Thermo-electrical and thermionic Conversions

Wind Energy

Unit: 4

RENEWABLE ENERGY RESOURCES(KOE-074)

Course Details
(B.Tech ME 7th Sem)

Avdhesh Kumar
Assistant Professor
Mechanical

Brief introduction of faculty with photograph

Mr. Avdhesh Kumar

I, Avdhesh Kumar, Assistant Professor, MED, NIET is currently associated with NIET, Gr. Noida. I have vast experience in the field of Fluid mechanics, fluid machinery, Manufacturing science, Automobile Engineering, Total Quality Management. I have 13 years teaching experience. Here (NIET Gr. Noida) I m teaching from 4 Feb 2019 to till now. I m currently pursuing PhD from National Institute of Technology (NIT) Patna.

Evaluation Scheme

B. Tech Mechanical Engineering Evaluation Scheme
Effective in Session 2021-22

SEMESTER- VII													
Sl. No.	Code	Subject	Periods			Evaluation Scheme				End Semester		Total	Credit
			L	T	P	CT	TA	Total	PS	TE	PE		
1		HSMC-1/HSMC-2	3	0	0	30	20	50		100		150	3
2		Departmental Elective-IV	3	0	0	30	20	50		100		150	3
3		Departmental Elective-V	3	0	0	30	20	50		100		150	3
4		Open Elective-II	3	0	0	30	20	50		100		150	3
5	KME 751	Measurement & Metrology Lab	0	0	2				25		25	50	1
6	KME 752	Mini Project or Internship Assessment*	0	0	2				50			50	1
7	KME 753	Project	0	0	8				150			150	4
8		MOOCs (Essential for Hons. Degree)											
		Total	9	0	12	21						850	18

*The Mini Project or internship (5 - 6 weeks) conducted during summer break after VI semester and will be assessed during VII semester.

Evaluation Scheme

B. Tech Mechanical Engineering
OPEN ELECTIVE-II

KOE071	FILTER DESIGN
KOE072	BIOECONOMICS
KOE073	MACHINE LEARNING
KOE074	RENEWABLE ENERGY RESOURCES
KOE075	OPERATIONS RESEARCH
KOE076	VALUE RELATIONSHIP & ETHICAL HUMAN CONDUCT- FOR A HAPPY & HARMONIOUS SOCIETY
KOE077	DESIGN THINKING
KOE078	SOIL AND WATER CONSERVATION ENGINEERING
KOE078	INTRODUCTION TO WOMEN’S AND GENDER STUDIES

Syllabus

Unit 1: Introduction: Various non-conventional energy resources- Introduction, availability, classification, relative merits and demerits. Solar Cells: Theory of solar cells. Solar cell materials, solar cell array, solar cell power plant, limitations.

Unit 2: Solar Thermal Energy: Solar radiation, flat plate collectors and their materials, applications and performance, focusing of collectors and
their materials, applications and performance; solar thermal power plants, thermal energy storage for solar heating and cooling, limitations.

Unit 3: Geothermal Energy: Resources of geothermal energy, thermodynamics of geo- thermal energy conversion-electrical conversion, non-electrical conversion, environmental considerations. Magneto-hydrodynamics (MHD): Principle of working of MHD Power plant, performance and limitations. Cells: Principle of working of various types of fuel cells and their working,
performance and limitations.

Syllabus

Unit 4: Thermo-electrical and thermionic Conversions: Principle of working, performance and limitations. Wind Energy: Wind power and its sources, site selection, criterion, momentum theory, classification of rotors, concentrations and augments, wind characteristics. Performance and limitations of energy conversion systems.

Unit 5: Bio-mass: Availability of bio-mass and its conversion theory. Ocean Thermal Energy Conversion (OTEC): Availability, theory and working principle, performance and limitations. Wave and Tidal Wave: Principle of working, performance and limitations. Waste Recycling
Plants.

Branch wise Application

- The renewable energy industry has seen impressive, global growth over the last decade, and mechanical engineers have played a key role in enabling the world's transition to clean energy and more sustainable practices.

- mechanical engineers looked at ways of improving the design of wind turbines, and mechanical engineering has led to similar improvements in solar and geothermal power, as well as every stage of renewable energy development.

- Many of the key skills that mechanical engineers learn and develop in mechanical engineering graduate programs have a wide range of applications for renewable energy engineering. Knowledge of thermodynamics, fluid mechanics and heat transfer, for example, is essential for solving the wind power challenge outlined above, but the same expertise is also critical in designing hydropower infrastructure, optimizing cooling systems and developing new energy storage technology such as thermochemical batteries and solar fuel (pioneered at MSU) for long duration energy storage.

