

Ecor Review

Engineering graphics has evolved into six major areas:

- Technical Illustration,
- Descriptive Geometry,
- Engineering Computer Graphics,
- Nomography,
- Graphical Mathematics,
- Empirical Equations

■ Engineers convey information in three main ways:

- Written Documents
- Oral Presentations
- Graphically

...Sometimes a combination is needed.

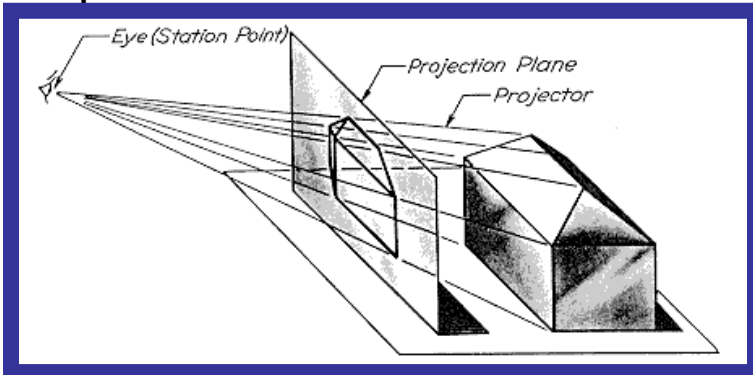
Technical Illustration:

Also called *pictorial drawings*, technical illustrations are used to describe products in catalogues, user, and maintenance manuals.

■ Three common types:

1. Perspective
2. Oblique
3. Isometric (Axonometric)

Perspective:



One-Point Perspective:

- The projection plane **is parallel to two principal axes**. Receding lines along one of the principal axis converge to a vanishing point.

Two-Point Perspective

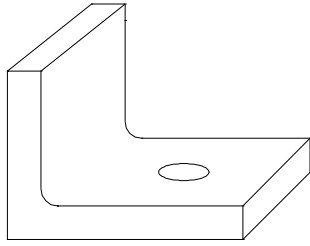
- If the projection plane is parallel to **one** of the principal axes or if the projection plane **intersects exactly two principal axes**, a two-point perspective projection occurs

Three-Point Perspective

- If the projection plane is **not parallel** to any principal axis, a three-point projection occurs with the visual rays converging to three vanishing points.

Oblique Projection

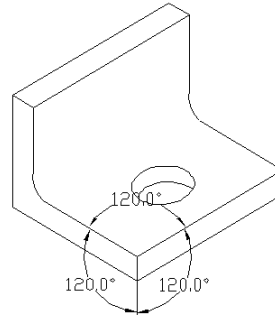
- Front face of object is parallel to the viewer, therefore that face is true size.



- Used to give an indication of depth.

Isometric Projection

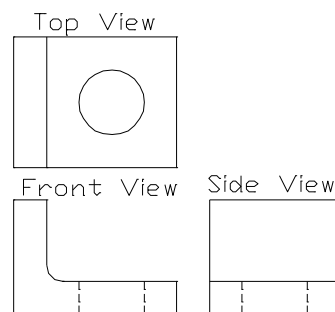
- Parallel lines remain parallel instead of converging to a vanishing point.
- Axis are **120 degrees** apart.
- Special case of *Axonometric* projection.



- Isometric projection uses **parallel projectors (orthogonal projection)**, but it shows **more than one** face of the object.
- The **x-, y- and z-axes have the same metric**.
- The projected cube is also symmetric. All sides are rhombuses (a rhombus is a parallelogram with sides that are equal in length).

Orthographic Projection

- Snapshot of the **top, front, and side view**.



Orthographic

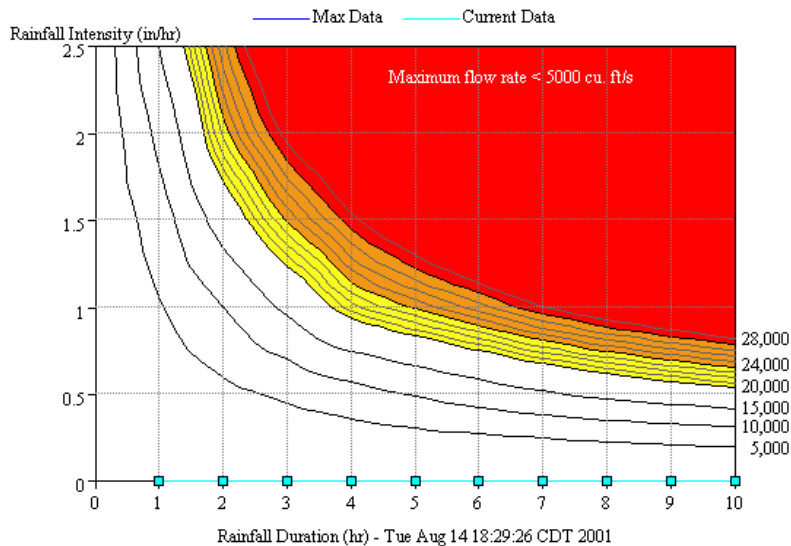
- Useful when **technical information is needed**.
- They enable parts to be made.
- Often an isometric view is included with the standard views.

Graphics

- Computer graphics with CAD and 3D Modeling.

Nomographs

- A **NOMOGRAPH**, also called an **ALIGNMENT CHART**, is a calculating chart with scales that contain values of three or more mathematical variables.



Graphical Mathematics Graphical Mathematics

- Solving algebraic equations using graphical techniques without projection.

Empirical Equations

- Modeling relations between empirical data as algebraic equations.
- Example: algebraic equation to describe how different parts of a robot heat up from ambient conditions during the course of performing a continuous cyclic task.

Line Types

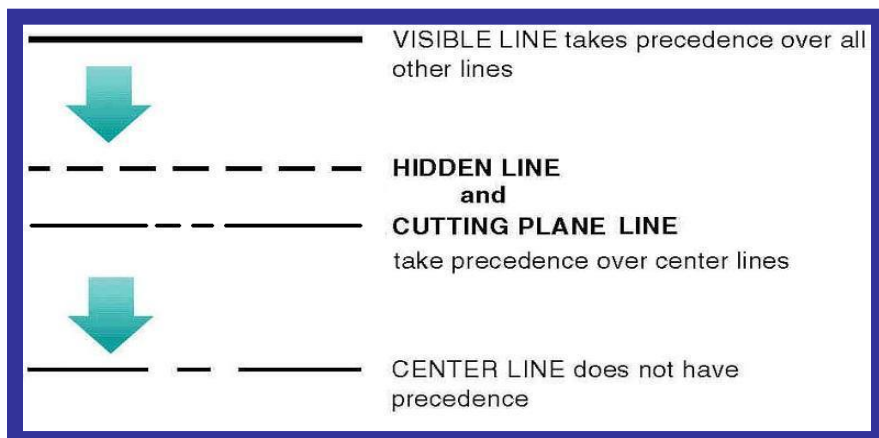
- **Object Lines**: indicate all visible edges of an object. They should stand out so the shape of an object is apparent to the eye.
- **Hidden Lines**: shows object lines that are hidden from view.
- **Cutting Plane Lines**: indicates edge view of an imaginary cutting plane.
- **Centre Lines**: indicates centres of holes and symmetrical features.

Object line →

Hidden Line →

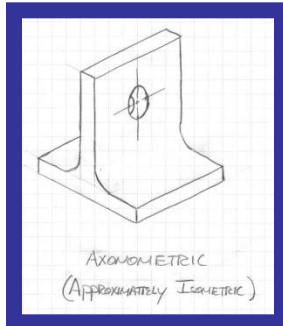
Cutting plane →

Center line →



Axonometric Sketching

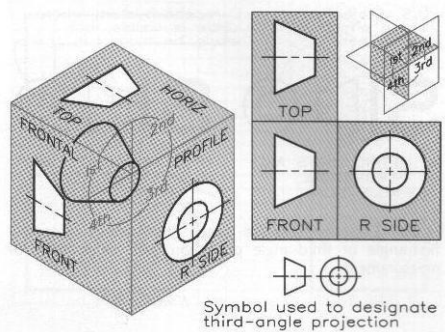
- Axonometric projection uses parallel projectors (orthogonal projection), but it shows more than one face of the object.



