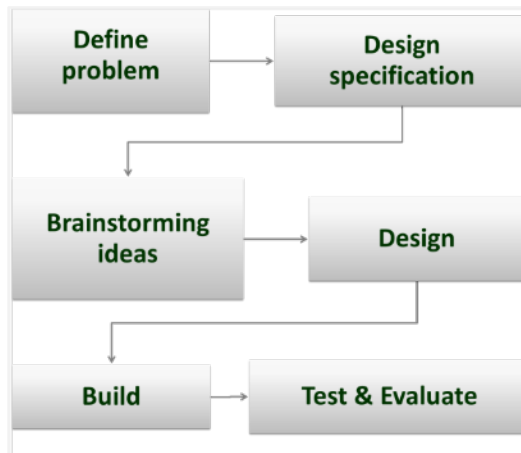


Figure 1: Engineering Design Process

Project grading scheme

- Attendance and **contribution** of a team member
- Each team should write a **report**. The report should include the following items:
 - ✚ Abstract (200-250 words)
 - ✚ Introduction (briefly cover Research, Problem Statement, Problem Justification, Importance of Problem); (3 -4 Paragraphs)
 - ✚ Design Process (Design Criteria, Rough Sketches, Detailed Sketches of final Design)
 - ✚ Construction and testing procedure (Briefly explain the procedure that was used for building the prototype, include some pictures)
 - ✚ Conclusion and recommendation

Please cite your references where applicable. Use quotations (“....”) where you exactly copy materials from a reference. If you are summarizing from a reference, please cite it where the sentence is.

- Each team should have the following **presentations**
 - ✚ Juried Panel and Trade Show Presentation and/or Class Presentation

Available Resources for Project on Campus:

- **Woodworking shop:** Table saw, drill and router saw
- **Vex robotic kit:** Microprocessor, motors, sensors, and metal platform. Easy to assemble and
- **3D printers and 3D scanners:** Design and build an object from scratch. Autodesk Inventor can be used to design a solid object.
- **Arduino kits**
- **Other components:** They can be purchased upon the request

Available Resources for Project on Virtual Platforms:

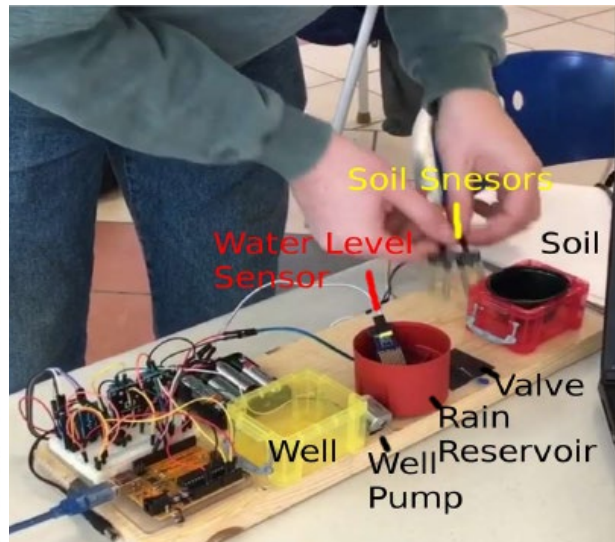
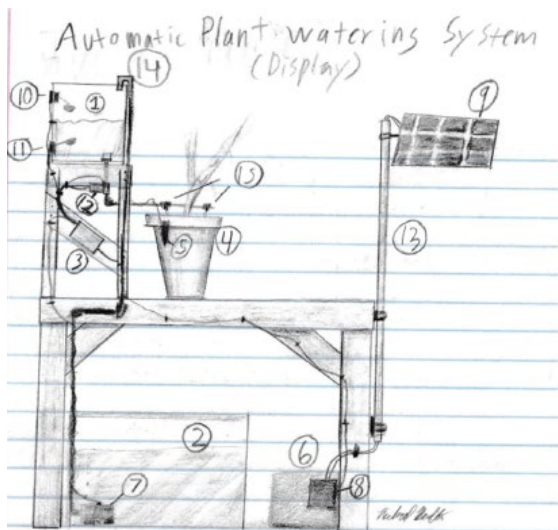
- www.TinkerCAD.com
- <https://www.instructables.com/>
- 3D models on www.thingiverse.com

14.2 Sample projects:

Selected projects in Introduction to Engineering class have been published in the Journal of Innovative Ideas in Engineering and Technology. Please visit www.jiiet.com to explore them.