Course Objectives

1. To impart knowledge on various non-conventional energy resources so that the students can apply them in the domestic and engineering industry.
2. To gain understanding of applications and performance of solar thermal power plants, thermal energy storage for solar heating and cooling in the domestic and industry.
3. To develop the knowledge of geothermal energy, Magneto-hydrodynamics and principle of working of various types of fuel cells, performance, limitations and environmental considerations.
4. To acquire knowledge and to solve problems associated with Thermo-electrical and thermionic conversions and Wind Energy, wind characteristics, performance and limitations of energy conversion systems.
5. To impart knowledge on Bio-mass, Ocean Thermal Energy Conversion, Wave and Tidal Wave, conversion theory, performance and limitations.

Course Outcomes

After completion of this course students will be able to-

CO 1. Identify and understand the concepts of various non-conventional energy resources and their application in the domestic and engineering industry.

CO 2. Understand the applications and performance of solar thermal power plants, thermal energy storage for solar heating and cooling in the domestic and industry.

CO 3. Analyze and predict about geothermal energy, Magneto-hydrodynamics and various types of fuel cells, performance, limitations and environmental considerations.

CO 4. Solve the problems associated with Thermo-electrical and thermionic conversions and Wind Energy, wind characteristics, performance and limitations.

CO 5. Use appropriate knowledge on Bio-mass, Ocean Thermal Energy Conversion, Wave and Tidal Wave their performance and limitations.

Program Outcomes

1. **Engineering knowledge:** Apply the knowledge of mathematics, science, engineering fundamentals, and an engineering specialization for the solution of complex engineering problems.
2. **Problem analysis:** Identify, formulate, research literature, and analyse complex engineering problems reaching substantiated conclusions using first principles of mathematics, natural sciences, and engineering sciences.
3. **Design/development of solutions:** Design solutions for complex engineering problems and design system components or processes that meet the specified needs with appropriate consideration for public health & safety, cultural, societal, & environmental considerations.
4. **Conduct investigations of complex problems:** Use research based knowledge and research methods including design of experiments, analysis and interpretation of data, and synthesis of information to provide valid conclusions.

Program Outcomes

5. **Modern tool usage:** Create, select, and apply appropriate techniques, resources, and modern engineering and IT tools, including prediction and modeling to complex engineering activities, with an understanding of the limitations.

6. **The engineer & society:** Apply reasoning informed by the contextual knowledge to assess societal, health, safety, legal & cultural issues and the consequent responsibilities relevant to the professional engineering practice.

7. **Environment and sustainability:** Understand the impact of the professional engineering solutions in societal and environmental contexts, and demonstrate the knowledge of, and need for sustainable development.

8. **Ethics:** Apply ethical principles and commit to professional ethics and responsibilities and norms of the engineering practice.

Program Outcomes

9. Individual and team work: Function effectively as an individual, and as a member or leader in diverse teams, and in multidisciplinary settings.

10. Communication: Communicate effectively on complex engineering activities with engineering community & society at large, such as, being able to comprehend & write effective reports & design documentation, make effective presentations, & give & receive clear instructions.

11. Project management and finance: Demonstrate knowledge and understanding of the engineering and management principles and apply these to one’s own work, as a member and leader in a team, to manage projects and in multidisciplinary environments.

12. Life-long learning: Recognize the need for, and have the preparation and ability to engage in independent and life-long learning in the broadest context of technological change.

CO-PO Mapping

CO/PO	PO1	PO2	PO3	PO4	PO5	PO6	PO7	PO8	PO9	PO10	PO11	PO12
CO1	2	2	1	2	1	2	3	-	3	1	2	2
CO2	2	2	1	1	3	1	3	2	3	-	1	3
CO3	2	1	2	1	2	2	3	2	3	1	2	3
CO4	2	2	2	1	2	2	3	2	3	1	1	2
CO5	1	2	1	1	2	1	3	3	3	1	2	3

Program Specific Outcomes

- **PSO1.** To impart proper knowledge of science, mathematics and mechanical engineering related subjects to the students.

- **PSO2.**To enhance the skills of the students with the ability to implement the scientific concepts for betterment of the society in professional and ethical manner.

- **PSO3.** To prepare the students to understand physical system, mechanical components and processes to address social, technical and engineering challenges.

CO- PSO Mapping

Mapping of Program Specific Outcomes and Course Outcomes:

CO/PSO	PSO1	PSO2	PSO3
CO1	1	3	3
CO2	1	2	3
CO3	2	1	2
CO4	1	1	1
CO5	2	2	1

PEOs

- PEO1 - Graduates will demonstrate technical competency and leadership to become professional engineers leading to a successful career.
- PEO2 - Graduates will demonstrate commitment towards sustainable development for the betterment of society.
- PEO3 - Graduates will pursue lifelong learning in generating innovative engineering solutions using research and complex problem-solving skills.