Third-Angle Orthographic Projection

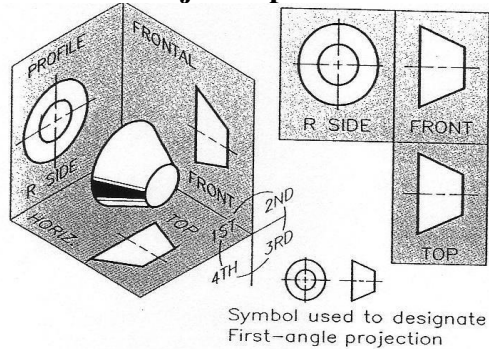
Third-Angle Projection

- The object is placed in the third quadrant and viewed from the first.



First-Angle Orthographic Projection

- The object is placed in the first quadrant and viewed from the first.



- We use third-angle projection.

Working and Detail Drawings

- **Working drawings** graphically provide *all* information required to fabricate design.
- **Detail drawings** are working drawings of a single part.
- **Assembly drawings** as the name implies, document all the parts that comprise a product, and how they are assembled (how the parts fit together).

Production Assembly Drawings

- The dimensions in an assembly drawing usually refer to the relationships among parts, not the size of the individual parts.
- The assembly drawing may be a multi-view drawing or consist of only a single profile view.
- The parts in the assembly are referenced by ballooned letters or numbers attached to leader lines.
- The letters, or numbers refer to *working* drawings, which are identified in the *bill of materials* for the assembly which is usually placed on the right side.
- The part list also provides information regarding the part material, the minimum number of each component required for one full assembly, and any other pertinent manufacturing information. The part drawing number is usually indicated. Standard "off -the-shelf" parts are also included in the part list.

Pictorial Assembly Drawings

- Used to illustrate catalogues, user manuals, etc

Dimensioning: Rule 1

1. The first dimensions should be three times the letter height from the object. Successive dimensions should be two times the letter height apart..

Design

- Good design requires:
 - **Organization**
 - **Teamwork**
 - **Communication**
- Before a problem can be solved, it must first be *identified!*
 - Problems must be identified.
 - Needs must be categorized and defined.
- Most design problems can be categorized as:
 - **Systems design.**
 - **Product design.**

Method Of Design

The design process can be summarized into 7 steps:

1. **Recognition of need**
2. **Definition of the design problem**
3. **Definition of the design criteria**
4. **The design loop**
5. **Optimization**
6. **Evaluation**
7. **Communication**

Standards Organizations

- International Standards Organization (ISO)
- American National Standards Institute (ANSI)
- Canadian Standards Association (CSA)
- Canadian Society for Mechanical Engineering (CSME)
- American Society of Mechanical Engineers (ASME)
- Institution of Mechanical Engineers (I. Mech. E.)
- Institute of Electrical and Electronics Engineers (IEEE)
- Society of Automotive Engineers (SAE)
- Society of Manufacturing Engineers (SME)

Design Reports

- There are only three means of communication:
 1. *written;*
 2. *oral;*
 3. *graphical.*

Experimental Data

- **Continuous**
 - Height of male students in this class (mm)
 - Fuel consumption of automobiles in Canada (Liters/100km)
 - Strength of steel (MPa)
 - Length of cracks in stress corrosion situations (mm)
- **Discrete**
 - Number of cars coming to campus every day
- **Binomial Discrete**
 - Proportion of the vote for a candidate (e.g. 60%)
 - Proportion of defective machine parts in a mfg operation (e.g. 5%)

Random Variations

- Height of male students (variable)
- Fuel consumption of automobiles in Canada (variable – where they live (city, country), etc.)
- Strength of steel members in a supply for a structure
- Voting on an issue: Poll is + 4%, 19 times out of 20

Source of Variability

- Inherent variability in the parameter, e.g., the height of male students in this class
- Variability in the measurement technique, e.g. fuel consumption, strength of steel
- Often these are treated together but if one wants only the inherent variability of the parameter, the measurement technique should be at least 10 times less variable.

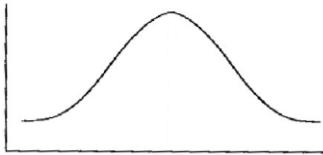
Measurement System Error

- Data Set – measurements under supposedly identical conditions
- Measurement variations (errors)
 - **Bias**
 - **Repeatability**
 - **Reproducibility**
 - **Stability (drift)**
 - **linearity**

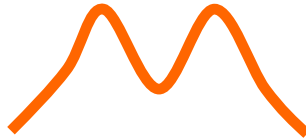
Samples

- Note that these were “samples” from a “population”.
- small samples (less than 30)
- Large samples – 30 or more

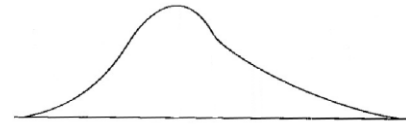
Normal Distribution



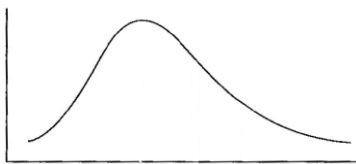
Bimodal Distribution



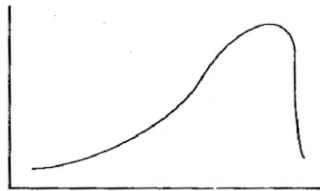
Skewed Distribution



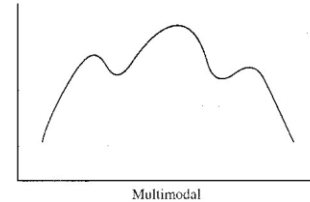
Distribution Skewed Right



Distribution Skewed Left



Multimodal Distribution



- They are histograms with bars that follow the barrier lines.

Managing Engineering Measurement Error

- To further develop our understanding of managing engineering measurements, we will study how statistics and probability relate to measurements.
- This includes a study of:
 - Mean value
 - Standard deviation
 - Confidence interval
 - Spread interval estimates (number of measurements in an interval)
 - Z and t statistics

Measures of Central Tendency (Population)

$$\mu = \frac{\sum_{i=1}^N x_i}{N} \quad (\text{arithmetic mean})$$

$$\sum_{i=1}^N x_i = x_1 + x_2 + \cdots + x_N, \quad \text{Einstein summation}$$

$$\mu = \text{mean (arithmetic average)}$$

$$N = \text{number of entries in the population}$$

Measures of Central Tendency (Samples)

$$\bar{x} = \frac{\sum_{i=1}^n x_i}{n} \quad (\text{arithmetic mean})$$

\bar{x} = mean (arithmetic average)

n = number of entries to be averaged

Measures of Dispersion (Population)

Population Variance

$$\sigma^2 = \frac{\sum (x - \mu)^2}{N}$$

Population Standard Deviation

$$\sigma = \sqrt{\frac{\sum (x - \mu)^2}{N}}$$

N = number of values in the population

x = member of the population

μ = population arithmetic mean (average)

Calculating the Sample Standard Deviation (Sample 1)

Sample Standard Deviation

$$s = \sqrt{\frac{\sum (x - \bar{x})^2}{n - 1}}$$

Concept of Probability

- No formal definition of probability
 - Best demonstrated by example
 - Flip a coin (H/T); $P(H) = 0.5$
 - Toss of die $P(3) = 1/6$
 - Toss of dice $P(3) = 2/36$