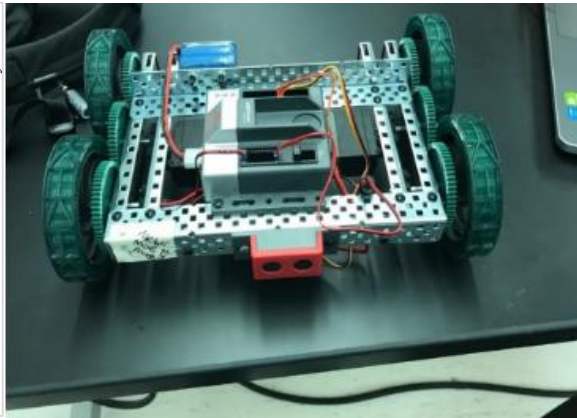
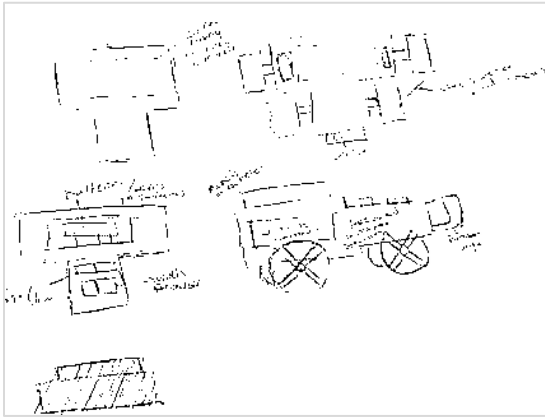
- **A Self Sufficient Gardening System**

The team used an Arduino Microcontroller along with water-level and soil- moisture sensors to automatically fill the tank and water the crop.



- **Building an Autonomous Car**

The team used an ultrasound sensor on a robot car. The robot avoids obstacles.



- **El Bache: The solution to potholes in Michigan**

This project was discovered to have the cars that we drive to be aware of the potholes and avoid them while also being aware of their surroundings.



Project idea generation:

Innovative projects address a need. The customer discovery method helps us identify the need for an engineering solution. The method includes surveys, interviews, and statistical analysis to find the need. However, due to time and resource limitations in this course, we work on a simple practice as listed below.

1) List 10 hobbies/interests

Example: Swimming, reading, watching TV shows, computer games, ...

2) List 10 loves and 10 hates

Love means: what you love to see in your hobby/interest and it does not exist at this moment

Hates means: what do you hate to see when it happens in your hobby/interest

Example of love: I wish I could stop hitting the snooze button on my alarm clock.

Example of hate: I hate to look for the key when I get close to my car.

3) List five topics for your projects

4) Finalize your project topic with your team

When each team member has five project topics, in a team of four students, there will be more than 10 project topics. It is now time to finalize and select one project topic. When discussing with your team, consider the following criteria.

- The project can be accomplished in one semester.
- The project can be done with available resources.
- Initial research indicates that others also believe the problem exists.
- The solution is likely to meet a specific need and/or be marketable.
- The problem is interesting enough to keep the team engaged.

14.3 Problem statement and justification and research

Create a new document on a cloud server (such as Google Drive), and share the document with your teammates. The following items should be included in this section:


1- Problem Statement: write a paragraph to describe the problem in which your project will address. Stay concise and to the point. Avoid general information and other unnecessary statements. Here is an example of a problem statement for a team trying to build a solar charger for cellphones.