Result Analysis

End Semester Question Paper

Section A

1. Attempt all questions in brief 2*10=20

(a) State Seebeck Effect and Peltier Effect.

(b) Write the chemical reaction takes place in Alkaline Fuel Cell.

(c) What is an aerobic digestion?

(d) Define solar constant. What is its standard value?

(e) Discuss the terms Energy conservation and Energy audit.

(f) What is the maximum energy conversion efficiency of a wind turbine for a given swept area?

(g) Define Fill Factor.

(h) On what factors does the collector efficiency of a solar flat plate collector depend?

(i) What is OTEC? Discuss in brief.

(j) Describe various Geothermal Energy Resources.

End Semester Question Paper

Section B

2. Attempt any five of the following 5*10=50

(a) Discuss the main features of various types of renewable and non-renewable energy sources. Also explain the importance of non-conventional energy sources in the context of global warming.

(b) Classify different types of solar thermal collector and show the constructional details of a flat plate collector. What are its main advantages?

(c) Explain the mechanism of photoconduction in a PV cell.

(d) Explain the process of gasification of solid biomass. What is the general composition of the gas produced and what is its heating value? What are its applications?

End Semester Question Paper

Section B

2. Attempt any five of the following 5*10=50

(e) Explain the ‘Single Basin’ and ‘Two Basin’ systems of tidal power harnessing. Discuss their advantages and limitations.

(f) Explain the essential features of a hydrogen-oxygen cell. Draw a suitable diagram of this cell and give the reactions took place at the electrodes.

(g) With the help of a schematic diagram, explain the operation of closed cycle MHD generating system.

(h) Explain the process of production of biogas from biomass. Describe Deen Bandhu Biogas plant.

End Semester Question Paper

Attempt any two of the following questions: **2 x 15 = 30**

3. What are the most favorable sites for installing wind turbines? Using Betz model of a wind turbine, derive the expression for power extracted from wind. Under what condition does the

maximum theoretical power can be extracted from the wind turbine?

4. Write short notes on: i) Practical problems associated with MHD power generation. ii) Solar Cell Arrays. iii) Vertical Axis Wind Mills.

5. Describe the principle of working and constructional details of basic thermionic generator.

What is the basic difference between thermoelectric and thermionic conversion systems? Also,

explain the working of thermoelectric generators.

Prerequisite and Recap

Students should have knowledge of

- Thermo-electric conversion which works on principle of Seeback effect which is a solid state device that converts heat flux (temperature differences) directly into electrical energy through a phenomenon called the *Seebeck effect*
- **In last unit we learnt about geothermal power generation and working for magneto hydrodynamics.**

Introduction about the subject with videos

Energy **generated by using wind, solar, small hydro, tides, geothermal heat and biomass** is known a non-conventional energy. All these sources are renewable process of energy generation and do not cause environmental pollution. Our country has been endowed with adequate natural resources.

Figure -1: Types of non conventional energy sources

Introduction about the subject with videos

Links for videos:-

1.https://nptel.ac.in/content/storage2/courses/113106065/Week%208/Lesson19.pdf
2.https://www.youtube.com/watch?v=CPlsarZGBOo
3.https://www.youtube.com/watch?v=Fuyq6WrM1EA
4.https://ocw.mit.edu/courses/mechanical-engineering/2-997-direct-solar-thermal-to-electrical-energy-conversion-technologies-fall-2009/audio-lectures/MIT2_997F09_lec07.pdf
5.EnergyResources Conventional and Non-Conventional

6. https://www.youtube.com/watch?v=Zgp86PVXXuQ
7. https://www.youtube.com/watch?v=X0OZ6tpZ3Mc
8. https://www.youtube.com/watch?v=xKxrkht7CpY
9. https://www.youtube.com/watch?v=x3AfhSHAcqg
10. https://www.youtube.com/watch?v=VkTRcTyDSyk
11. https://www.youtube.com/watch?v=eyOXmqu4PS8
12. https://www.youtube.com/watch?v=e9LvM8EThyk
13. https://www.youtube.com/watch?v=9zgx-PlDEKA

Content

Thermo-electrical and thermionic Conversions

- Principle of working, performance and limitations

Wind Energy

- Wind power and its sources,
- site selection, criterion,
- momentum theory,
- classification of rotors,
- concentrations and augments,
- wind characteristics.
- Performance and limitations of energy conversion systems.

Objective of Unit

Students will be able to:

- Understand how to convert heat energy into electrical energy and difference between thermo-electric and thermionic conversion.
- Understand the concept of wind energy and how to convert momentum energy into mechanical and then into electrical energy.

