Dalat University
Faculty of Physics & Nuclear Engineering

Introduction to Engineering

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Contents

Chapter 3

Science versus Engineering

Contents of Chapter 3

I. Industrial Revolutions

❖ **The 1st industrial revolution:**

- **Period : 1760-1840**
- **Symbol : Steam engine**
- **Region : Great Britain**
- **Energy : Coal**
- **Tech. developments : Textiles, iron making, steam power**
- **Characteristics: (1) mechanical production; (2) local business**

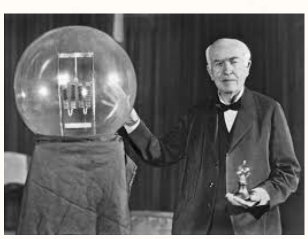
Passenger carriers using steam engine

A cotton factory

I. Industrial Revolutions

❖ **The 2nd industrial revolution:**

- **Period : 1870-1914**
- **Energy : Oil, electricity**
- **Region : Euro, USA, Japan**
- **Symbol : Electricity**
- **Technologies : Steel, electricity, automobile, telegraph.**
- **Characteristics: (1) mix of science & industry (applied science); (2) mass production; (3) big business.**



Electric light invented in 1879 (Edison)

Ford Car Model T created in 1908

The Eiffel Tower, built in 1889

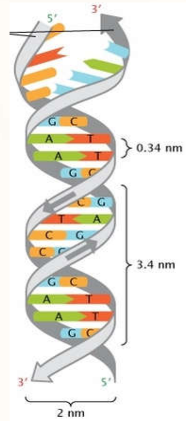
I. Industrial Revolutions

❖ The 3rd industrial revolution:

- Period : 1970-2010
- Energy : Nuclear, renewable
- Region : Over the world
- Symbol : Electronics
- Technologies : Semiconductor, biotech, digital telecom
- Characteristics: (1) automated production; (2) mass marketing; (3) free market.

1983 Industrial Robots KUKA IR160/60

First iPhone released in 2007



The double-helical structure of DNA

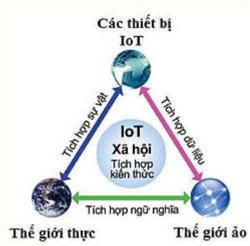
I. Industrial Revolutions

❖ The 4rd industrial revolution:

- Period : 2010-?
- Energy : Nuclear, renewable
- Region : Over the world
- Symbol : Artificial intelligence (AI)
- Technologies : AI, IoT, Nano, 3D printing.
- Characteristics: (1) intelligent production; (2) big data; (3) smart market; (4) associated world.

Social Networking Service Company

Interview with Sophia the Robot in 2017

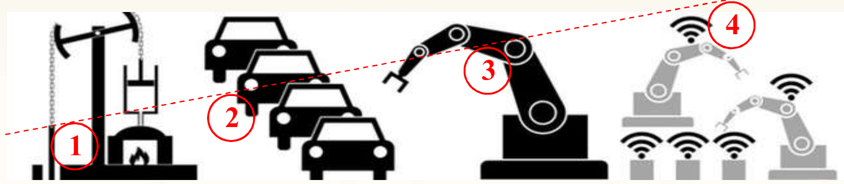


IoT model

Multinational Technology Company

I. Industrial Revolutions

❖ **Development fields of industrial 4.0:**



Mechanization | Electrification | Automation | **Association**

Physics

- New generation robots
- Nano technologies
- 3D printers
- Quantum computers

(Hardware)

Digital Engineering

- Internet of things
- Artificial intelligence
- Info storage & trans.
- Big data analysis

(Connection, Processing)

Biotechnology

- Agriculture
- Medicine, food
- Environment
- Renewable energy

(Applications)

I. Industrial Revolutions

❖ **Time for Teamwork:**

- ***Discuss the characteristics of universities associated with 4 industrial revolutions (IR):***

Items	Univ. in the era of 1st IR	Univ. in the era of 2nd IR	Univ. in the era of 3rd IR	Univ. in the era of 4nd IR
Purpose				
Academic activities				
Outcome				