Sample problem statement: We highly depend on our phone for all our daily tasks such as communication, navigation, checking emails, and shopping ... Running out of battery on your phone during the long school hours becomes a hassle. Also remembering to recharge your phone and laptop every night is inconvenient.

2- Problem justifications: List five justification points why your problem is important. Try to back it up with science.

3- Problem research:

If we need to find information related to a topic, we google it. However, we cannot assure the accuracy and trustworthiness of the obtained information. As listed below. Google usually shows us information on social media channels, weblogs, news articles, and scientific magazines. However, researchers do not rely on information available on the general public domain. Instead, they use information from articles in a higher academic-level such as in textbooks, conference proceedings, and journals. These articles can be found on the Google Scholar website.

	Google http://google.com	<ul style="list-style-type: none">- Social media channels: Twitter, Facebook, Google plus- Weblogs where the author is trustworthy and known.- News articles by agencies like BBC, NBC, CNN, and etc.- Scientific magazines
	Google Scholar http://scholar.google.com	<ul style="list-style-type: none">- Textbooks- Conference proceedings- Peer-reviewed journals

Please visit Google Scholar at scholar.google.com. Use relevant keywords and start browsing. Please keep in mind to research your problem, not the solution. For instance, search for “how often people use their phone, and how much they rely on it”. Please do not search for “how to

build a phone charger”. At this stage, we are researching the need, justification, and validity of our problem, not the solution.

In your document, for five articles copy and write the following items:

- 1- Title of the article,
- 2- Citations: if you use Google Scholar, in the list of articles, click on Citation button, and copy the citation.
- 3- Abstract
- 4- Summary and relevance of the article: write a paragraph to summarize the article, and explain how this article is relevant to your project.

14.4 Prior solutions

Create a new document in the shared drive and add three patents and three commercial products to it. You can browse patents on the Google Patents website at <http://patents.google.com>.

For every patent, copy and write the following items:

- 1- Patent title
- 2- Patent inventor/s
- 3- A sketch of main part/s
- 3- Pros and cons: write a paragraph for the pros and cons of the patent

The patent lifetime in the USA is 20 years. It means the inventor can keep his intellectual rights for 20 years. Therefore, try to find patents within the past 20 years.

Intellectual properties in the USA are in the following three categories: Patents, Copyright, and Trademark. Patents are usually used for a physical object or a process. Copyrights are used for written or produced works such as books, computer codes, songs, and videos. Trademarks are used for branding and identity matters such as logos, color, shapes, and etc. The time and resources to register a patent or trademark are extensive compared to registering a copyright.

Similarly, for three commercial products, list the following items. You can use a regular Google search to find commercial products.

For every commercial product, copy and write the following items:

- 1- Product name/brand/manufacturer
- 2- Web address of where to purchase the product
- 3- A picture of the product
- 3- Pros and cons: write a paragraph for the pros and cons of the product

14.5 Design specification

After researching the market and prior solutions, now is the time to come up with a basic idea of what we want to create:

- How physically we want it to look like?
- What materials do we want to use?
- How much money customers will be willing to purchase our product or service?
- What regulations or safety concerns are around our perceived product?

Here is an example of Design Specification for a given project about a boat project to clean up waterbody:

- Form: the shape of a fish, Length about 12 inches, Width about 6 inches
- Function
 - Performance: The user can pick up garbage in a pool
 - Durability: Lasts for 1-2 years
 - Maintenance:
 - Changing filters
 - Recharging batteries
 - Replacing batteries
 - Waste disposal
 - Standardization
- Material:
 - Infrared sensor
 - Suction
 - Plastic
 - Filter
 - pump
 - batteries or solar panels
- Cost:
 - \$50
- Aesthetics
 - Similar to a real fish
- Ergonomics
 - Ergonomically beneficial reduces possible back strain
- Safety and legal issues: Needs to be researched through government websites such as at EPA.gov
- Customer Needs and Wants
 - Needs: something to clean the pool, garbage to be picked up
 - Wants: the filter to not have to be changed all the time, to be easy to use