Topic wise Objective (CO4)

Topic : Thermo-electrical and thermionic Conversions

Objective : Objective is to know about Thermo-electrical and Thermionic conversions, the difference between them. Also to understand the principle of working. It's performance and limitations.

CO 4. Solve the problems associated with Thermo-electrical and thermionic conversions and Wind Energy, wind characteristics, performance and limitations.

Prerequisite (CO4)

Topic : Thermo-electrical and thermionic Conversions

Prerequisite :Thermo-electric conversion works on principle of Seeback effect which is a solid state device that converts heat flux (temperature differences) directly into electrical energy through a phenomenon called the *Seebeck effect*

Introduction Thermoelectricity (CO4)

- The emf of thermocouple is rather too small for it to be used as a device for converting heat energy to electrical energy.

- However, thermocouples are of great practical use in measurement of temperatures, particularly in high temperature region, where the tolerable sensitivity is about C.

- The principle of measurement is to use the Seebeck equation.

- Where is the change in voltage, is the Seebeck coefficient for the thermocouple pair and is the change in temperature. (The relationship is not quite linear and one can use a nonlinear relationship with tabulated values of coefficients.)

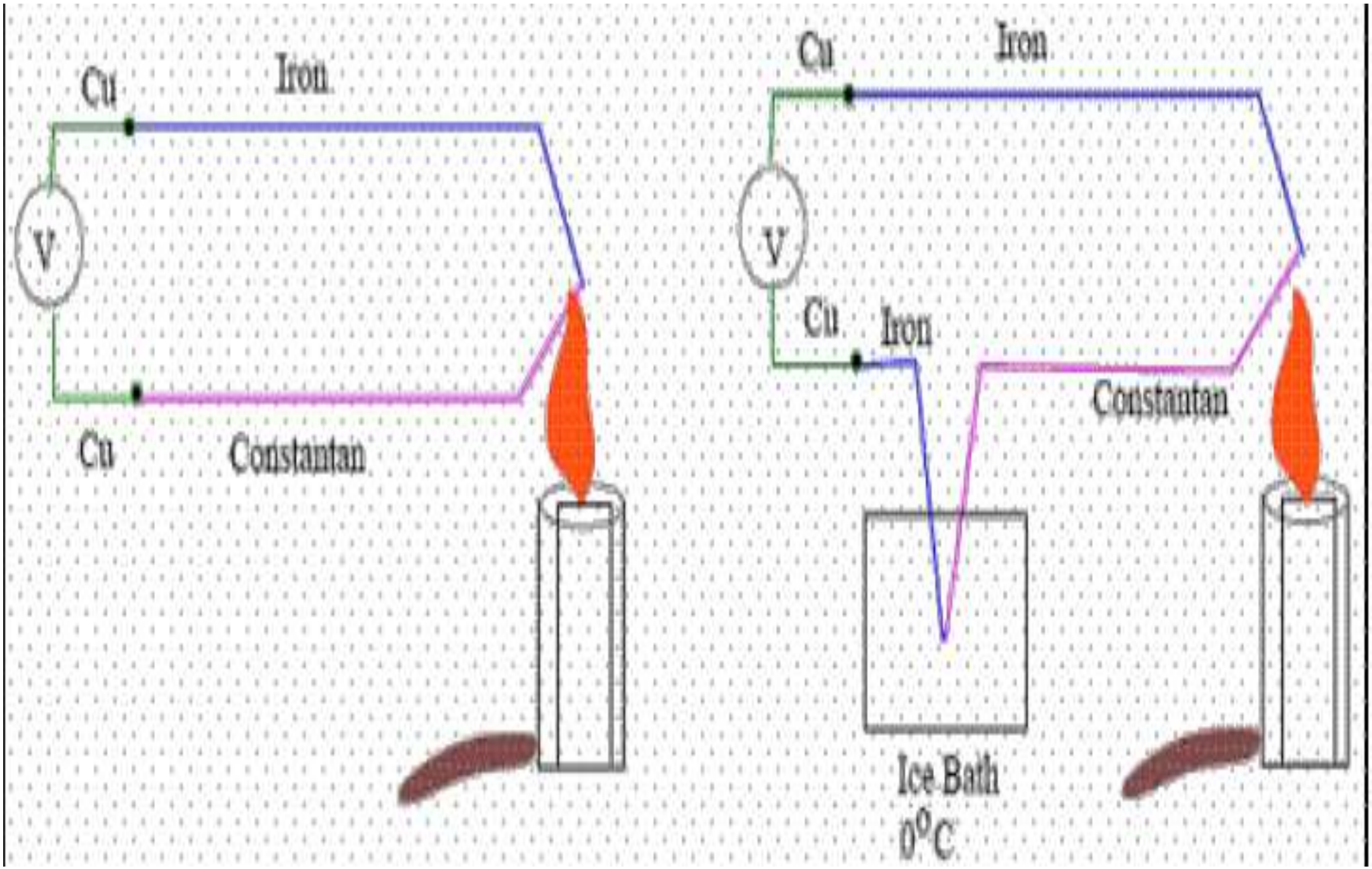
Introduction Thermoelectricity (CO4)

- We can measure the e.m.f. of the thermocouple with one of the junctions at a known temperature (called the reference temperature) and use the above equation to determine the temperature of the second junction.

