Paper ID #36225

Training Middle and High School Teachers in Introducing Science and Engineering to Students

Prof. Rajpal S Sodhi, NJIT

Training Middle and High School Teachers in Introducing Science and Engineering to Students

Abstract:

Students enrolled in elementary and secondary schools, who want to pursue a career in science and engineering need a realistic introduction to these topics through hands on and meaningful experiments not normally available in schools. Author has developed a workshop on Energy and Machines introducing grade 6-12 teachers to these topics through simple mechanical models and computer based animated programs. This was accomplished through the Pre-Engineering Instructional and Outreach Program (PrE-IOP) at NJIT to enlarge the future pool of qualified high-tech workers in New Jersey, including those who have been historically underrepresented (such as minorities and women). The workshop uses hands on experience to explain scientific laws related to mass, motion, work, power and energy. Principles such as Newton's Laws of Motion are explained through practical examples. The concepts of simple machines and mechanisms to solve practical design problems are presented through geometrical constructions and model building. They learn how simple machines work through physical models. These include inclined plane, lever, wedge, screw, pulley, wheel and axle etc. Examples are given on how combination of simple machines produce complex machines such as a bicycle, pendulum clock and auto transmission.

Workshop on Energy and Machines:

In this workshop, a two-week curriculum is presented through eight modules which use hands on experience to illustrate scientific laws related to mass, motion, work, power and energy. They are introduced to the Engineering profession and learn the design process to solve problems. Physical models are used to explain principles such as Newton's Laws of Motion. The concepts of simple machines and mechanisms are explained through geometrical constructions and model building. This section summarizes the curriculum of seven modules in the areas of machines and energy; work and power, simple machines and laws of motion[1,2]. The module on design of mechanisms and robotics is presented in greater detail.

1. Introduction to Engineering
2. Engineering Design
3. Simple Machines
4. Gears
5. Complex Machines
6. Work and Power
7. Energy
8. Mechanisms and Robots

1. *Introduction to Engineering*: This module deals with what is science and engineering. What is an engineer's day-to-day work like ? What abilities are important for an engineer to be successful ? What are some of the major benefits to be had from an engineering education? Engineering is defined as the art of applying science and mathematical principles and using creativity, experience and knowledge to solve problems to help people. Engineers design electric cars, mobile phones, bridges and processes to clean environment and mass transportation systems to move people and goods. Engineers can choose different types of jobs such as design, manufacturing, research, testing or sales etc. A student interested in discovering new knowledge can consider a career in research. If you are imaginative and creative, design engineering may interest you. If you like computers, you can be a CAD engineer. If you like laboratory and experiments, you may choose development engineering. Engineering is also organized in traditional fields such a mechanical, electrical, civil, chemical, biomedical or computer engineering. Then there are more specialized engineering fields such as aerospace, nuclear, environmental or ocean engineering. In considering what is science, we describe key scientific discoveries and their adaptation to useful products. Our scientific discoveries are increasing at a fast pace, but now there is less time between a scientific discovery and its adaptation to useful products. For example there are numerous application in engineering and medicine of laser. The participants study the impact of science and technology throughout the history and compile a list of unsolved problems which need engineering and science for their solution.

2. *Engineering Design:* Design is basically a plan to solve a problem of technical nature. When the focus of engineering is solving specific problems using science and mathematics, it is required that the solutions must meet certain legal, economic, environmental and other constraints. This is *Engineering design*. Discovery is the knowledge base , but design is a product of planning and work to use this discovery to satisfy a given need. Design breaks a problem to manageable parts and looks for acceptable optimum solutions. The ability to do design is both a science and an art and the art of design is learnt through experience. More recently, design uses artificial intelligence, computers with large data analysis to solve problems faced by humanity. The participants are taught engineering design problem solving through problem definition, statement of human needs and developing design objectives. They learn how design progresses through various stages and how creative solutions are obtained. They are asked to list design short comings in daily use household devices. They learn to do marketing surveys and simple statistical analysis of consumer information and learn the role of ethics and professionalism in design.

3. *Simple Machines*: A machine is a combination of resistant bodies properly designed and arranged to work together as a whole, so that certain predetermined objectives can be achieved and certain specific motions can be obtained. The simplest definition of a machine is it is a system in which some input is fed, and as a result some output comes out. The relationship between input and output depends upon the function which is desired from the machine. A machine can also be a device that assist in converting force into required work. The main objective of the machine is to get the

required work done with a minimum force. The input to the machine can be a force and the output would be the required work. The simple machines demonstrated here are inclined plane, lever, wedge, screw, pulley, wheel and axle [3]. They learn through models how these simple machines work. They also learn about forces acting and types of motion used in these simple machines. Simple calculations such as determination of efficiency of machines are performed.