For your product/process, create a list for Design Specification. Please may prioritize the list

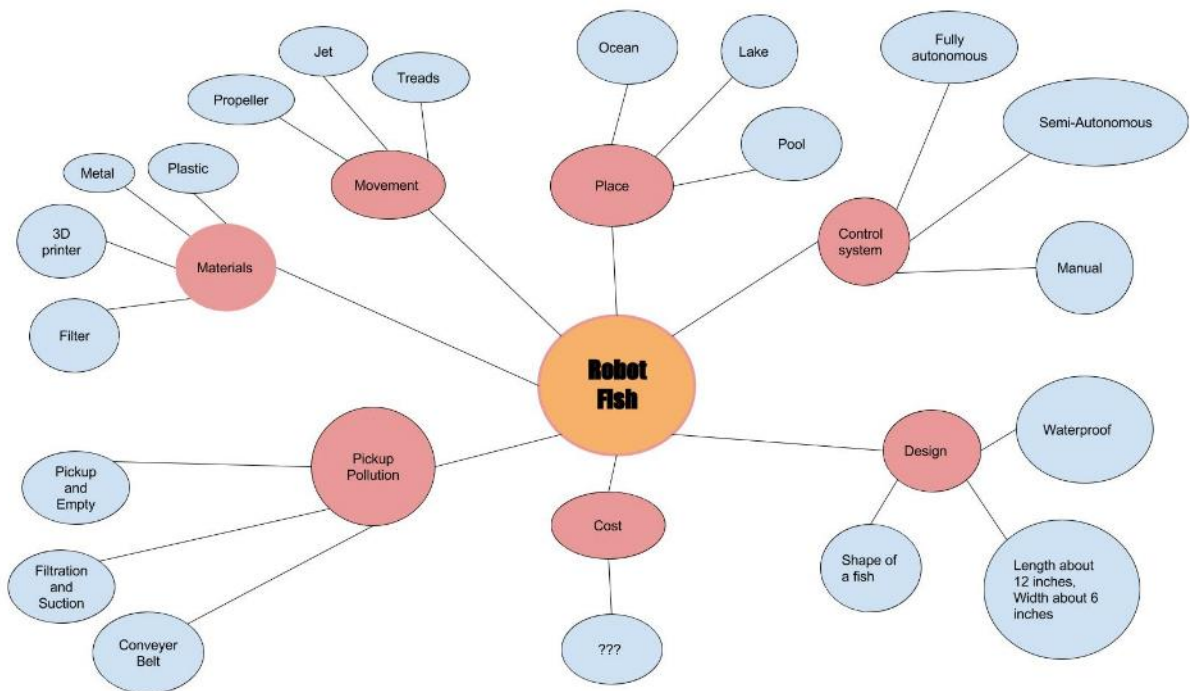
14.6 Design

We are one step closer to create a product/process to fulfill a need. However, before constructing a building, we need to have a blueprint for main columns, beams, and details maps for bathrooms and bedrooms. Similarly, we need to design the details of our proposed solutions. The rough idea maps are called conceptual design. We used conceptual designs to sketch the product and proceed to detailed design.

14.6.1 Brainstorming

There are hundreds of solutions to address an open-ended problem. However, the question is how to come up with a list of solutions, and how to prioritize them. One way is to create a visual picture of solutions is to create a mindmap. This will allow us to explore different possibilities for a proposed project.

Here is an example of a mindmap for “Robot Fish” A robot that will pick up pollution from water.