- Measurements and Probability
 - The mean strength of a steel alloy is 200MPa with a standard deviation of 20 MPa. What is the probability that an arbitrary sample of this steel will have a strength between 180-185MPa

Continuous Form of the Gaussian Distribution (Infinite Statistics)

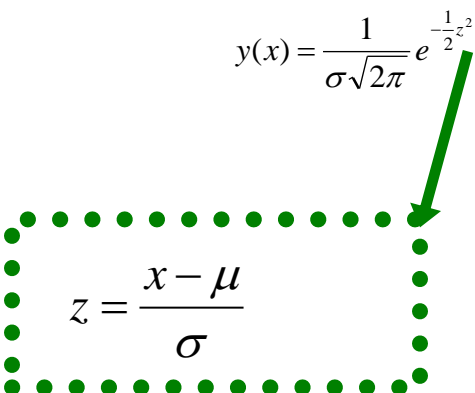
$$y(x) = \frac{1}{\sigma\sqrt{2\pi}} e^{-\frac{1}{2}\frac{x-\mu}{\sigma}^2}$$

$y(x)$ = Gaussian probability density function

x = a random variable, (e.g., crack length)

μ = arithmetic mean (mean crack length)

σ = standard deviation


$$z = \frac{x - \mu}{\sigma}$$

Property to Note

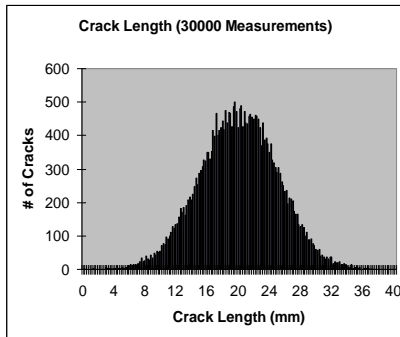
Total area under curve is **1**.

The number of cracks in a normal sample corresponding to a certain range (e.g., x_L to x_H which corresponds with z_L to z_H) is proportional to the area under the Gaussian curve in that range.

In principle the probability density function can be integrated mathematically to find the area.

Determining the Z-statistic

1) Determine z values given $x_L = 13$ mm and $x_H = 17$ mm



Mean	19.994
StDev	5.011

$$z = \frac{x - \bar{x}}{s}$$

Need an upper and lower limit:

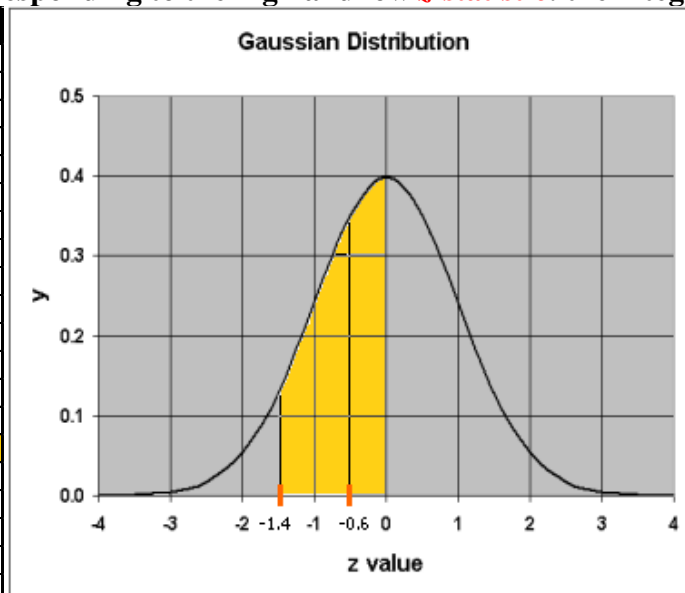
$$z_L = \frac{x_L - \bar{x}}{s} = \frac{13.0 - 20.0}{5.01} = -1.40$$

$$z_H = \frac{x_H - \bar{x}}{s} = \frac{17.0 - 20.0}{5.01} = -0.599 \approx -0.6$$

Obtaining the area from z

2) Find the **area** corresponding to the high and low z -statistic: the integration limits

z value	Area
0	0
0.1	0.04
0.2	0.079
0.3	0.118
0.4	0.155
0.5	0.192
0.6	0.23
0.7	0.26
0.8	0.29
0.9	0.32
1	0.34
1.1	0.36
1.2	0.38
1.3	0.4
1.4	0.42
1.5	0.43
1.6	0.44
1.7	0.45
1.8	0.46
1.9	0.47
2	0.48



$$z_L = -1.4 \quad z_H = -0.6$$

3) Calculate the probability that the crack length will be $13 < x < 17$ mm.

Graphically, the probability $P(-1.4 < z < -0.6)$ can be represented as:

$$\text{Area} = 0.42 - \text{Area} = 0.23$$

Probability $P(-1.4 < z < -0.6)$

$$= 0.42 - 0.23 = 0.19$$

$$\# \text{ of cracks} = (30000)(0.19) = 5700$$

Probability that the next crack will be in this range is

$$5700/30000 = 0.19 \text{ (19\%)}$$

Spread Limits Containing 90% of the Measurements

What is the **interval** that contains **90%** of the cracks?

$$x_c = \bar{x} \pm z_c s$$

$$x_{90} = 19.99 \pm (1.65)(5.011)$$

$$x_{90} = 19.99 \pm 8.27$$

Spread Limits	z_c Value
90%	1.645
95%	1.96
99%	2.58

The crack lengths are predicted to fall within the range 11.7 to 28.3 mm, 90% of the time.

The Standard Error

- The *standard deviation of the means* (called the *standard error*) is used to describe the variation in the distribution of the sample means about the true mean, and is defined as:

$$S_{\bar{x}} = \frac{s}{\sqrt{n}} \quad \text{"s" is the standard deviation for the sample}$$

An estimate of the population mean can be expressed as:

$$\mu = \bar{x} \pm z_c \frac{s}{\sqrt{n}}$$

Student t-Distribution

- The interval $\pm t_{v,P} s$ represents the **spread limit**.
- The value of the t-estimator is a function of the degrees of freedom ν , and the spread limits required.
- The degree of freedom, ν , of a data set is the number of independent measurements that are available to estimate a statistical quantity.

$$\nu = n - 1$$

Finding the Population Mean

- The population mean can be calculated in small samples using the **standard error**.

$$S_{\bar{x}} = \frac{s}{\sqrt{n}}$$

- You only need to substitute the **t-statistic** for the **z-statistic**:

$$\mu = \bar{x} \pm t_{v,P} \frac{s}{\sqrt{n}}$$

What is Regression?

- Regression is a process by which a mathematical model is applied to a set of data in order to make predictions about future values that follow a similar trend.
- Regression can be used to analyze the relationship (if any) found in a set of data.
- **Correlation is a measure of the strength of a relationship. How well does a line of best fit reflect the trend in the data?**
- We will apply these concepts to Linear Regression first

Linear Trendlines

Apply a linear line of best fit (**trendline**) of the form: $\hat{y} = mx + b$

\hat{y} → The dependent variable trendline values
→ The mileage

x → The independent trendline values
→ The vehicle weight

m → The slope of the trendline

b → The y-intercept of the trendline

Linear Regression

- The objective of a trendline is to **minimize the errors**.
- This error, or residual, is the difference between the data point y-value and the regression line y-value at each x value.

$$e = y - \hat{y}$$

Minimizing the Sum of Squares

The objective is to **minimize each of the residual errors** $e = y - \hat{y}$

This is accomplished by minimizing the sum of the squares of the error (**SSE**):

$$SSE = \sum_{i=1}^N e_i^2 = \sum_{i=1}^N (y_i - \hat{y}_i)^2$$

Line of Best Fit

$$\hat{y} = mx + b$$

Where:

$$m = \frac{N(\sum_{i=1}^N x_i y_i) - (\sum_{i=1}^N x_i)(\sum_{i=1}^N y_i)}{N(\sum_{i=1}^N x_i^2) - (\sum_{i=1}^N x_i)^2}$$

N = number of data values x and y are the measured data values

\bar{x} and \bar{y} **coefficient**: are the means of measured data

Significance of Linear Correlation

- **If r is near 1 and positive:**
 - Positive slope.
 - Both variables have a high degree of linear covariance in the same direction.