4. *Gears*: gears are used in most mechanical devices. They do several important functions, most prominent is to provide speed reduction in motorized equipment. This is important because a small motor, rotating at very high speed can provide power to a hand tool, but not enough torque. For example, an electric screw driver has a very large gear reduction because it needs a lot of torque to turn screws, though the motor runs at high speeds. Another thing the gears do is adjust the direction of rotation. For example in the differential between the rear wheels on your car, the power is transmitted by a shaft that runs down the center of the car, and the differential has to turn that power 90 degrees to apply to the wheels. We see gears in about every device which is rotating. Gears are generally used for four different functions:
   a) To reverse the direction of rotation.
   b) To increase or decrease the speed of rotation.
   c) To move rotational motion to a different axis.
   d) To keep the rotation of two axes synchronized.

   Different types of gears are shown with physical models. The types of gears include Spur gears, helical gears, bevel gears, hypoid gears, rack and pinion and worm gears.

5. *Complex Machines*: A complex machine is defined as a combination of simple machines in order to achieve a specific output or accomplish a function. Multiple simple machines can be combined to produce a complex machine. Examples are motor bikes, cranes, watches, power winch and so on. In all these complex machines, simple machines are arranged in a specific way to achieve the required output. The different components of a complex machine transfer energy from one part to another. The participants are presented with a complex machine like a bike and asked to identify all the simple machines which make up the bike. Complex machines enable a machine to do it work more easily and efficiently. Complex machines are custom designed to perform the specific task. This process is called machine design. Concept of *mechanical advantage* which is defined as the ratio of work input to work output is introduced. The mechanical advantage of a complex machine is the product of mechanical advantages of the respective simple machines. Examples are given on how combination of simple machines produce complex machines such as a bicycle, pendulum clock and auto transmission.

6. *Work and Power*: In physics, *work* is defined as a force acting upon an object to cause a displacement. There are three key words in this definition – force, displacement and cause. In order for a force to qualify as having done work on an object, there must be displacement and the force must cause the displacement. There are several good examples of work which can be observed in everyday life – an ox pulling a plow through the fields, a woman pushing a grocery cart in the store, a

student lifting his backpack of books upon his shoulder, a hunter launching an arrow. In each case there is a force exerted upon an object to cause the object to be displaced. On the other hand, *power* is the rate at which work is done. We learnt that work is to do with a force causing a displacement, but time was not included. Power is the work per unit time. They learn definitions and units and Newton's laws of motion are explained through examples. Examples of work and how machines make work easier are provided. Calculations of work and power are done with simple formulas. Powering of simple machines is demonstrated.

7. *Energy*: Energy is the capacity to do work, to make things move. Different forms of energy can be used to do work. They learn about energy conversion – the transformation of energy from forms provided by nature that can be used by people. A vast number of mechanical systems have been developed for this purpose. For example a wind mill transforms kinetic energy of wind into mechanical energy for pumping water etc or convert mechanical energy into electrical power. First they learn about different forms of energy [4]: Electrical Energy, Chemical energy, Mechanical energy, Light energy, Heat energy and Nuclear energy. They learn about sources of energy which could be renewable or non-renewable.

   Renewable sources of energy:
   - Energy from the Sun
   - Energy from the rivers
   - Energy from winds
   - Energy from the tides
   - Energy from hot springs
   - Energy from biomass.

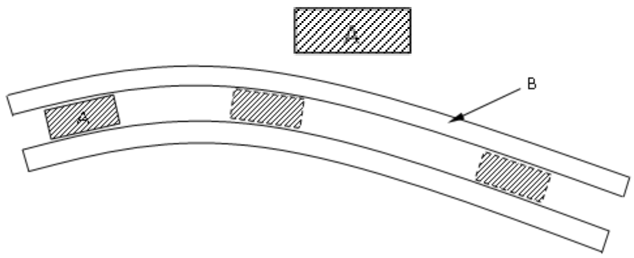
   Non-renewable sources of energy:
   - Energy from fossil fuels
     - Coal,
     - Petroleum.

The concepts of potential and kinetic energy are explained through a physical model depicting a roller coaster. How energy is stored ? What is the impact of energy on environment ? Demonstrations are used showing different moving machine parts using different forms of energy.