I. Industrial Revolutions

❖ **Education from 1.0 to 4.0: basic differences**

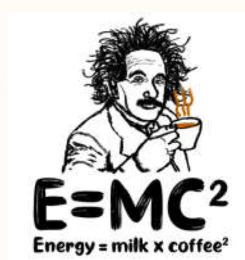
Đặc điểm	Trước 1980 Giáo dục 1.0	1980 Giáo dục 2.0	1990 Giáo dục 3.0	2000 Giáo dục 4.0
Mục đích	Giáo dục	Tuyển dụng	Tạo ra tri thức	Sáng tạo và tạo ra giá trị
Chương trình đào tạo	Đơn ngành (Single-disciplinary)	Liên ngành (inter-disciplinary)	Đa ngành (multi-disciplinary)	Xuyên ngành (trans-disciplinary)
Công nghệ	Giấy + Bút	PC và laptop	Internet + thiết bị di động	Internet kết nối vạn vật
Trình độ kỹ thuật số	Người tị nạn KT số	Dân nhập cư KT số	Người bản địa KT số	Công dân KT số
Giảng dạy	Một chiều	Hai chiều	Nhiều chiều	Mọi nơi
Đảm bảo chất lượng	Chất lượng học thuật	Chất lượng giảng dạy	ĐBCL theo luật quy định	ĐBCL theo nguyên tắc
Trường	Mô hình offline	Mô hình kết hợp offline và online	Mạng lưới, hệ thống	Hệ sinh thái
Đầu ra	Người lao động có kỹ năng	Người lao động có tri thức	Người đồng kiến tạo tri thức	Người sáng tạo và khởi nghiệp

Where we are?

II. Science vs Engineering

❖ **What is science?**

- ***Systematic*** **work;**
- **Build and organize knowledge by *explanations* and *predictions*;**
- ***Testable & verifiable.***



❖ **Classification of sciences:**

- **Natural science & social science;**
- **Pure science & applied science;**
- **Theoretical science & experimental science;**
- **Specialized science & interdisciplinary science.**

II. Science vs Engineering

❖ **What is engineering?**

- **Be a *profession;***
- ***Apply knowledge* of the mathematical and natural sciences** (gained by study, experience and practice)**;**
- **To *develop ways to use,* economically, the materials and forces of nature for the benefit of mankind.**

II. Science vs Engineering

❖ **Distinguishing between Science & Engineering:**

Build knowledge **Apply knowledge**

***Why* does this happen?** ***How* do I make this?**

II. Science vs Engineering

❖ **Some examples:**

- **Scientists study atomic structure to *understand* the nature of matter; engineers study the atomic structure to *build* smaller and faster microprocessors.**
- **Scientists study the movement of tectonic plates to *understand* and predict earthquakes; engineers study the movement of tectonic plates to *design* safer buildings.**

Scientist	Engineer
Both search for answers to technological questions	
to obtain a knowledge of why a phenomenon occurs	to obtain an application in practice
"*Scientists explore what is; engineers create what has not been*" - T. V. Karman – a pioneer of America's aerospace industry.	

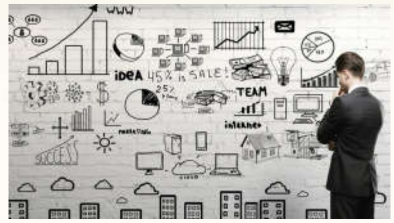
II. Science vs Engineering

❖ **What is technology?**

- **Be a *collection of techniques, skills, methods, and processes* used in the production of goods or services.**
- ***Directly apply* established engineering principles & processes.**
- **More interest in *hardware* and *processes*.**
- ***Embedded in machines* to operate without detailed knowledge.**
- **Mass production.**

III. Scientific Research Methodology

Contents



III-1. What is scientific research?

- **Definition**
  - ***Creative*** **activities**
  - ***Create*** **new knowledge**
  - ***Apply knowledge*** **to make new applications**

Answer the question: *Why?*

- **Criteria of research results**
  - **New**
    - ✓ subject
    - ✓ phenomenon
    - ✓ explanation
    - ✓ demonstration
    - ✓ method
    - ✓ application
  - **Verified**
    - ✓ experimentally
    - ✓ Transcendentally

New

Globally !

III-2. Determining main & narrow topics

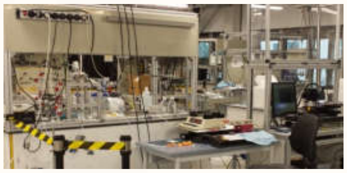
❖ **Understanding all main topics of your major:**

- ❑ **Cosmology & Astrophysics**
- ❑ **High-energy & particle physics**
- ❑ **Nuclear physics**
- ❑ **Computational physics**
- ❑ **Theoretical physics**
- ❑ **Atomic & molecular physics**
- ❑ **Condensed matter physics**
- ❑ **Medical & Biophysics**
- ❑ **Optics & Photonics**
- ❑ **Nano-material & Nano-tech.**

III-2. Determining main & narrow topics

❖ **What are your interests? (main / narrow topics)**

❖ **How is your work/study environment?**



❖ **The topic is chosen to simultaneously optimized three factors**

- **Yourself (interest, ability)**
- **Working environment**
- **Perspective of the research topic**

❖ **Find and read some textbooks:**

- **A webpage providing many electronic books freely:** **http://gen.lib.rus.ec/**

❖ **Search and get all papers in the topic:**

- **If knowing DOI, the link of paper is: http://dx.doi.org/DOI**
- **Author's private pages**
- **Use Sci-Hub illegally created by A. Elbaykyan (Kazakhstan)**
- **Ask your friends/colleagues**