- **If r is near -1 and negative:**
 - Negative slope.
 - Both variables have a high degree of linear covariance in opposite directions.

- **If $r = 0$**
 - There is little to no linear relationship between x and y .
 - The regression of y on x is orthogonal to that of x on y (i.e., $m = 0$).

Calculating the Linear Correlation Coefficient

$$r = \frac{\sum (x - \bar{x})(y - \bar{y})}{(N-1)s_x s_y} \quad \text{where } r = \text{correlation}$$

y = dependent variable (city mileage)

N = number of data points

s = sample standard deviation

Problems with r

- The correlation coefficient is very limited in quantitative applications.
- It can often imply the existence of more covariation than actually exists.
- The correlation coefficient does not necessarily indicate the closeness of the data points to the trend line.
- A *Coefficient of Determination* (r^2) is therefore used when results require interpretation.

$$\text{TSS} = \text{SSR} + \text{SSE}$$

Linear Systems

- Provides methods for structured data representation, management, and analysis
- Provides clear, logical, algebraic methods for solving related engineering problems

$Ax=b$

- For the linear system, A may be thought of as the $m \times n$ coefficient matrix for a particular system of linear equations.
- m is always the number of **rows**.
- n is always the number of **columns**.
- The typical engineering application is given A and b , determine x that satisfies the linear system (**the solution**).

Systems of Linear Equations

- Applications: Matrix Equations

- Current flow in simple **resistor networks** (electrical engineering): determine i .

$$Ri = v$$

- Displacement in **spring systems** (mechanical engineering) : determine x .

$$Kx = f$$

Matlab

Assigning Variables

- Define variables by typing a variable name, followed by the equals sign and then a value of a mathematical expression:

```
Number1 = 412;
```

```
% the value 412 is assigned to the variable Number1
```

```
Number_1 = -18;
```

```
% Note that Number1 and Number_1 are different variables
```

```
Number 2 = 15;
```

```
%invalid -> variable names cannot have spaces
```

```
blahblahblah1234 = [1 2 3;4 5 6;7 8 9];
```

```
% Assigns a matrix to a variable name
```

```
AVector = [-1;0;1;0;-1;0];
```

```
2Vector = [34;52];
```

```
% invalid -> variable names must begin with a letter
```

Scalar Operations

Operation	Algebraic Form	MATLAB Form
Addition	$a + b$	$a + b$
Subtraction	$a - b$	$a - b$
Multiplication	$a \times b$	$a * b$
Division	$\frac{a}{b}$	a / b
Exponentiation	a^b	$a ^ b$

Euclidean Norm of a Vector

$$\|v\| = \sqrt{v_1^2 + v_2^2 + v_3^2 + \dots + v_n^2}$$

Dot Product

- Also called the **Inner Product**
- The dot product of two vectors will produce a scalar.
- The vectors must have the same number of elements
- **Dot Product** = $u \cdot v$

Ex. $S \cdot m = s_1m_1 + s_2m_2 + s_3m_3 =$

Orthogonal Projection

$$\frac{u \cdot v}{\|v\|} = \frac{\|u\| \|v\| \cos(\theta)}{\|v\|} = \|u\| \cos(\theta)$$

Matrix Operators in MATLAB

Operation	Algebraic	MATLAB
Addition	+	+
Subtraction	-	-
Multiplication	*	*
Left-Division	Undefined: used to solve systems of equations	\
Transpose	ST	S'

Script m-files

- **Sequence of MATLAB commands**
- Equivalent to typing a series of commands in the command window, except that scripts can be run at any time
- Cannot accept input
- All constants/values that need to be used should be defined at the beginning of the script file
- Values cannot be passed between script files.

Function M-Files

- **Sub-program**
- Can accept input and return outputs
- Creating a file that works just like a pre-defined MATLAB function ($\sin(x)$, $\text{mean}(x)$), where the input x is required
- Can extend the MATLAB language
- Can access functions from within other scripts and functions

Solutions to Linear Systems

- Finding the solution(s) of m equations linear in n unknowns boils down to the following three classes:
 1. Underdetermined: $m < n$. If a **finite solution** exists, it is **not unique**. In fact, if one exists, then an infinite number exists.
 1. Overdetermined: $m > n$. A **finite solution(s) may exist**, but not in general.
 1. Determined system: $m = n$. A **unique solution may exist**, although it **may not be finite**. Additionally there may be infinitely **many**, or **no finite solutions**.
- In 3D Euclidean space, every system of linear equations has either:
 1. **No solution** (the system is **inconsistent**), or
 2. **Exactly one solution** (the system is **consistent**), or
 3. **Infinitely many solutions** (the system is **inconsistent**).
- For now we shall concentrate on determined systems: 3 equations linear in 3 unknowns.
- **Geometrically**, 1 linear equation in 3 unknowns (x,y,z) represents a **plane** in the **space** of the **unknowns**.
- If we **extend 3D Euclidean space** to include all points at infinity, we obtain **3D Projective space** and things change.
 - Now every parallel line intersects in a **point** on a **line at infinity**.
 - Every parallel plane intersects in a **line** on the **plane at infinity**.
- In this sense, there are **5 possibilities** for a system of **3 equations** linear in **3 unknowns**.
 - **Unique finite solution.**
 - **Infinite finite solutions.**
 - **Double infinity of finite solutions.**
 - **Unique solution at Infinity.**
 - **Infinite solutions at infinity (occurs in two ways).**

Maple

What can Maple do for you?

- 2D Plotting
- Extensive 3D plotting
- Symbolic and numerical computations
- Differential and integral calculus
- Matrix manipulation
- Statistics and data management
- Algebraic geometry
- Differential geometry...

; vs :

- In Maple, the colon (:) suppresses **output**, while the semi-colon (;) displays the **result** of the command
- All commands must be terminated by a **semi-colon or a colon**, or Maple will produce the following message:
Warning, premature end of input

Mathematical Operations

- Maple uses **radians** and not degrees.

Description	Maple Name
Absolute value, $ -2 $	abs(-2)
Square root,	sqrt(2)
Exponential function,	exp(x)
Natural logarithm,	ln(x), or log(x)
Base 10 logarithm,	log[10](x)
Trigonometric functions	sin(x), cos(x), tan(x), csc(x), sec(x), cot(x)
Inverse trigonometric functions	arcsin(x), arccos(x), arctan(x), arccsc(x), arcsec(x), arccot(x)

- Maple treats *spelled-out* Greek letters as Greek letters.
- **pi** represents the greek letter π .
- **Pi** represents **3.14159...** need capital P for π to be evaluated.
- We can let **theta** represent an **arbitrary angle**.

The Assignment Operator :=

- To assign equations and values to variables in Maple, use the **:=** operator
- The variable on the left-hand side of the := operator is assigned the result on the right-hand side of the := sign
- = and := are not the same. In Maple, = is just a symbolic operator.
- Cannot perform recursive operations \diamond Number := Number + 1

%

- In Maple, the % operator refers to the **previous result**.
- % allows you to use the result from the previous command in the current calculation/command.
- % can represent **numbers** as well as **expressions and equations**

Ministry of Labour

- Enforces OHSA.
- Audits workplaces for compliance.
- Investigates accidents.
- May prosecute defined parties for contravention.