- The system whose temperature is to be measured can easily be brought into thermal equilibrium with the second junction because of the small mass of the thermocouple.

- In scientific work, it is standard to use a thermocouple with Pt as one of the materials and an alloy of Pt-Rh as the other, to measure temperatures in the range of 1000 degree Celsius.

Introduction Thermoelectricity (CO4)



Empirical Laws of Thermoelectricity (CO4)

Law of Homogeneous Circuits:

- It is observed that electric current cannot be sustained in a circuit with a single homogeneous metal by application of heat alone.

- A consequence of this law is that given that junctions between two dissimilar metals are maintained at some temperatures.

- The thermal emf is not affected by the lead wires even when a thermal gradient exists along the lead wires.

Empirical Laws of Thermoelectricity (CO4)

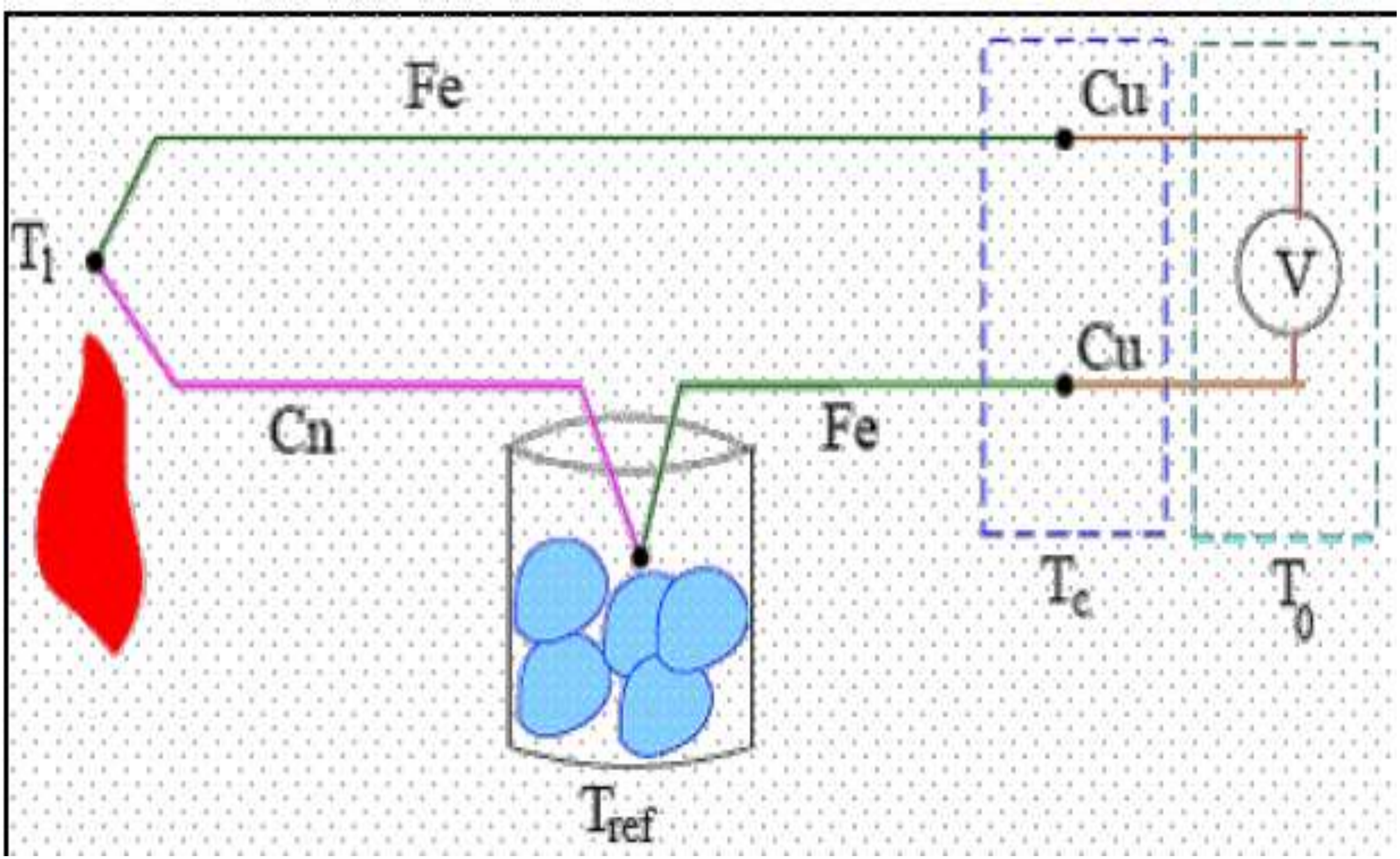
Law of Successive temperatures:

The law is useful in relating the value of emf found using some arbitrary but known reference junction temperature to that which one would obtain if a standard reference junction temperature (like freezing point of water) were used.