IOP

IEEE

Elsevier

Springer

Taylor & Francis

❖ **How to read papers?**

❑ **At the beginning stage of research:**

- **Need reviewing all aspects (mechanisms, models, methods, techniques, explanations, problems, solutions…) of the topic.**
- **First read review/invited papers that have many citations:**
- **Then read all papers you have.**

❑ **After having a full review of the topic:**

- **Read the title and abstract of papers:**
- **Look at figures, tables, focus on the text if needed.**
- **Concentrate on the information that supports, explains, or completes your idea.**

III-3. Searching and using references

❖ **Make a complete literature review:**

- **To make sure you understand the up-to-date situation of the topic.**
- **Follow the research process of the topic.**
- **Describe models, methods or techniques, and explain:**
    - **why they were proposed,**
    - **what were their advantages,**
    - **what were the limitations,**
    - **What were next solutions to overcome the limitations.**
- **For each statement, cite references exactly.**

III-4. How to define a research problem

❖ **What is a research problem?**

- **Be some difficulty in theory or practice that needs a solution.** (in form of *question, assumption or assertion*)

❖ **How to arise a research problem?**

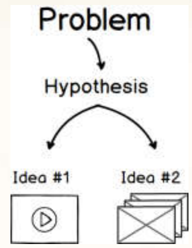
- **The researcher should himself pose a question by:**
    - **Do some field observation;**
    - **Undertake pilot survey;**
    - **Discuss with colleagues;**
    - **Read published researches and realize disadvantages.**

A problem clearly stated is a problem half solved !

III-5. Constructing hypotheses

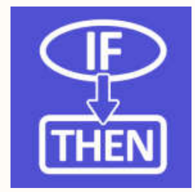
❖ **What is a hypothesis?**

- **A hunch, assumption, suspicion, assertion or an idea about a phenomenon, relationship or situation;**
- **The reality / truth of which you do not know.**
  - ➢ **It specifies a relationship between two or more variables**



❖ **Constructing Hypotheses:**

- **Based on the research problem, related concepts & associated variables.**
- **A hypothesis provides a study with focus:** (1) specific aspects to investigate; (2) what data to collect; (3) what is true or what is false.



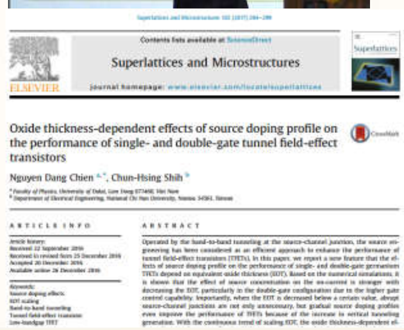
III-6. Course of research action

(a) Review the Literature: Review concepts and theories; Review previous research findings → (b) Define research problem → (c) Formulate hypotheses → (d) Design research → (e) Collect data (Execution) → (f) Analyze data → (g) Interpret & discuss → (h) Write a report

IV. Publication, Journal & Scientists

❖ **Publication forms**

- **Private communications**
- **Seminars, meetings**
- **Preprints (technical/research reports)**
- **Conference/symposium presentations**
- **Journal articles**
- **Book chapters**
- **Books**



IV. Publication, Journal & Scientists

❖ **Journal Ranking**

- **WoS-indexed journals**

Journal Impact Factor

Cites in 2014 to items published in: 2013	= 8798	Number of items published in: 2013	= 4353
2012	= 10216	2012	= 4356
Sum:	19014	Sum:	8709

Calculation: $\frac{\text{Cites to recent items}}{\text{Number of recent items}} = \frac{19014}{8709} = \mathbf{2.183}$

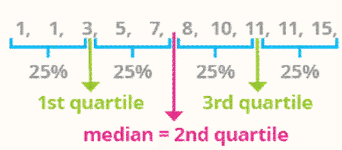
❖ **Quartile ranking for ISI & SCOPUS journals:**

✓ **Q1: Top 25%**

✓ **Q2: Top 25% - 50%**

✓ **Q3: Top 50% – 75%**

✓ **Q4: Top 75% – 100%**

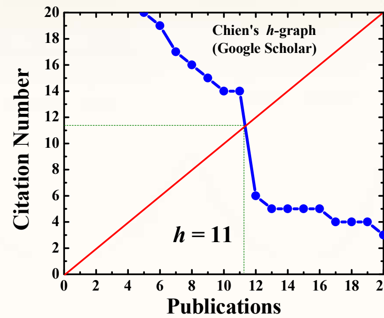


IV. Publication, Journal & Scientists

❖ **Evaluating a scientist**

- **h-index**
  - **Quantity of papers**
  - **Quality of papers**

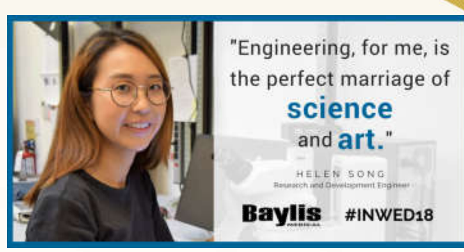
(Proposed by a physicist J. Hirsch in 2005)