The Occupational Health and Safety Act (OHSA)

- Enforced by the Provincial Ministry of Labour.
- Intended for the protection of workers against health and safety hazards on the job.
- Each province has its own act but the general idea is the same for all.
- Almost every workplace in Canada is covered by the Act and regulations.
- Sets out the framework for making Ontario's workplaces healthy and safe.
- Defines the rights and duties of all parties in the workplace.
- Establishes procedures for dealing with workplace hazards.
- Provides for enforcement of the law and penalties where compliance has not been achieved voluntarily.

- The Occupational Health and Safety Act is modified and changed from time to time.

The Engineer's Work

- Engineers work in various fields:
 - **Design**
 - **Manufacturing**
 - **Quality Control**
 - **Management & Supervision**
 - **Consulting**
 - **Troubleshooting**, etc.
- The same rules and liabilities apply in all cases.
- Professional engineers have obligations to their clients/employers, the workers under them and to the public.

Workplace Responsibilities

- Engineers responsible under OHSA as:
 - **Worker**
 - **Supervisor**
 - **Employer**
 - **Engineer**
- Responsible for implementing, enforcing OHSA.

Internal Responsibility System (IRS)

- The concept of the *Internal Responsibility System* is based on *Workplace Partnership*.
- Workers and employers must share the responsibility for occupational health and safety.
- The workplace parties themselves are in the best position to identify health and safety problems and to develop solutions.
- Involves everyone, from the company chief executive officer to the janitors.
- Several provisions of the Act are aimed at fostering the internal responsibility system.
- The joint health and safety committee, or, in smaller workplaces, the health and safety representative monitors the internal responsibility system.

Joint Health and Safety Committee

- An advisory group of worker and management representatives.
- Any organization with more than **20 members**.
- Joint – workers, management.
 - **At least half the members on the committee must represent workers.**
- Certified members – received special training.
- Employer is responsible for establishing a committee.

- Maintain the workplace partnership to improve health and safety.
- Discuss health and safety concerns.
- Identify workplace hazards.
- Obtain information from the employers about health and safety concerns.

- Investigate work refusals and serious injuries.
- Obtain information from the Workplace Safety and Insurance Board.
- Make recommendations to the employers and to the workers on ways to improve workplace health and safety.

Employer's Duty to Co-operate with the Committee

- Provide any information that the committee demands.
- Respond to committee recommendations.
- Give the committee copies of all orders and reports issued by the Ministry of Labour inspector.
- Report any workplace deaths, injuries and illnesses to the committee.

Response to Recommendations

- The employer must respond to any written recommendations from the committee, in writing, **within 21 days**.
- The response must include a timetable for implementation if the employer agrees with the recommendations.
- The response must give the reasons for disagreement if the employer disagrees with a recommendation.

Health and Safety Representative

- Required at a project or workplace where a joint health and safety committee is not needed and where the number of workers **regularly exceeds five**.
- The employer or constructor is responsible for making the workers select a representative.
- The representative has to be a member of the workers' team who does not perform managerial functions.

Site Inspections

- A health and safety representative will inspect the physical condition of the workplace **at least once a month**.
- If it is not practical to inspect the workplace at least once a month, the health and safety representative will inspect the physical condition of the workplace at **least once a year**, inspecting at least a part of the workplace in each month.
- Where a person is killed or critically injured at a workplace from any cause, the health and safety representative will inspect the place where the accident occurred and any machine or device involved.

- The employer and workers must provide a health and safety representative with required information and assistance during the inspection.
- A health and safety representative has power to identify situations that may be a source of danger or hazard to workers.
- Based on the inspection a health and safety representative can make recommendations or report the findings to the employer and the workers.

Duties of Workers

- Work in compliance with **OHS Act** and regulations.
- Use protective equipment, devices or clothing that is required by the employer.
- Report defects in equipment.
- Report contraventions and hazards.

- Not bypass any safety device.
- Not to operate equipment that may endanger the safety of any worker.
- Not remove or make ineffective any protective device required by the employer or by the regulations.

Rights of Workers

- To balance the employer's general right to direct the work force and control the processes in the workplace, the Act gives **four basic rights to workers** :
 - **Right to Participate**
 - **Right to Know**
 - **Right to Refuse to Work**
 - **Right to Stop Work**

Right to Participate

- The right to be part of the process of identifying and resolving workplace health and safety concerns.
- Expressed through worker membership in joint health and safety committees.
- Practiced through exercising their rights and duties in a responsible manner.

Right to Know

- The right to know about any potential dangers to which the workers may be exposed.
- The right to be trained and to have information on machinery, equipment and hazardous substances.
- The implementation of the **Workplace Hazardous Materials Information Systems (WHMIS)** play an important role in giving workers the right to know.

Workplace Hazardous Materials Information Systems (WHMIS)

Right to Refuse to Work

- Workers have right to refuse any work where unreasonable safety risks are apparent.
 - **There are exceptions:** police officers for example.
- Must report refusal to employer/supervisor.
- Refusal must be investigated.
- Worker must remain at workstation if safe to do so.

Right to Stop Work

- In certain circumstances, certified members of a joint health and safety committee have the right to stop work that is dangerous to any worker.

Duties of the Supervisor

- Ensure workers follow safe procedures.
- Ensure workers wear appropriate safety clothing or devices.
- Must advise workers of hazardous situations.
- Must take every reasonable precaution to ensure worker safety.

Duties of Employer

- Supply protective equipment, devices and clothing.
- Maintain protective equipment.
- Ensure OHSA provisions followed.
- Ensure workplace structurally sound.
- Develop and implement a health and safety program and policy.
- Post a copy of OHSA in the workplace.

- Provide health and safety reports to the JHSC.
- Provide training for supervisors.
- Provide the means for training of workers.
- Appoint competent supervisors.
- Must take every reasonable precaution to ensure safe workplace.

Duties of the Engineer

- Ensure safety of public.
- Report or correct any hazardous situation.
- Maintain competence.
- Not perform work outside field of expertise (gained by training and experience).
- Apply applicable national and international codes and standards.

WHMIS

- The **Workplace Hazardous Materials Information System (WHMIS)** - **Canada's hazard communication standard.**
- Implemented through coordinated federal, provincial and territorial legislation.
- Balances workers' right-to-know with industry's right to protect confidential business information.

- The key elements of the system are:
 - Cautionary labelling of containers of WHMIS "controlled products"
 - The provision of **material safety data sheets (MSDSs)**
 - Worker education programs

Penalties

- Individuals
 - Up to **\$25K** or imprisoned for one year per offence
- Corporations
 - **\$500K** per offence
- Penalties imposed by professional bodies

Note:

OHSA penalties refer to the *person*, (i.e. engineer) and not to the employer of the engineer. The engineer is *personally liable* under the requirements of the **OHSA**.

Engineer may also be subject to **civil litigation**.

Definition of Profession

- What does *Professional Engineer* mean?
- In the debates leading to the passage of the Professional Engineers Act by the Ontario Legislature in 1969 it was defined to be:
 - A self-selected, self-disciplined group of individuals who hold themselves out to the public as possessing a special skill derived from training and education and are prepared to exercise that skill in the interests of others.

Professionalism

- Recognizable body of knowledge
- Exclusive right to practice in an area
- Medicine – best example
- Others
 - Dentists
 - Lawyers
 - Accountants
 - Engineers

Engineering Body of Knowledge

Unifying theme – public safety

- **Bridge**
- **Design an aircraft, automobile**
- **Software to shut down a nuclear reactor**
- **Electrical/Electronics – control systems**
- **Environmental Engineering**

General Engineering

- Professional Engineering vs. General Engineering
- Some engineering work does not involve public safety
 - Microsoft Word
 - Microsoft Excel ??????
 - Telephone system ???
- Sometimes you will be working under the supervision of a Professional Engineer

Legislative mandate

- Provincial (Can) or state (USA)
 - Professional Engineers Act
- Definition of Professional Engineering under the Act:
 - any act of designing, composing, evaluating, advising, reporting, directing or supervising; wherein the safeguarding of life, health, property or the public welfare is concerned, and that requires the application of engineering principles, but does not include practising as a natural scientist.