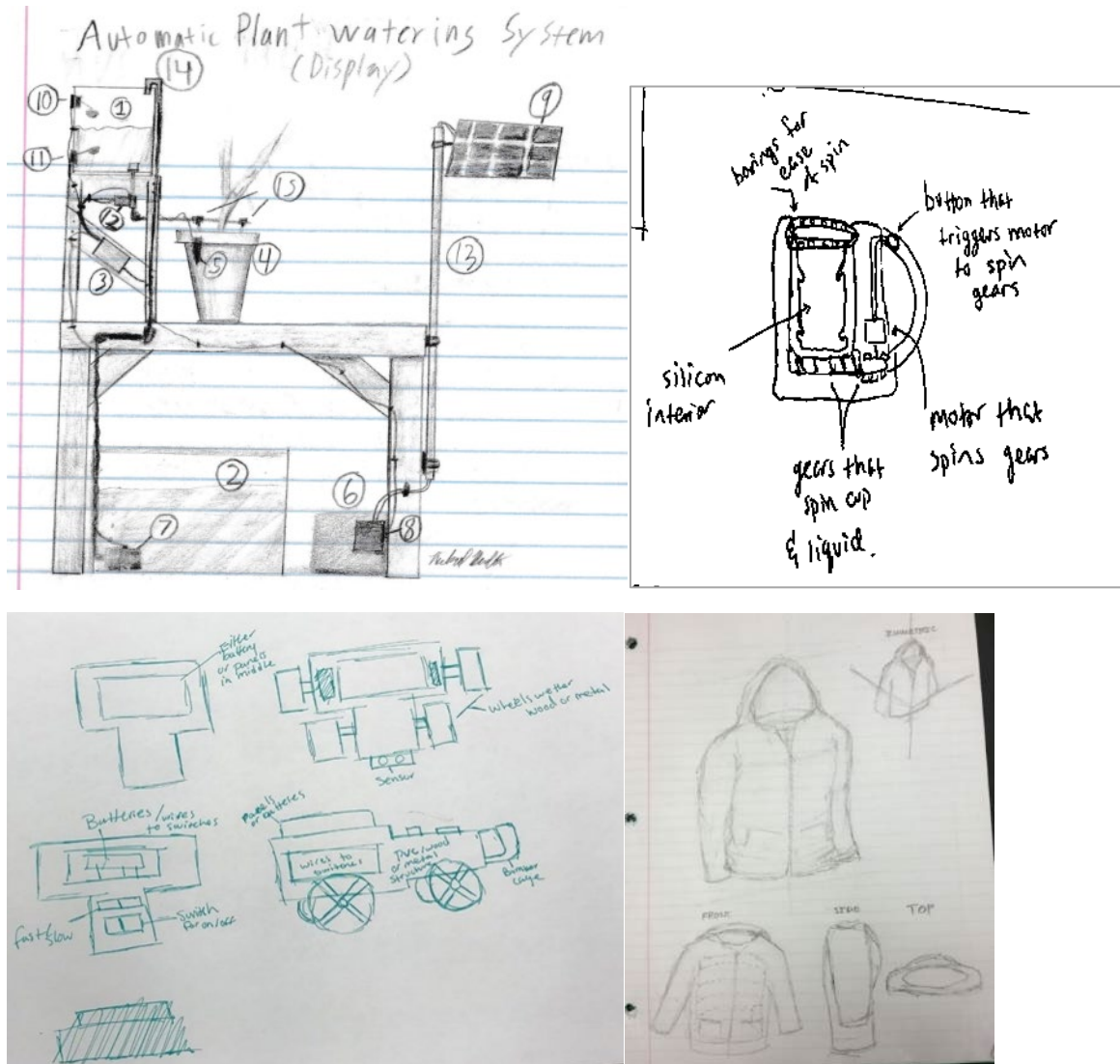
The team explores different possibilities for movements in water: propeller, jet, and threads. They also have listed different control systems for the device such as fully-automated, semi-autonomous, and, manual.