- **$h = n$ if he published n papers cited at least n times;**
- **For a professor of a big university in US, after 20 years working.**
  - ✓ ***h*** **= 20: successful**
  - ✓ ***h*** **= 40: excellent**
  - ✓ **h = 60: distinguished**

V. Engineers' Jobs & Engineering Design

1. **What do engineers do?**
2. **Engineering design**



Engineers are professionals who *invent, design, analyze, build, and test machines, systems, structures and materials* to *fulfill objectives and requirements* while considering *the limitations imposed by practicality, regulation, safety, and cost.*

V-1. What do engineers do?

❖ **Research:**

- **Research engineers *explore fundamental principles* of chemistry, physics, biology and mathematics in order to *overcome barriers* preventing advancement in their field.**
- **Research engineers may be involved in the *design* and *implementation* of experiments and the *interpreting* of the results.**
- **Research engineers also might *develop the computational techniques* to perform the complex calculations in a timely and cost-effective fashion.**
- **Research engineers *work for* some type of *research center* (a university, a government laboratory, an industrial research center).**
- **In most research positions an *advanced degree is required*, and often a Ph.D. is needed.**

❖ **Development:**

- **Development engineers take the knowledge acquired by the researchers and apply it to a specific product or application.** (coupled with research in so-called **R&D**)
- **The researcher may prove something is possible in a laboratory; the development engineer shows that it will work on a large, production-size scale and under actual conditions.** (pilot manufacturing plants or ***prototypes***)
- **Development engineers bridge the gap between laboratory research and full-scale production.**

V-1. What do engineers do?

❖ **Testing:**

- **Test engineers are responsible for designing and implementing tests to verify the integrity, reliability and quality of products.**
- **The test engineer devises ways to simulate the conditions a product will be subjected to during its life.**
- **Data from prototype tests are used to decide whether full production versions will be made or changes needed.**
- **Challenges: acquiring accurate and reliable data;**
- **Test engineers must have:**
  - **A wide range of technical and problem-solving skills;**
  - **Good teamwork skills.**

V-1. What do engineers do?

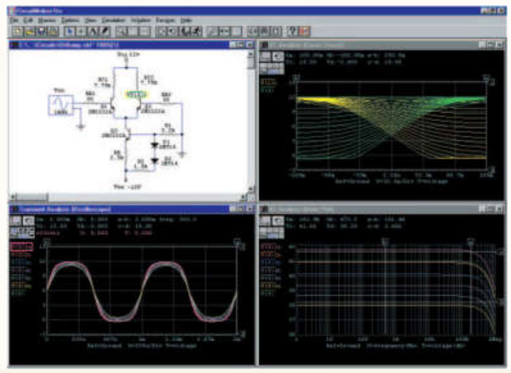
❖ **Design:**

- **The design engineer is responsible for providing the detailed specifications of the products (usually a component or part).**
- **They use their knowledge of scientific and mathematical laws, coupled with experience, to generate a shape to meet the specifications.**
- **They also redesign parts to reduce manufacturing costs and time, modify products for new uses or more convenience.**
- **They use modern computer design tools.**
- **They must verify that the part meets the reliability and safety standards.**
- **Cost is a critical factor → Communicate with manufacturing engineers.**

V-1. What do engineers do?

❖ **Analysis:**

- **Analysis engineers use *mathematical models & computational tools* to provide the information to design, development or research engineers.**
- **Test data are used to validate their computer programs or mathematical models.**



- **They are specialists in a technology area which is important in the product manufacturing.**
- **They often possess an advanced degree and are experienced in their area of expertise.**

V-1. What do engineers do?

❖ **Systems:**

- **Systems engineers are responsible for the integration of the components into a functioning product.**
- **They are also responsible for identifying the over all design requirements → working with customers or marketing personnel to determine market needs.**
- **They work with the overall design, development, manufacture & operation of a complete system or product.**

- **Be a systems engineer only after becoming proficient in an area important to the systems, such as design or R&D.**

V-1. What do engineers do?

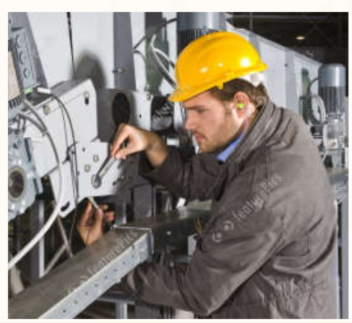
❖ **Manufacturing:**

- **Manufacturing engineers develop processes to turn the specifications of the design engineer into a finished product.**
- **They keep track of the equipment, associated maintenance, safety of workplace.**
- **Since manufacturing cost is such an important component, the design process must take into account manufacturing concerns.**
- **They are very concerned about the quality of the products.**
- **As technology advances, new processes often must be developed for manufacturing the products.**

V-1. What do engineers do?