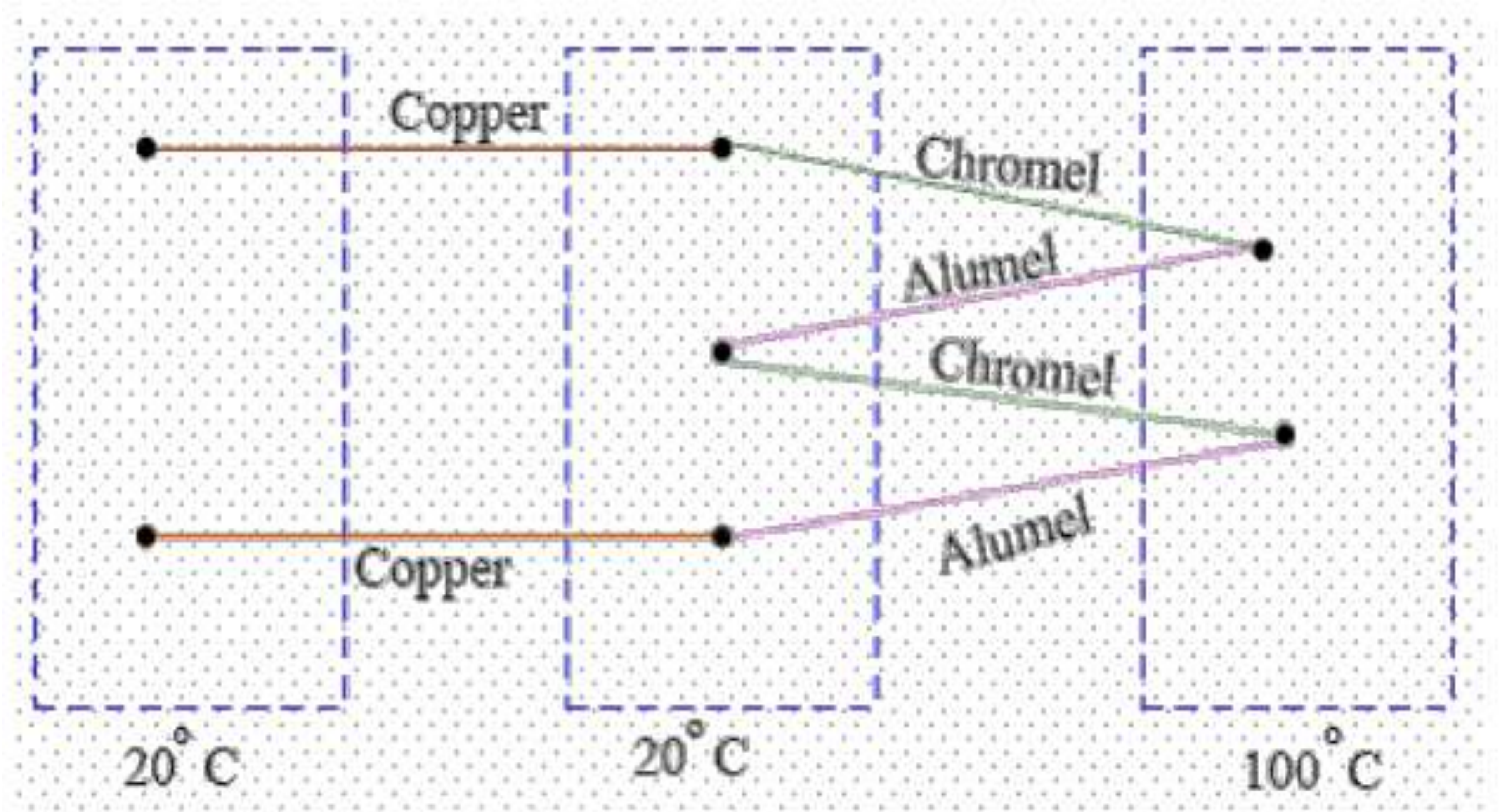
Law of Intermediate Metals:

According to this law, inserting an wire of arbitrary material into a thermocouple circuit has no effect on the thermal emf of the original circuit, if the additional junctions introduced in the circuit are at the same temperature.