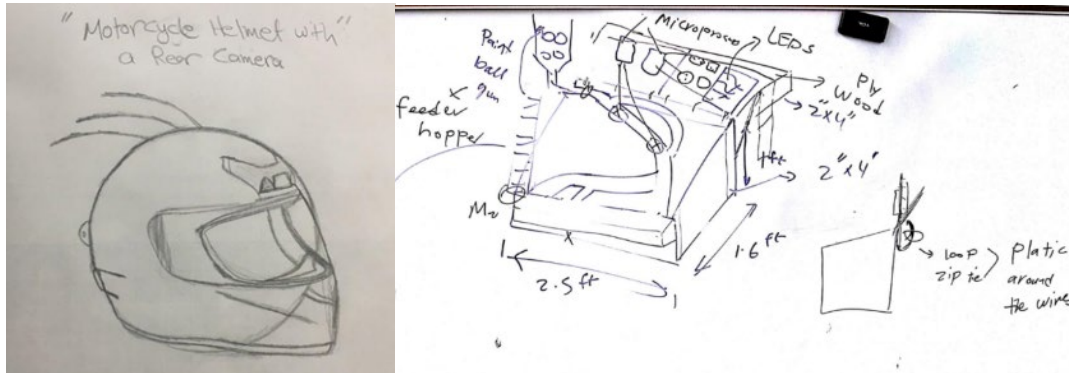
Get together with your teammates and create a mindmap for your project. Remember, to include performance/operation and shape/form.

14.6.2 Sketching

For a given solution, draw a sketch. These sketches would help us figure out how a product physically looks like. They also enable us to communicate our ideas with other team members. They also can address some fundamental questions like is it physically possible to put these many features in a product?

Sample sketches for different projects





Sketches for your project: create three rough sketches for different solutions for your product. In addition, draw a detailed sketch for a preferred solution including some dimensioning.

14.7 Bill of materials

Before we start to construct a product, we should have a list of required materials. This list is called the “bill of materials.”

Bill of Materials for building a robot that cleans the water stream.

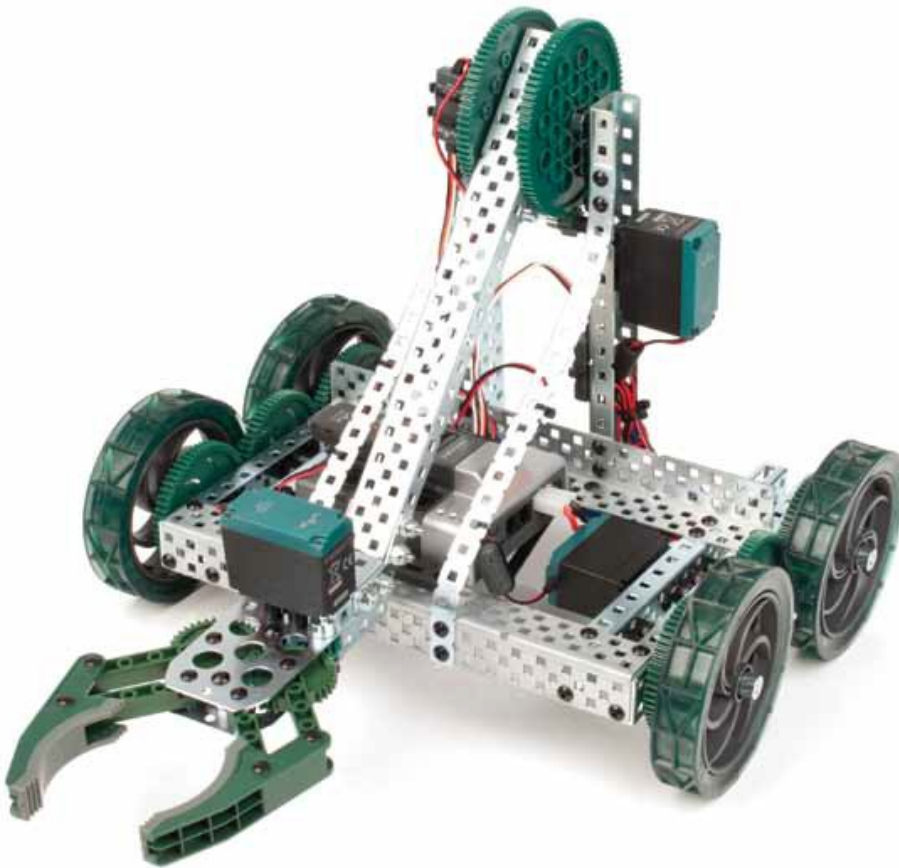
Name of Material	Where to Buy	Cost
Propellor	3D Print	\$0
Motor	In stock	\$0
Net	Walmart	\$9
Rechargeable Battery Pack	In stock	\$0
Sensor	In stock	\$0
Arduino Board	In stock	\$0
Battery Charger	In Stock	\$0
Hull	3D print	\$0
Arduino Motor Shield	In stock	\$0