❖ **Operations and Maintenance:**

- **The operations engineer oversees and inspects the ongoing performance of the facility.**
- **They must have a wide range of expertise dealing with the mechanical and electrical issues to maintain a production line.**
- **They must be able to interact with manufacturing engineers, line workers and technicians who service the equipment.**
- **The production facility must be maintained periodically.**



V-1. What do engineers do?

❖ **Technical & customer supports:**

- **A technical support engineer serves as the link between customer and product and assists with installation, setup and using.**
- **To be effective, the technical engineer must have good interpersonal and problem-solving skills as well as solid technical training.**
- **Modern technical support is being used as an added service.**
- **Customer support personnel are involved in the business aspect of the customer relationship (warranty issues, contractual agreements)**
- **Technical knowledge, problem solving ability & business training are required for the customer support person.**
- **Customer support personnel work very closely with the technical support engineers and also with management personnel.**

V-1. What do engineers do?

❖ **Sales & Consulting:**

- **Engineers are valuable members of the sales force because they have the technical background to answer customer questions and concerns.**
- **Sales engineers are trained to identify which products are right for the customer and how they can be applied.**
- **More and more sophisticated products result in an ever-increasing demand for sales engineers.**

- **Consulting engineers are either self-employed or they work for a firm that does not provide goods or services directly to consumers.**
- **Consulting engineers also might be asked to (1) evaluate the effectiveness of an organization; (2) provide suggestions and guidelines for improving the company's processes.**

V-2. Engineering design

❖ **10-stage design:**

- **Stage 1 : identify the problem**
- **Stage 2 : define the working criteria/goals**
- **Stage 3 : research and gather data**
- **Stage 4 : brainstorm/generate creative ideas**
- **Stage 5 : analyze potential solutions**
- **Stage 6 : develop and test models**
- **Stage 7 : make the decision**
- **Stage 8 : communicate and specify**
- **Stage 9 : implement and commercialize**
- **Stage 10 : perform post-implementation review and assessment**

V-2. Engineering design

❖ **Stage 1: Identify the problem**

- **Problems are often the *specific needs and problems* of customers.**
- **Ideas may come from:**
  - **sales engineers; existing or prospective clients;**
  - **trade shows, conferences, technical presentations, publications;**
  - **external research agencies, laboratories;**
- **Engineers establish a preliminary, formal statement of the problem.**
- **The problem needs to be approved by the project manager.**

❑ Example: *make a paper pinwheel that will protect children from possible hurts.*

❖ **Stage 2: define the working criteria/goals**

- **Establish *preliminary criteria* which will act as the focal point.**
- **Working criteria provides a means to compare possible solutions.**
- **Everything is preliminary, the team can modify the criteria.**
- **Some criteria are involved:**

1. size	**5. easy to use**	*Diameter=25cm; 5000 VND*
2. difficulty	**6. reliability, durability**	*Handle: not hard, 30cm*
3. cost	**7. can it be recycled?**	*4 swings w/o sharp edges*
4. safety	**8. willing to purchase it?**	*120 rpm at 20 km/h of wind*

❑ Example: (right column above)

- **Once the criteria established, develop *overall goals* for the process.**
  - ❑ Example: *to develop a paper pinwheel which produces 120 rpm at 20 km/h of wind while ensuring safety for children aged 3-6 years.*

❖ **Stage 3: research and gather data**

- **Based on the criteria and the goals, the team members selected what types and the best sources of *information* will be needed.**

- **Types of information:**
  - **related information published**
  - **Available solutions & whose?**
  - **advantages & disadvantages**
  - **the cost & the time spend**
  - **legal issues**
  - **environmental concerns**
- **Sources of information:**
  - **libraries**
  - **trade journals, newspapers**
  - **market assessment surveys**
  - **salespersons, experts**
  - **professional associations**
  - **government publications**

❑ Example: *Pinwheels at market (cost, shape, material, operation, etc);*
Air density; momentum conservation; torque; rotary friction;
Analytical models, experimental data for the pinwheel speed.