Responsibilities and Accountability

- Exclusive right to practice
- In return society expects:
 - **Responsibility**
 - **Accountability**
 - **Can't make unreasonable errors or omissions that involve public safety**
 - **Liability and Liability Insurance**

Professional Organizations

- All recognized professional bodies organize themselves into self-governing professional societies or associations.
- Major function is to define the duties and responsibilities of their members.

Self-Governing and Disciplined

- E.g., College of Physicians and Surgeons
- Professional Engineers of Ontario
 - **Code of Ethics**
 - **Guidelines for Practice**
 - **Discipline Procedure**

Professional Engineers of Ontario

- Licensing and enforcement body
- Enforces Professional Engineers Act
- Enforces standards of competence
- Enforces use of the title "Professional Engineer"
- Responsible for safety of public
- Has NO function for protection of engineers

Code of Ethics

- Part of Regulation 941 of the Professional Engineers Act.
- Adherence is required for all professional engineers.
- Primarily addresses their duties and responsibilities at work.

Defines the engineer's responsibilities to:

- **The society and the environment,**
- **The employer or the client,**
- **Fellow engineers**

- Other engineering obligations arise from:
 - **Technical standards and protocols**
 - **Business and corporate practice**
 - **International treaties** (in some cases)

Tenets of the Code of Ethics (APPEGA-PEO)

- Health and welfare of the public.
- Practitioners are to do work only within their competence.
- Practitioners are to conduct themselves with honesty, integrity, fairness and objectivity.
- Comply with applicable codes, statutes, regulations, etc..
- Uphold and enhance the honor, dignity of the profession.

Requirements for Registration

- be at least **18 years** old;
- be a citizen or permanent resident of Canada;
- be of good character;
- meet education standards established by PEO;
- pass the professional practice exam (**PPE**) on **engineering law and ethics**; and
- meet engineering experience requirements: **4 years**

Acceptable Experience

Based on **five** quality-based criteria:

- 1) **Application of Theory**
- 2) **Practical Experience**
- 3) **Management of Engineering**
- 4) **Communication Skills**
- 5) **Social Implications of Engineering**

Pre-graduation Experience

- B.Eng. counts for up to **12 months** experience
- Summer and co-op work experience only counts after **50%** of course work completed

Postgraduate Experience Credit (PEO)

- Graduate degrees count for up to **12 months** experience credit
- Thesis can count if:
 - Applied engineering in nature
 - External funding or use
- Total time credit cannot exceed time required for degree and thesis

!!!PEO Academic Requirements!!!

- Mathematics: linear algebra, differential and integral calculus, differential equations, probability and statistics, and numerical analysis
- Basic Sciences
- Engineering sciences
- Engineering design
- ES plus ED
- Complementary studies
- Complementary studies must include engineering economics
- Environment and sustainable development
- Health and safety
- Ethics and professional practice

Why Conform to PEO?

- If you want to become a professional engineer, then one of the principal requirements is that you graduate from an accredited program
- After graduation you complete your experience requirement of **48 months** as an *Engineer in Training (EIT)*
- You must also write the **PPE**.

Non-Engineers

- Practicing **without a license** – PEO goes to public court.
- If found guilty - **\$10K fine - \$50K for repeat offenders**.

Certificate of Authorization

- Anywhere a firm or individual offers professional engineering services to the public
- **Individual**
 - Must be licensed professional engineer
 - Must have five years of licensed practice
 - Must demonstrate competency in CofA area
 - Must be Insured
- **Firm**
 - Designates an individual P.Eng.

PEO Act

- **Public Safety** is central to **PEO Act and practice**.
- Two sides to this issue:
 - Regulated behavior of Engineers as employers, employees
 - Engineers are often asked to act as a consultant on matters of safety and to report

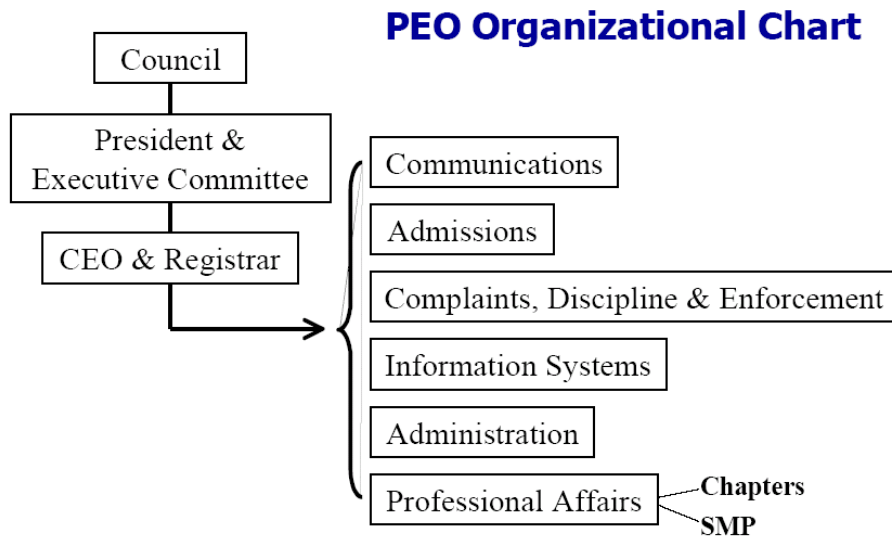
Types of Certification

Report stating:

- Equipment etc. not likely to endanger a worker.
- Load limits of a floor, temporary work etc.
- Floor etc. capable of supporting or withstanding applied loads.
- Allowable stresses do not exceed material limits with appropriate safety factor.

What type of work can pose a risk to the engineer?

- Design work
- Producing reports
- Certifying equipment
- Certifying structures
- Performing Pre-Start Health and Safety Reviews



Student Membership Program (SMP)

Objectives:

- Raise your level of professional knowledge
- Promote better communication between students and the engineering community
- Standardize the delivery of PEO's programs and activities to students
- Provide a seamless transition from student to P.Eng.

TSE Section

Population Growth Is Not Uniform

- >95% of global population growth is occurring in developing countries
- Population growth in many industrialized countries is declining
- Urban areas are growing fastest
- Increased and differing demands on environmental services
- Age structure is changing - more children, more elderly people

Economic Growth Has Been Uneven

- Rich countries economies > 2.2% per annum over the last 20 years
- Poor countries best growth was in 60s-70s (3.3%)
- However, dynamics are changing
 - In 2004, China grew 9%, India 6.4%, Africa 4.5%, Middle East 5.1%
- International Trade expanding rapidly, 20% GWP
- Distribution uneven – rich get richer, poor get poorer, 2 billion live off less than 2\$/day
- World economy exceeds ecological capacity by 20%

Economic Indicators

Agriculture

- Grain harvest exceeds 2 billion tons
 - Yields exceeded 3t/ha, 3 times the level in 1960
- Provides half of worlds calories but 1 billion still go hungry
- World meat production > 250M tons, > 40kg/per person
 - By 2020 consumption will be 73kg/capita in China and 90kg/capita in industrialized nations
- World fish production 133M tons, 93M wild, and 40M aquaculture.
 - Over 70% wild stocks in decline or depleted.