14.8 Construction

Here is a list of different technologies/resources at Henry Ford College to build your prototypes:

VEX Robotics equipment:

Equipment includes metal frames, gears, electrical motors, micro-controller, wirings, and bolts, and nuts.

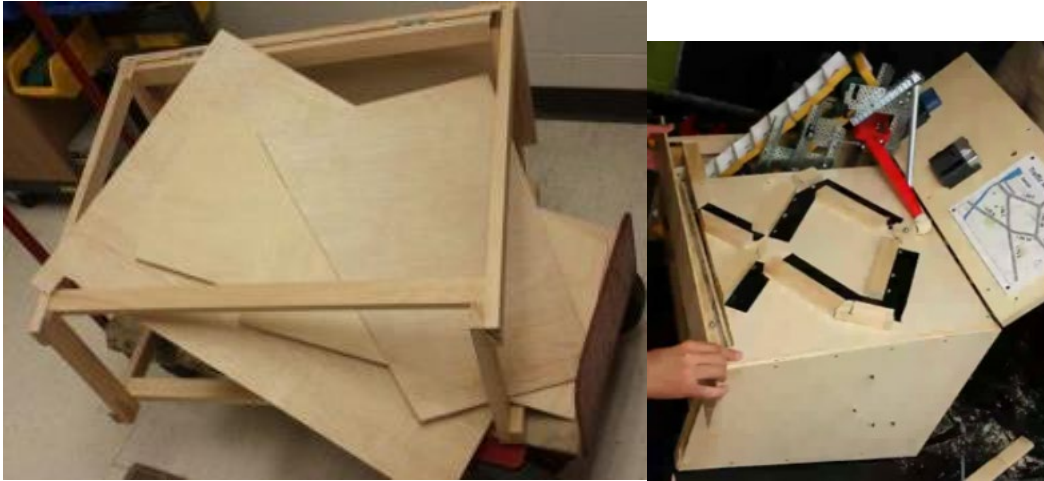


Please refer to this link for manuals on how to build a robot and how to program it by VEX robotics equipment: http://cmra.rec.ri.cmu.edu/products/cortex_video_trainer/

Woodworking

Alternatively, to create a frame for your product, you can use woodworking technologies.

Sample wooden frames created for a prototype:



3D printing

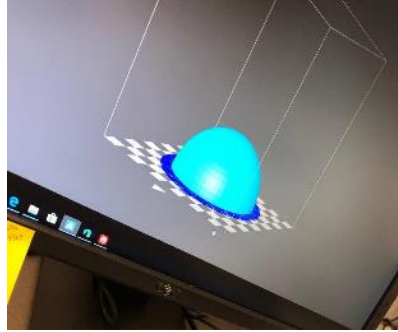
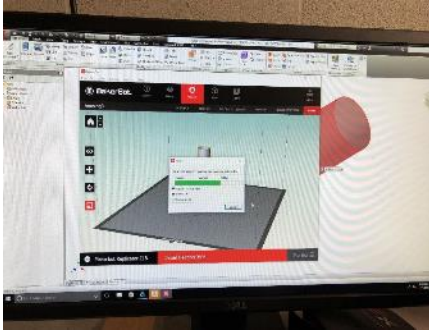
3D printing technology allows us to simply design and construct a three-dimensional object. For instance, if you are planning to construct a cellphone holder, 3D printing is a good idea. You can design the product in 3D solid modeling software like Autodesk Inventor, and import the object to a 3D printer for printing.