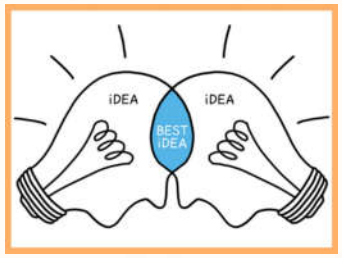
❖ **Stage 4: brainstorm/generate creative ideas**

- **The project manager gathers a *group*** (engineers, scientists, technicians, etc.) **to provide their unique perspective.**
- **A large number of ideas is generated at the *brainstorming* session.**
- **Note that no ideas are to be considered *ridiculous*.**
- **If the problem is large, divide it into some modules.**

➢ **Time for Teamwork:**

***Brainstorm* to generate ideas:**

✓ **Group 1: for the wings**
✓ **Group 2: for the handle**



❖ **Stage 5: analyze potential solutions**

- **Phase I: *narrow* the ideas to a few ideas:**
  - **Clarify ideas**
  - **Evaluate ideas**
  - **Eliminate duplicates**
  - **Vote top three ideas**
- **Phase II: apply mathematics, science, general engineering principles, and computer analysis techniques to *evaluate* the potential solutions.**
  - **time consuming, important**
  - **engineers are of importance**

❑ Example phase I:

- ....
- Photocopy paper (80 gsm)
- Poster paper (150 gsm)
- Paperboard (350 gsm)

❑ Example phase II:

- Analyze based on (1) paper stiffness & toughness; (2) wind force on swings at highest speed.

→ *Poster paper, paperboard are possible.*

❖ **Stage 6: develop and test models**

- ***Develop/create specific models* to represent the dependence of these parameters on others.**
    - Parameters: related to structure, material, function, operation.
    - **Mathematical models: performed into *equations*.**
    - **Computer models: most common computer modeling is *CAD*.**
    - **Physical scale models: *prototypes* are built to simulate the proposed design** (may not include all of the features or functions)**.**
- **Perform tests on the models for *comparison* against the working criteria and the overall goals.**

❑ Example:
- $S_{rot} = f(v, \rho, s, \alpha, \gamma, \epsilon \ldots)$
- Prototype of pinwheel
- Compare between physical & theoretical models

❖ **Stage 7: make the decision**

- **Establish a *means to evaluate* the testing results to determine which solution will be implemented.**
- **Develop a *decision table* to help the team visualize the merits of each:**

Working Criteria	Weight point available	Solution #1	Solution #2
Cost	20	10	16
Size, weight	15	13	11
Speed	20	15	18
Appearance	10	8	9
Safety	30	25	24
Reliability/Durability	5	3	4
Total	**100**	**74**	**82**

❖ **Stage 8: communicate and specify**

- **Before a part or product is manufactured, all aspects of the item must be *communicated, reported & specified*.**
- **Team members must work together to develop the materials:**
  - detailed written reports, summaries of technical presentations and memos, relevant e-mails, diagrams, drawings and sketches, computer printouts, charts, graphs, etc.

❑ For the example:

- Team members communicate their work to the rest of group.
- Specification of all aspects must be communicated & unified.
- A detailed report on: ideas, materials, methods, mechanisms, models, test data, comparison, evaluation, decision, notes... has to be made.

❖ **Stage 9: implement and commercialize**

- **Costs begin to escalate dramatically, so all *serious issues* should be resolved by this time.** (the final opportunity for revision or termination)
- **Many *individuals* are involved in this stage:**
  - **the project manager and team leaders;**
  - **Management and key supervisory personnel;**
  - **Technical representatives;**
  - **human resource personnel;**
  - **financial people, purchasing personnel;**
  - **Marketing, advertising staff members & sales people;**
  - **Lawyers and legal support staff.**

❖ **Stage 10: perform post-implementation review and assessment**

- **At this point, the project is in full production**
- **The product's performance is reviewed:**
  - **efficiency**
  - **revenues**
  - **Expenditures**
  - **quality**
  - **costs**
  - **profits**
  - **sales**
- **An assessment report is prepared:**
  - **Strengths**
  - **what has been learned**
  - **weaknesses**
  - **Experiences for future project**
- **Since the product is considered to be a regular product, *the project team is terminated now !***

VI. Units of measurement

❖ **Definition**

- **Unit is a *chosen magnitude* of an *attribute*, which is used as a standard for measurement of that attribute.**
- **Notation: Each unit is denoted by some character(s).**

  Examples: $kg, m, s, \dots$

❖ **Physical quantity**

- **A physical quantity is an *attribute / property* of a physical system that can be *quantified* by measurement.**
- **A physical quantity is represented completely by its *magnitude* and *unit*:**

  Physical quantity = Magnitude ⊗ Unit

  – Note: ⊗ is denoted for *direct product*, usually skipped in writing.

  – Examples: $5\ kg, 7\ m, 23\ s$.