8. *Mechanisms and Robots*. They are taught how arranging machine elements such as joints and links form mechanisms. Examples of mechanisms such as four-bar linkage and slider crank mechanism are provided through physical models which are given to each participant to take with them for demonstration to their classes. Different types of mechanism design problems [5] such as motion generation, path generation and function generation are illustrated through physical models and computer simulations. Basic principles of mechanisms and simple geometrical constructions such as drawing similar triangles etc are explained next. They design new mechanisms for motion generation using these geometrical constructions and finally learn to build working models of the designed mechanisms using card board etc.

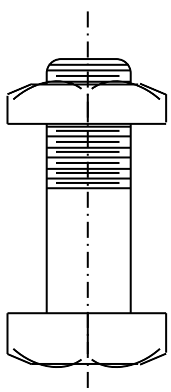
Some Principles:

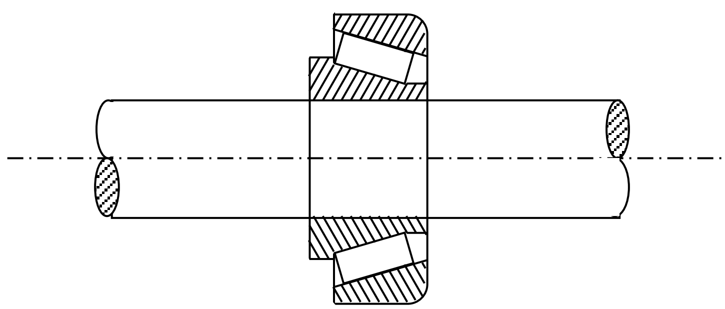
Body A is free to move anywhere in the plane. **Body A** can be made to move to a series of positions by bringing it in contact with another **body B**. The **body B** is stationary and has a special form. Now these two bodies (a pair) have a definite motion due to the contact. Combining two bodies makes a pair or a **joint**.



A **machine** consists solely of bodies which form corresponding pairs. We could have either of the two bodies moving. These pairs are the kinematic elements of a **machine**. Other examples of pairs are shaft and bearing, screw and nut. Hence kinematic elements of a machine are not employed singly but always in pairs. *Therefore a machine consists of elements as pairs of elements*.

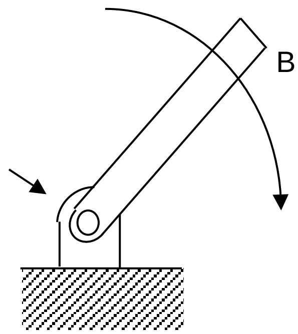
Screw and Nut





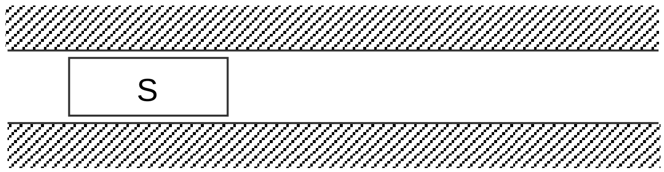
Shaft and Bearing

Examples of Joints:



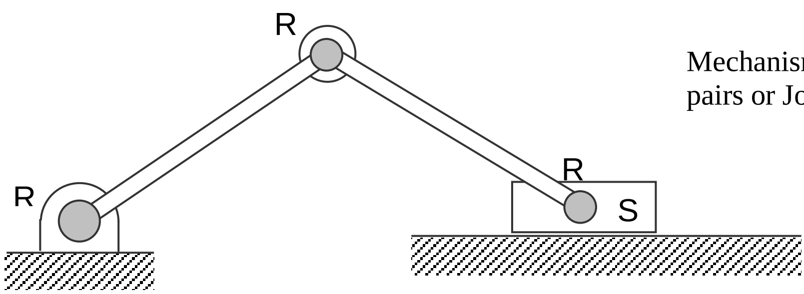
All points on bar B move in circles.

Revolute Joint



All points on Slider S move on a straight line

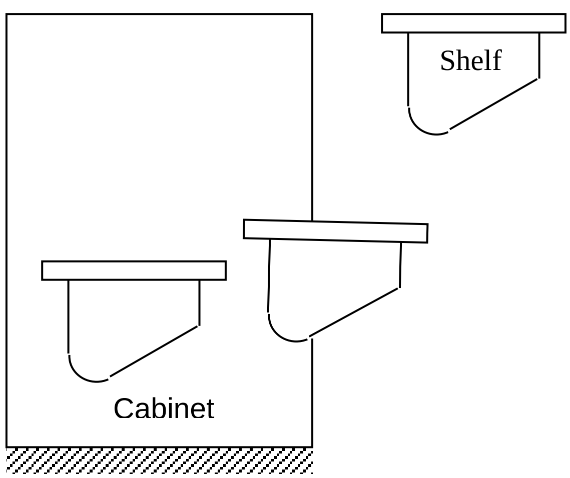
Slider or Prismatic Joint



Mechanism consisting of 4 pairs or Joints.