Design in 3D Solid Modeling Software → Export 3D object in STL format → Import STL file into 3D printing software

Here is a summary of the work by a team of students who designed a portable fan by 3D printing:

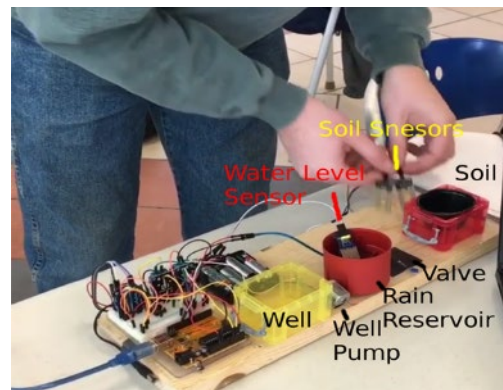
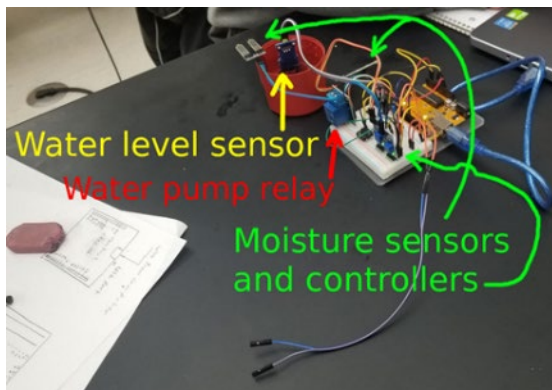
We will start by 3D printing the fan blades then assembling the motor to the trigger. Then connect the fan blades to the wiring that's connected to the motor which is powered by batteries. Then we will place it within the custom 3D printed housing.

The 3D printer is run through several software programs. Including our primary software Makerbot. We've found that the initial process involves a lot of trial and error; however, the website thingiverse.com can be a fantastic resource for professionally designed, scalable (and most importantly) free designs anyone can use for a project such as the one we've all embarked on.



Arduino technology:

Arduino is an inexpensive technology for the design and construction of control systems. Here is an example where a team of students uses Arduino technology for the construction of an automatic watering system for crops. The systems read the soil moisture, and when the moisture level is low, it will start pumping the water. Refer to Chapter 6 for more on Arduino technology.

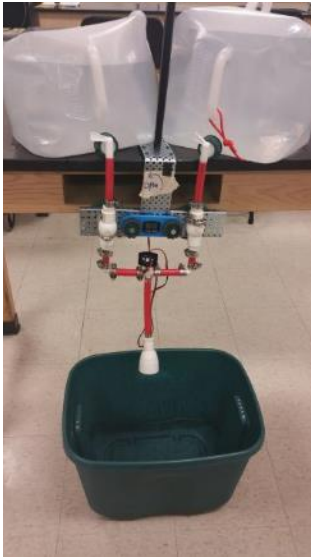


14.9 Testing and refining

Usually, in the first trial, our product does not function as expected. Therefore, we need to test and refine the prototype. Sometimes, few adjustments can help us to make our prototype functional.

Example of testing

Most people have trouble finding the perfect thermal comfort in the shower year around. A team of students designed a system where the user can adjust the valves and observe the temperature before releasing water from the shower. The team has come up with a testing procedure. In the test, they will challenge six volunteers to see how fast they could set the temperature to 90 Degrees F. Each volunteer will do the test three times.



Testing results showed that there is a learning curve for each user. After three trails, on average the time to set the temperature to 90 F, reduces from 50 seconds to 20 seconds.