Empirical Laws of Thermoelectricity (CO4)



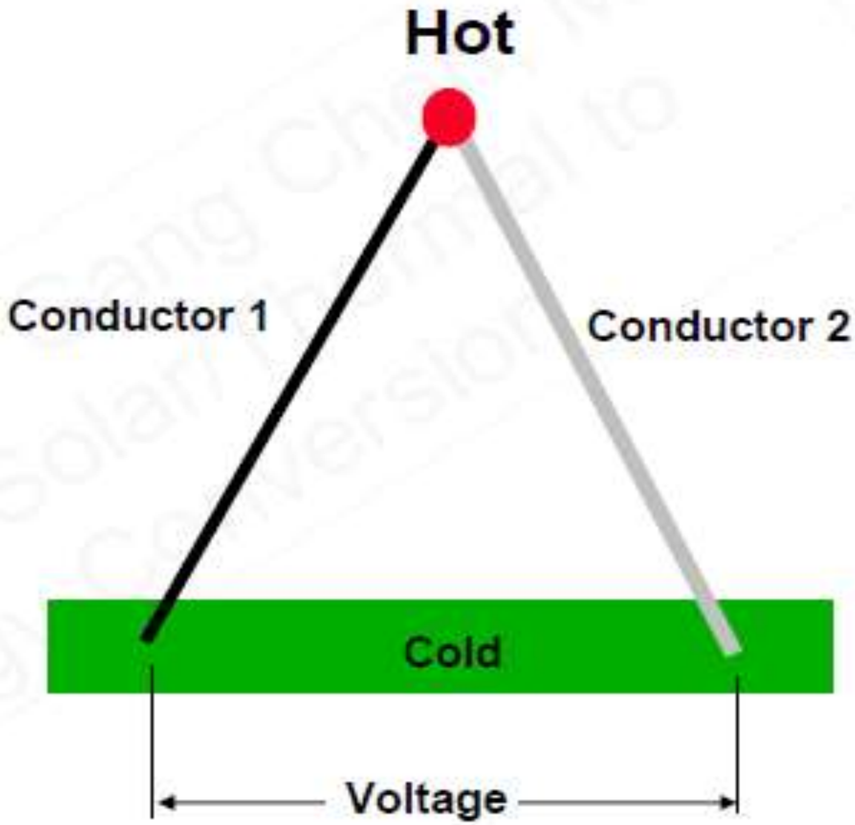
Application of Thermodynamics to Thermocouple (CO4)



Seeback Effect (CO4)

Seebeck Effect

Thomas Johann Seebeck
1770-1831

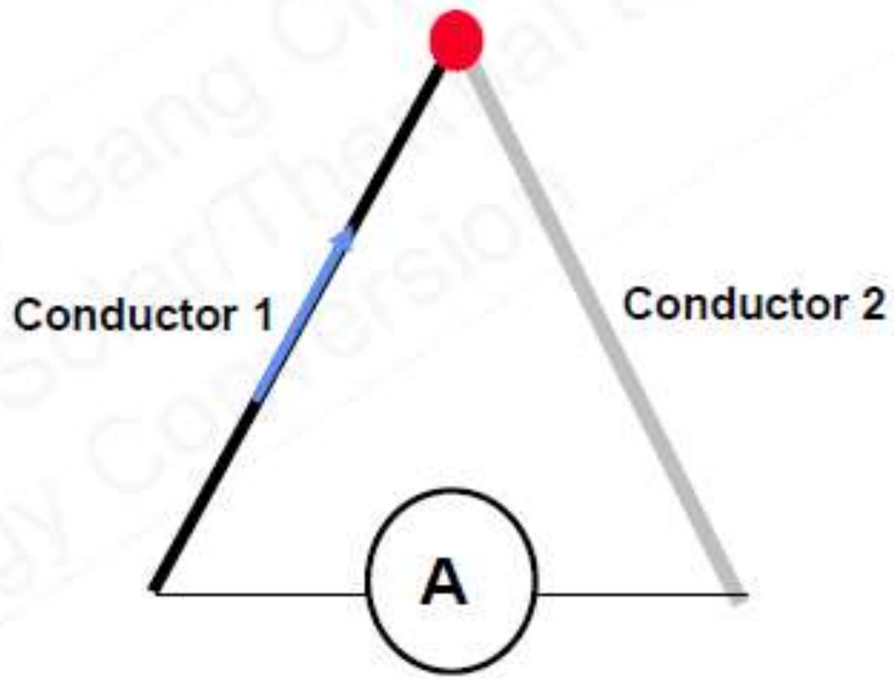


Seebeck effect: Discovered in 1821
Temperature difference generates voltage

Peltier effect (CO4)