VI. Units of measurement

❖ **History**

- **Primitive societies: used *crude measures* such as hand (length), sun & moon (time), plant seeds (volume), stones (weight).**
- **1790: the *metric system was developed* by the French Academy of Sciences.**
- **1875: the Metric Convention was established including 3 organs:**
  - General Conference on Weights and Measures (CGPM): *highest organ*
  - Int. Committee for Weights and Measures (CIPM): *secretariat*
  - Int. Bureau of Weights and Measures (BIPM): *office*
  - ➢ *It set up well-defined standards for* ***length*** *and* ***mass****.*
- **1921: CGPM *extended* to all other units in physics.** (at the 6th meeting)
- **1960: CGPM *ratified* the International System of Units (SI).**
- **2019: CGPM *redefined* the base units based on the physical constants.**

VI. Units of measurement

❖ **5 constants of nature**

Constant	Exact value	Note
Speed of light c	299792458 meter per second ($m \cdot s^{-1}$)	*Recommended by the CGPM in 1975.*
Planck constant h	$6.62607015 \times 10^{-34}$ joule-second (J·s)	D. B. Newell, "The CODATA 2017 Values of h, e, k, and NA for the Revision of the SI". *Metrologia* 55 (1): L13. *The CIPM had proposed them for the definition of base units.*
elementary charge e	$1.602176634 \times 10^{-19}$ coulomb (C)	
Boltzmann constant k	1.380649×10^{-23} joule per kelvin ($J \cdot K^{-1}$)	
Avogadro constant N_A	$6.02214076 \times 10^{23}$ reciprocal mole (mol^{-1})	

❖ **2 supplementary units**

Unit (Symbol) Quantity	Definition
radian (rad) plan angle	The plane angle with its vertex at the center of a circle that is subtended by an arc equal in length to the radius.
steradian (sr) solid angle	The solid angle with its vertex at the center of a sphere that is subtended by an area of the spherical surface equal to that of a square with sides equal in length to the radius.

VI. Units of measurement

❖ **7 base units**

Unit (Symbol) Quantity	**Definition** (Approved by the CGPM at the 26 meeting in November 2018)
second (s) time	defined by taking the fixed value of the ground-state hyperfine transition frequency of the caesium-133 atom to be 9192631770 ($\mathrm{Hz} = \mathrm{s}^{-1}$)
meter (m) length	defined by taking the fixed value of the speed of light in vacuum c to be 299792458 ($\mathrm{m} \cdot \mathrm{s}^{-1}$)
kilogram*) (kg) mass	defined by taking the fixed value of the Planck constant h to be $6.62607015 \times 10^{-34}$ ($\mathrm{J} \cdot \mathrm{s} = \mathrm{kg} \cdot \mathrm{m}^2 \cdot \mathrm{s}^{-1}$)
ampere) (A)** electric current	defined by taking the fixed value of the elementary charge e to be $1.602176634 \times 10^{-19}$ ($\mathrm{C} = \mathrm{A} \cdot \mathrm{s}$)
kelvin*) (K) temperature	defined by taking the fixed value of the Boltzmann constant k to be 1.380649×10^{-23} ($\mathrm{J} \cdot \mathrm{K}^{-1} = \mathrm{kg} \cdot \mathrm{m}^2 \cdot \mathrm{s}^{-2}\mathrm{K}^{-1}$)
mole) (mol)** amount of substance	defined by taking the fixed value of the Avogadro constant N_A to be $6.02214076 \times 10^{23}$ (elementary entities = mol^{-1})
candela (cd) luminous intensity	defined by taking the fixed value of the luminous efficacy of monochromatic radiation of frequency 540×10^{12} (Hz) K_{cd} to be 683 ($\mathrm{lm} \cdot \mathrm{W}^{-1} = \mathrm{cd} \cdot \mathrm{sr} \cdot \mathrm{W}^{-1} = \mathrm{cd} \cdot \mathrm{sr} \cdot \mathrm{kg}^{-1} \cdot \mathrm{m}^{-2} \cdot \mathrm{s}^3$)

*) *fundamental changes* ; **) *major revisions (compared to previous definitions)*

VI. Units of measurement

❖ **Convention of writing unit symbols**

- **The first letter of a symbol is capitalized if the name of a symbol is derived from a person's name, otherwise it is lowercase;**
- **The symbol for the liter is recommended to be "L,"** (since the lowercase "l" may cause a confusion with the numeral "1");
- **Use standing letters;**
- **Use one space between the numeral & the unit of quantity.**

Unit Name	Unit Symbol
meter	m
liter	L or l
kilogram	kg
ampere	A
pascal	Pa

❖ **The Measurement System in Viet Nam**

- **Based on the Ordinance of Measurement** (Pháp lệnh Đo lường) **adopted by the National Assembly in 1999.**
- **The decree 134/2007/NĐ-CP** (signed by the Prime Minister on 15/8/2007).