Social Trends

- Selected Millennium Development Goals for 2015
 - Halve the number living in extreme poverty and hunger
 - Universal Primary Education
 - Reduce child mortality by two thirds
 - Combat disease by halving share without access to safe drinking water and sanitation
 - Ensure environment sustainability
- Donor countries provided \$68 billion in 2003
- 0.7% of GDP would provide \$200 billion

Technology Trends

- General purpose technologies – biotech, nanotech,..
- New old – wind and solar energy
- Efficiency, conservation, and conversion
- Biomimicry – blue butterfly wings, abalone
- Connected and distributed systems
- Move towards service orientation

Ecosystem Services

- **3 Categories**
 - **Provisioning**
 - **Regulating**
 - **Cultural**

Provisioning Services

- **Food**
- **Water**
- **Fiber**
- **Genetic diversity**
- **Biochemicals**

Example: Water

- **Forests and mountain ecosystems provide water for 4 billion people**
- **Water supply unchanged but demand has doubled between 1960 and 2000**
- **5-25% of water use exceeds accessible supplies**
- **15-35% of irrigation is unsustainable**
- **Solutions**
 - **Demand-side management**
 - **Technology**

Regulating Services

- **Air quality**
- **Climate**
- **Erosion**
- **Water purification and waste treatment**
- **Disease**
- **Pests**
- **Natural hazards**

Example: Natural Hazard Regulation

- **People live in vulnerable areas – coastal areas and floodplains**
- **Cost and impact increasing**
 - **600,000 fatalities, \$1.3 Trillion since 1980 from weather alone**
- **Ecosystems degradation**
 - **wetlands, mangroves, mountain forests**
 - **reduces natural systems and protection**
- **Wildfires increase and vector range expands as climate changes**

Cultural Services

- **Spiritual and religious**
- **Aesthetic**
- **Recreation**
- **Ecotourism**

Example: Ecotourism

- Non-consumptive use
- Accounts for >20% international travel
- Environmental offsets for facilities and travel
- Fragile environments have limited capacity and low resiliency

Supporting Services

- Soil formation
- Primary production
- Water cycling
- Photosynthesis
- Nutrient cycling
- Carbon cycling

Example: Nitrogen Nutrient Cycle

- Humanity doubled reactive N on the land
- Food production increased but freshwater and coastal ecosystem services reduced
- Less wetlands/ estuaries reduces nutrient reservoirs

Human Well-being

- Security
- Basic material for good life
- Health
- Good social relations
- Freedom of choice and action

Takeaways

- **Humans depend on nature for survival and well-being**
- **Unprecedented change, including an increase in both human well-being and environmental degradation**
- **If we continue to draw down ecological services at the current rate, the level of human well-being will inevitably decline**

Nature of Environmental Issues

- Environmental issues can be local, regional, and global
- Impacts affect different groups differently
 - Poor
 - Contribute least to global warming and are the greatest affected by it
 - Less able to adapt and cope with the effects
 - Women
 - Often bare burden of having to go farther to access resources (food and firewood)
 - Raise families alone when men leave to find work
 -

Approaches to Dealing with Environmental Issues

- React and Cure
- Prevention
- Sustainable Development

React and Cure

1. Establish scientific proof of environmental degradation, its significance and its causes
 2. Measures to fix problem
 3. Fundamental questions that halt progress on remediation:
 - Who pays? Who benefits? Who supports?
 4. Track performance and report to the public
- Many interested parties with different agendas
 - Industry, municipalities, NGO's, government
 - Governments are accountable for ecological services as public goods
 - Problems with this approach
 - Long and demanding, frequently contested claims, expensive (i.e. climate change)

Prevention

- Applied when hazardous effects are known and preparations can be made to mitigate them in advance
- Precautionary Principle - prevention before scientific evidence of damage
 - Clean-up produces few winners
- Some sectors have a comprehensive preventative approach
 - Environmental Management Systems

The Process

1. Science
2. Agree on measures to solve problems
3. Implementation
4. Monitor performance and report to public

Sustainable Development (an Opportunities Agenda)

- Dealing with environmental issues can viewed as a way to create new markets and promote progress
- Agenda created through
 - Possibility for economic growth
 - New technologies
 - Increasing population
 - Need for greater equity
 - Approaching ecological limits
 - Surprises

Sustainable Development cont'd

- Led by
 - Individuals, companies, sectors
- Easy Part
 - Efficiency
 - Raw materials, energy, waste
 - Lower liabilities
- Tough Part
 - Choosing your future
 - Transition from product to service-based society
 - Staying the course

Local Issues

- Urban air quality
- Garbage
- Oil spills
- Sanitation
- Pesticides
- Mines

Regional Issues

- Transboundary water (Great lakes)
- Acid rain
- Polar degradation
- Forestry
- GMO

Global Issues

- Climate change
 - Arctic
 - Islands and coastlines
- Water
 - Fisheries
 - Transboundary water
- Ozone depleting substances
- Biodiversity

Issues on the Current Agenda

- Climate change
- Arctic
- Air quality
- Biodiversity and genetic modification
- Extraction of natural resources

Who Are The Players and What do They Do?

- **Government - Federal/prov/ter/mun/aboriginal**
 - Spend, tax and regulation
 - Leadership
- **Business/Industry**
 - Meet standards
 - Innovate
- **Universities and Colleges**
 - Research, new technologies
 - Produce Highly Qualified personnel
- **NGOs**
 - Leadership, advocacy and accountability
 - Challenge function
- **Labour**
 - Workers interests and safety
- **Religious organizations**
 - Voice for their constituencies
- **Individuals**
 - Act
 - Provide or deny political support

How Much Does it Cost?

- **Cost of Action: conventional wisdom**
 - 1-3% investments in new facilities
 - Hugely variable for existing facilities
 - Stern estimates 1% Global GDP for CC
- **Cost of Inaction**
 - Decreased long-term economic viability
 - Decreased health and well-being
 - Increased inequity
 - Higher cost to clean up than to prevent
 - Stern estimates 5-20% Global GDP

Takeaways

- **Issues have moved from obvious local problems to complex global enduring ones**
- **Three approaches operating simultaneously - react, prevent and sustainable development**
- **Science and technology important**
- **Government role key**
- **Casting as an 'opportunity' not as a 'worthy problem'**

Green House Gases (GHGs)

- Methane
- Nitrous oxide
- Sulphur hexafluoride
- Hydrofluorocarbons
- Perfluorocarbons

Up to 20,000 times more potent than CO₂

Come from diverse sources: from wetlands and cow burps to transportation and industry

Primary Sources of GHGs

- Burning fossil fuels
 - Industry
 - Transportation
- Refrigeration systems
- Deforestation
- Agriculture and livestock

The problem is not just about increasing sources, but also the reduction of 'sinks'

Not Just Warming

- Some places will experience cooling
- Changes in water distribution
- Melting glaciers and rising sea level
- Change in disease vector distribution
- Increase in variability and intensity of natural disasters (floods, hurricanes, etc)

Impacts of Climate Change

- Impacts are felt on many different scales
 - Local – urban heat
 - Regional – Arctic
 - National
 - Global
- Affect different groups differently
 - Arctic
 - Islands
 - Coastal areas
 - Poor

Impacts in Other Countries Have Implications for Canada

- Environmental refugees
 - 3 billion more in water stressed regions
 - 200 million more displaced by sea level rise
 - 80 million more malnourished
- Offshore disasters
 - Financial assistance
 - Peace making/keeping
- International conflict over dwindling natural resources
 - Darfur

Reminder from Short History of Environment Issues

- Science
 - Agree on measures to solve problems
 - Implementation
 - Monitor performance and report to public

State of Play of Climate Change

- Science is clear – serious problem that needs to be dealt with immediately
- Must be dealt with at global level
- Emission reductions can take place anywhere in world
- Global Convention 1992
- Kyoto Protocol 1997
- Protocol ratified in 2002, in effect 2003

So What is Needed?

- New sources of energy
- New technologies
- New ways of doing business
- Responsible extraction and use of resources
- New social/community values
- Regulations, taxes, trade in emissions
- Incentives, rewards, recognition
- Leadership

What Has Happened Since Kyoto?