Plane Position Mechanism Design Problem:

Here we demonstrate the design application to design a linkage to move the shelf through three different positions.



Some Principles from Geometry: Before we attempt to solve the design problem, we review some simple geometrical constructions.

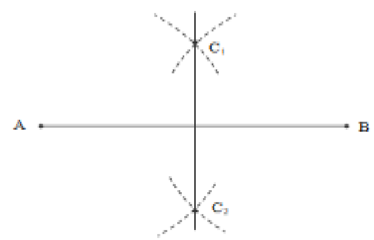
1. **To Draw the Right Bisector of a Straight Line**

Given: A line AB, draw its right bisector.

Steps: 1) With A as center, draw an arc with a suitable radius.

2) With B as center, draw an arc having the same radius.

3) These arcs intersect at C_1 and C_2. Join C_1 and C_2 with a straight line, which is the right bisector of AB.



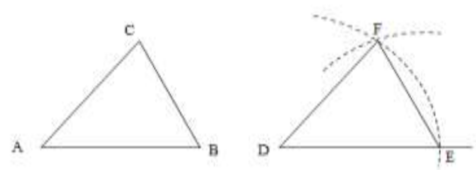
2. To Draw Two Similar Triangles

Given: A triangle ABC. Draw another triangle DEF similar to triangle ABC having DE as its base.

Steps: 1) With D as center, draw an arc with radius AC.

2) With E as center, draw an arc with radius BC.

3) These two arcs intersect at F. Join DF and EF. DEF is the desired triangle.



3. To Draw a Circle Through 2 Points.

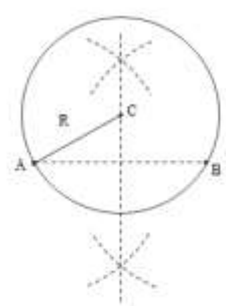
Given: Two points A and B. Draw a circle passing through A and B.

Steps: 1) Join A and B draw the right bisector of AB.

2) Choose a point C anywhere on the right bisector as the center of the desired circle.

3) With C as center and CA as radius draw the required circle.

Note: A circle required to pass through two points is not unique.



4. **To Draw a Circle Through 3 Points**

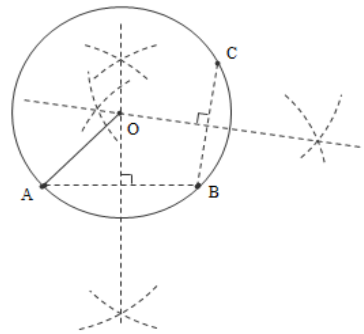
Given: 3 points A, B and C. Draw a circle passing through them.

Steps: 1) Join A and B and draw the right bisector of AB.

2) Join B and C and draw its right bisector.

3) These two right bisectors intersect at O, which is the center of the required circle.

4) With O as center and OA radius, draw the required circle.

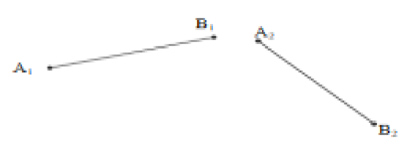


Plain Position Design Problem

A body is required to pass exactly through a number of specified positions. Here we give the example of body passing through 2 positions.

Two Position Synthesis

Design a four bar mechanism to move a body to 2 design position A_1B_1 and A_2B_2 as shown.

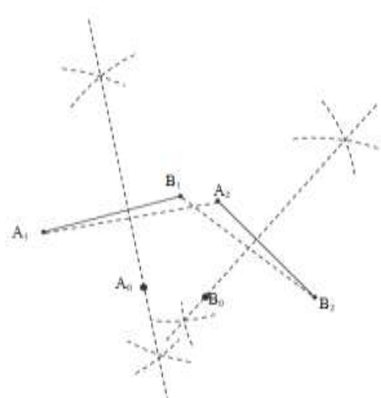


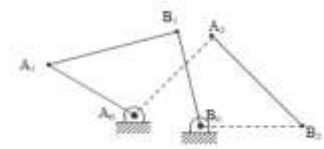
Solution Steps:

1)Draw right bisector of A_1A_2.

2) Select any point A_0 anywhere on this bisector. This is the fixed pivot of one of the cranks.