VI. Units of measurement

❖ Quantities whose units are expressed in terms of base and supplementary units

Quantity	SI Unit	SI Symbol
area	square meter	m^2
volume	cubic meter	m^3
speed, velocity	meter per second	m / s
acceleration	meter per second squared	m / s^2
density	kilogram per cubic meter	kg / m^3
specific volume	cubic meter per kilogram	m^3 / kg
magnetic field strength	ampere per meter	A/m
concentration	mole per cubic meter	mol / m^3
luminance	candela per square meter	cd / m^2
kinematic viscosity	square meter per second	m^2 / s
angular velocity	radian per second	rad/s
angular acceleration	radian per second squared	rad / s^2

VI. Units of measurement

❖ Quantities whose units have special names

Quantity	SI Name	SI Symbol	Other SI Units
frequency	hertz	Hz	cycle/s
force	newton	N	$kg \cdot m / s^2$
pressure, stress	pascal	Pa	N / m^2
energy, work	joule	J	N·m
power	watt	W	J/s
electric charge	coulomb	C	A·s
electric potential	volt	V	W/A
capacitance	farad	F	C/V
electric resistance	ohm	Ω	V/A
conductance	siemens	S	A/V
magnetic flux	weber	Wb	V·s
magnetic flux density	tesla	T	Wb / m^2
inductance	henry	H	Wb/A
luminous flux	lumen	lm	
illuminance	lux	lx	

VI. Units of measurement

❖ **Quantities whose units are expressed in terms of derived units with special names**

Quantity	SI Unit	SI Symbol
viscosity	pascal second	$Pa \cdot s$
moment of force, torque	newton meter	$N \cdot m$
surface tension	newton per meter	N/m
heat flux density	watt per square meter	W / m^2
entropy	joule per kelvin	J/K
specific heat	joule per kilogram kelvin	$J/(kg \cdot K)$
specific entropy	joule per kilogram kelvin	$J/(kg \cdot K)$
specific energy	joule per kilogram	J/kg
thermal conductivity	watt per meter kelvin	$W/K \cdot m$
electric field strength	volt per meter	V/m
electric charge density	coulomb per cubic meter	C / m^3
electric flux density	coulomb per square meter	C / m^2
permittivity	farad per meter	F/m
permeability	henry per meter	H/m

VI. Units of measurement

❖ **Units used with the SI system**

Name	Symbol	Value in SI units
minute (time)	min	1 min = 60 s
hour	h	1 h = 3600 s
day	d	1 d = 86 400 s
degree	°	$1° = \pi / 180$ rad
minute (angle)	'	$1' = \pi / 10800$ rad
second	"	$1'' = \pi / 648000$ rad
tonne	t	1 t = 1000 kg

VI. Units of measurement

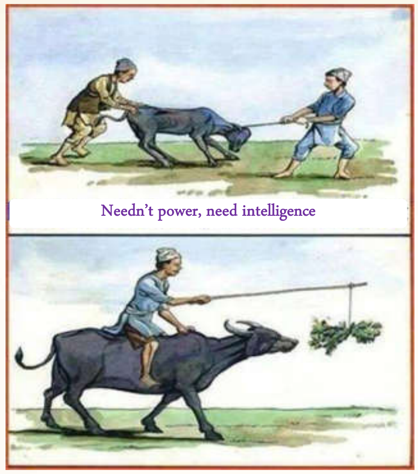
❖ **Units that are being used temporarily**

Name	Symbol	Value in SI Units
nautical mile		1 nautical mile = 1852 m
knot		1 knot = 0.5144 m/s
ångström	Å	1 Å = 10^{-10} m
are	a	1 a = 100 m^2
hectare	ha	1 ha = 10 000 m^2
barn	b	1 b = 10^{-28} m^2
bar	bar	1 bar = 10^5 Pa
standard atmosphere	atm	1 atm = 101 325 Pa
gal	Gal	1 Gal = 0.01 m / s^2
curie	Ci	1 Ci = 3.7 × 10^{10} s^{-1}
röntgen	R	1 R = 2.58 × 10^{-4} C/kg
rad	rad	1 rad = 0.01 J/kg

VI. Units of measurement

❖ **Prefixes for metric units**

Multiplication Factor	Prefix	Symbol	Pronunciation	Term (USA)
1000 000 000 000 000 000 = 10^{18}	exa	E	Texas	one quintillion
1000 000 000 000 000 = 10^{15}	peta	P	petal	one quadrillion
1000 000 000 000 = 10^{12}	tera	T	terrace	one trillion
1000 000 000 = 10^9	giga	G	giggle	one billion
1000 000 = 10^6	mega	M	megaphone	one million
1000 = 10^3	kilo	k	kilowatt	one thousand
100 = 10^2	hecto	h	heck	one hundred
10	deka	da	deck	ten
0.1 = 10^{-1}	deci	d	decimal	one tenth
0.01 = 10^{-2}	centi	c	sentiment	one hundredth
0.001 = 10^{-3}	milli	m	military	one thousandth
0.000 001 = 10^{-6}	micro		mike	one millionth
0.000 000 001 = 10^{-9}	nano	n	Nancy	one billionth
0.000 000 000 001 = 10^{-12}	pico	p	peek	one trillionth
0.000 000 000 000 001 = 10^{-15}	femto	f	feminine	one quadrillionth
0.000 000 000 000 000 001 = 10^{-18}	atto	a	anatomy	one quintillionth



Needn't power, need intelligence

The End of Chapter 3