- Main elements of program in place but very slow implementation
- Conservative government backed out but now is legally obligated to follow-up on Kyoto commitments
- 30% increase in CO₂ emissions
- Problem owned by GoC—many industries, governments, communities hiding in the weeds
- Opportunity agenda elusive
- Strong criticism by Commissioner on Environment and Sustainable Development

Takeaways

- Climate change is real and already happening
- “greatest challenge to humanity this century”
- Global approach essential but Canada not pulling its weight
- Technology is seen as being integral to combat climate change
- Full long-term consequences unknown

What are Biofuels?

- Fuel produced from biomass
- Two main biofuels
 - Biodiesel
 - Similar to conventional fossil fuel
 - Vegetable oil, animal oil/fats, tallow and waste cooking oil
 - Bioethanol
 - Petro substitute for vehicles
 - Sugar fermentation
- Methane from anaerobic decomposition of organic materials

The Role Biofuels Can Play

- Burning fossil carbon adds GHG to the atmosphere, whereas burning biofuels like wood, straw, and dung does not
- Can replace and/or complement fossil fuels
- Renewable source of energy

Ethanol Production Processes

- Corn starch ferments to produce ethanol (moonshine) and is distilled to give gas pump grade
- Life cycle analysis
 - ploughing, fertilizer, pesticides, transportation, processing, distillation, distribution, blending
- Market influences
 - cost, taxes, subsidies

Cellulose Ethanol

- Made from the non-food portion of renewable feedstocks such as cereal straws
- Enzymes break down cellulose to sugars
- Life cycle analysis gives GHG reduction advantage to cellulosic ethanol
- Can be used in today's cars
 - All North American automotive manufacturers warrant the use of 10 percent ethanol blends
 - DaimlerChrysler and General Motors flexible fuel cars are designed to use any ethanol up to 85%

Iogen Technology

- Combination of thermal, chemical and biochemical techniques
- Yield is more than 340 litres per tonne of fibre
- Lignin in the plant fibre is used to drive the process by generating steam and electricity, thus eliminating the need for fossil CO₂ sources such as coal or natural gas

Biofuels – The Down Side

- Planting of biofuel crops uses up land that could be used to grow food
 - Drives up the price of food
 - Contributes to destruction of forests and other habitat
- Can disrupt the energy and nutrient cycle of an ecosystem by removing all byproducts
- Some biofuels are better than others
 - Some biofuel crops use little water and can be grown on marginal land (i.e. switch grass)

Takeaways

- Fuels are a large contributor to greenhouse gases
- Biofuels are an important less carbon-intense energy source, but also have some drawbacks
- As technology and crop choice improves, has significant potential to be an important part of the world's future energy mix

What are POPs?

- Chemical substances that persist in the environment
- Accumulate in the fatty tissue of living organisms
- Bioaccumulate through the food web
- Become widely distributed geographically
- Adverse effects on human health and the environment

Why Does This Matter?

- Build up in food chain
- Birth deformities
- Cancer
- Behavioural change
- Moves from mother to child
- Disrupts endocrine systems
- Suppression of immune system functions
- Affects both people and wildlife

Where Do They Come From?

- Industrial Chemicals
 - PCB's
 - Pesticides
 - DDT
 - Toxaphene
- Industrial and Natural Byproducts
 - Dioxins
 - Furans
- Industrial chemicals are the #1 priority

Environmental Detective Work

- First Discoveries in Great Lakes
 - PCBs
- Arctic
 - Toxaphene
- Ice Fields
 - Pesticides from Asia

Canadian Priority

- Canadian house in order
 - Policy
 - Legislation and regulations
 - Science
 - Leadership at all levels
- Mobilise the global community
 - North America
 - The UN's Economic Commission for Europe
 - The UN's Environment Program

Takeaways

- **Strong scientific case for action**
- **Canadians and their interests under threat from decisions by others**
- **Canadian 'house in order' before leadership role exercised**
- **Continental deal leads to global treaty**
- **Business opportunity**
- **Stay the course**

Tech

Fundamentals

- **Derived from knowledge of**
 - mechanics
 - chemistry
 - biology
 - light
 - electrons
 - psyche
 - integration of human and natural sciences

Definition

- **A General Purpose Technology (GPT) is a technology which:**
 - initially has much scope for improvement
 - is eventually widely used
 - has many uses
 - has many spillover effects

Characteristics

- **Obvious only in retrospect**
- **Can give rise to sustained economic growth**
- **Significant social implications**
- **Requires technologically/scientifically literate and supportive society**
- **The right conditions for development and commercialization over 50 years+/-**
- **Environment an afterthought**

Agriculture as an Example

- **Domestication of plants and animals**
for food, clothing, tools, settlements
- **Mechanization through animal, water, wind, steam, IC, electrical, GPS**
- **Productivity through selective breeding, fertilizers, drugs**
- **Next wave through biotechnology– new life forms, pharming, biorefineries for new products, reduce POPs and GHGs**

The Next Big Wave

- Environmentally-driven
- Aim to reduce ecological footprint
- Improvements in efficiency useful but not sufficient – move towards ecoeffectiveness
- Radical changes required
- Prepare for surprises, anticipate, prevent, precaution—transform the psyche
- Nobel prize for economics in 2020

Eco-Effectiveness - “Go Big or Go Home”

- Eco-efficiency – making bad things a bit better (not an adequate response)
- Eco-effectiveness – using design to ensure that there are no negative side effects
 - Waste becomes food for other aspects of the system (cherry tree)
- Responsibility for waste rests with the manufacturer
 - Send back to producer once finished with the product

Takeaways

- Technology has been and will be a major force in human history
- Innovation occurs in products, processes and organizations
- Transformative technologies have particular characteristics
- A new wave of technological and philosophical change is essential

Environmental Industry Sector

- Policy driven
- In Canada
 - 530,414 environmental employees within major industry groups - \$18 Billion/yr
 - Ontario, British Columbia and Quebec have greatest proportion of environmental employees
- Worldwide
 - \$500-800 Billion now to \$1 trillion by 2010
- General Electric’s story

Top Ten Environment Employment by Major Industry Group

1. Administration and Support, Waste Management and Remediation - 15%
2. Professional, Scientific and Technical Services – 13%
3. Education, Health and Social Assistance - 11%
4. Public Administration - 10%
5. Wholesale, Retail and Trade - 9%
6. Manufacturing - 8%
7. Construction - 7%
8. Arts, Recreation, Accommodation and Food Service - 7%
9. Agriculture, Forestry, Fisheries and Hunting - 6%
10. Other Services (except Public Admin) - 5%

Employer's Expectations

- **Technical competence**
- **Understand and competent to meet legal obligations**
- **Working skills**
 - **ethics, teamwork, live with ambiguity, creativity, self starter, global perspective**
- **Economics**
- **Social**
- **Environmental**

- **Tools**
 - **Standards, best practices, metrics, lifecycle analysis, benchmarks**
- **Thinking**
 - **Integrated, continuous discovery and life long learning**
- **Will they:**
 - **Fit in, add value, grow, lead, create, develop, stay-- be a good investment**

Employee's Considerations

- **Economic**
 - **Assets**
 - **Performance**
 - **History and trends**
 - **Salaries, profit sharing, bonus schemes, and benefits**
 - **Sector trends**
 - **Domestic/international competition**
 - **Comparative advantage**

- **Social**
 - **Public licence to operate**
 - **Corporate social responsibility**
 - **Ethics and values**
 - **Philanthropy**
 - **Community engagement**
 - **Public disclosure**
 - **Spirit of comraderie**

- **Environmental**
 - **View environment as a problem or opportunity**
 - **Source of innovation**
 - **Policies on environment and sustainable development**
 - **Performance and record**
 - **Work environment – natural light and fresh air**

- **Workplace**
 - **Working conditions**
 - **Level of turnover, orientation/retention initiatives**
 - **Rewards and recognition**
 - **Training, continuous learning and coaching**
 - **Cubicles**
 - **Culture - social place, sense of humour**