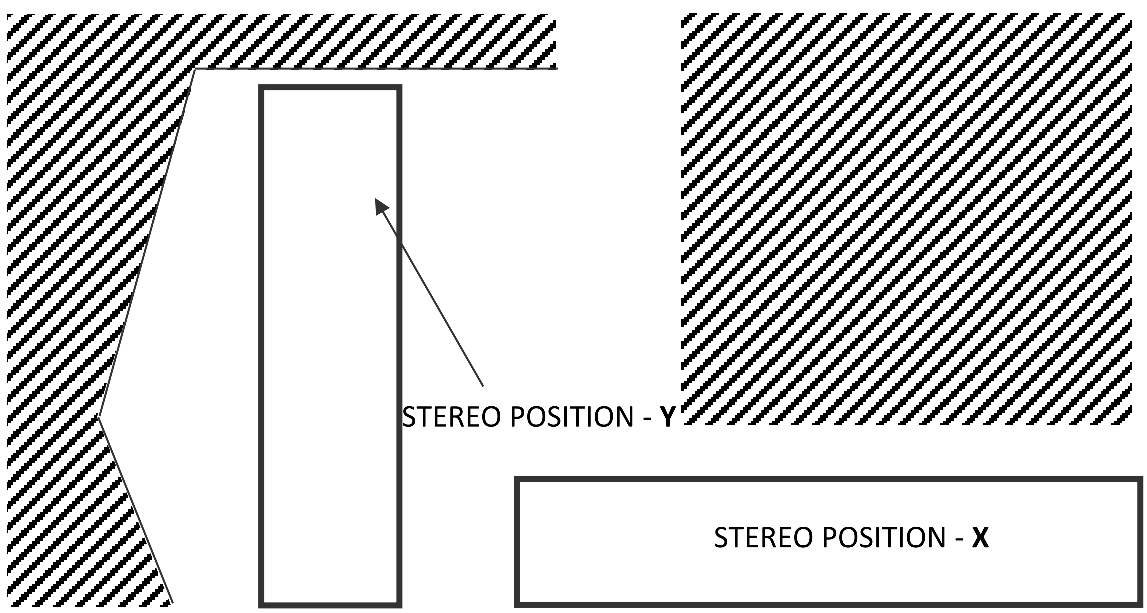
3) Draw right bisector of B_1B_2. Select any point B_0 as the second fixed pivot of the second crank.



Final Mechanism 4) $A_0A_1B_1B_0$ is the desired four bar mechanism. When the crank A_0A_1 is made to rotate to A0A2, the body moves from A_1B_1 to A_2B_2.	

Assignment: After learning the constructions, the participants are asked to solve the design problem shown below. They check their solution by making a prototype using simple card boards and clips etc.

Because of a theft problem, a stereo unit in a car is to be mounted on a mechanism, which will permit it to be swung from its operating position X to position Y out of sight behind the dash. Design a four-bar linkage to do this. The fixed pivots should be selected anywhere on the shaded material. At no time should any part of the linkage interfere with the fixed structure indicated by hatching.



Conclusions:

The workshop on Energy and Machines presented here trains grade 6-12 teachers to introduce science and engineering principles to their students through simple examples and physical models and computer based animated programs [6]. This will enlarge the future pool of qualified high-tech workers in New Jersey, including those who have been historically underrepresented (such as minorities and women). The workshop uses hands on experience to explain scientific laws related to mass, motion, work, power and energy. Principles such as Newton's Laws of Motion are explained through practical examples. The concepts of simple machines and mechanisms to solve practical design problems are presented through geometrical constructions and model building. They learn how simple machines work through physical models. Examples are given on how combination of simple machines produce complex machines such as a bicycle, pendulum clock and auto transmission. This program provides teaching materials, physical models, and tools that teachers can bring directly in to their own classrooms. By exposing students to this material, an interest is generated in these students in pursuing degrees and careers in engineering and science.

References:

[1] R. Sodhi, *Machines and Energy*, NJIT, 2002.
[2] Sodhi R. and Kimmel, H. "Introduction to Machines and Energy through Model Building for Pre-Engineering Instruction," *Proceedings of the International Conference on Engineering Education*," Florida. October 2004.
[3] https://www.britannica.com/technology/simple-machine
[4] Noelle Eckley Selin, "Renewable Energy" Encyclopædia Britannica, Inc.
[5]. Kevin Russell, Qiong Shen and Raj S Sodhi. "*Mechanism Design: Visual and Programmable Approaches*," Taylor and Francis Publishers. September, 2013.
[6] J. D. Carpinelli, L. E. Burr-Alexander, D. Hanesian, H. Kimmel Ral S. Sodhi, "The Pre-Engineering Instructional and Outreach Program at the New Jersey Institute of Technology."*Proceedings of International Conference on Engineering Education"*, Florida, October 2004.