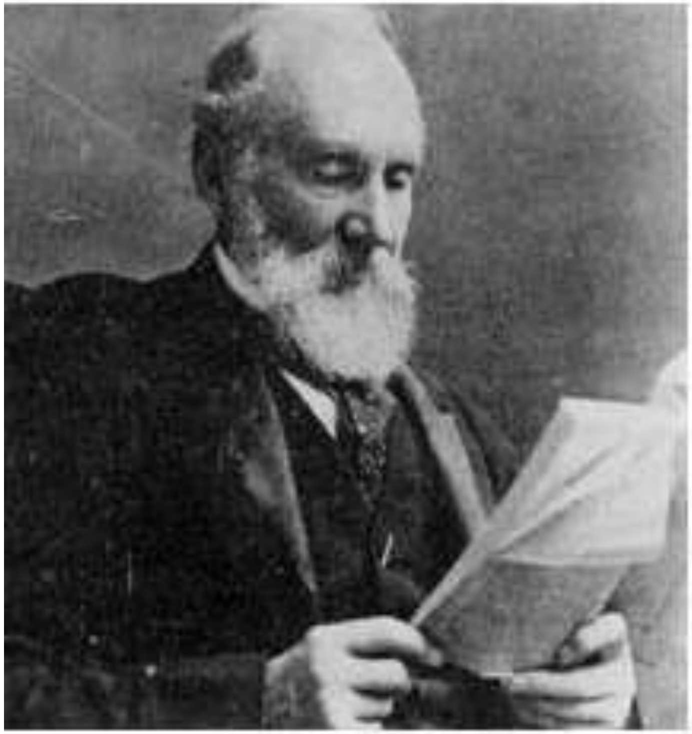
Jean Charles Athanase Peltier
1785-1845

Heating or Cooling



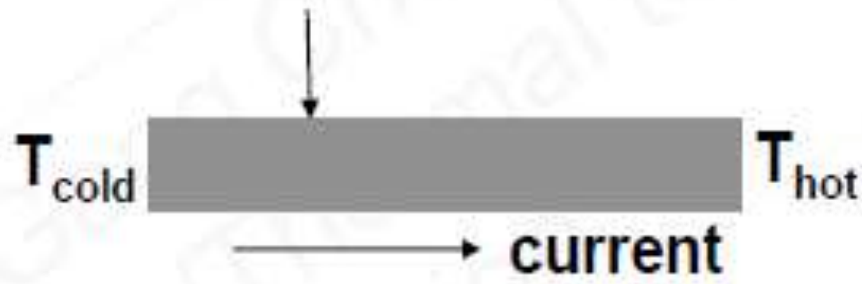
Peltier Effect: Discovered in 1834
An electrical current creates a cooling or heating effect at the junction depending on the direction of current flow.

Thomson Effect (CO4)



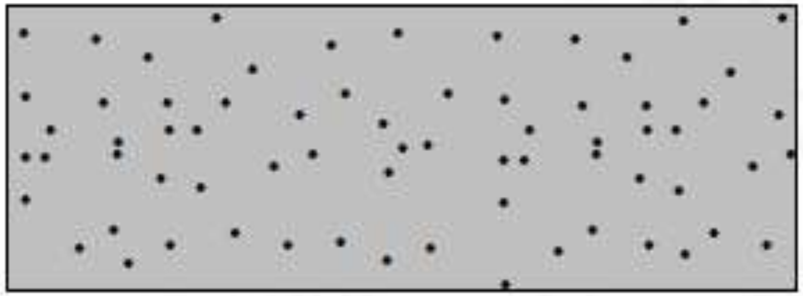
William Thomson
(Lord Kelvin)
1824 – 1907

heat release/absorption q(x)



Thomson effect predicted, 1855

Current Flow in an Isothermal Conductor (CO4)



Current Density $\mathbf{J}_e = en\mathbf{v} = en\mu\boldsymbol{\varepsilon} = \sigma\boldsymbol{\varepsilon} = \boldsymbol{\varepsilon}/\rho$

- Electron Charge [C]: e
- Electron Density [1/m^3]: n
- Drift Velocity [m/s]: $\mathbf{v}$
- Mobility [m^2/s.V]: μ
- Electrical Field [V/m]: $\boldsymbol{\varepsilon}$
- Electrical Conductivity [1/Ωm]: σ
- Electrical Resistivity [Ωm]: ρ

Heat Flux $\mathbf{J}_q = qn\mathbf{v} = \dfrac{q}{e}\mathbf{J}_e = \Pi\mathbf{J}_e$

- Heat Per Charge [J]: q
- Peltier Coefficient [J/A]: Π

Other Basic Relations: Heat Conduction (CO4)

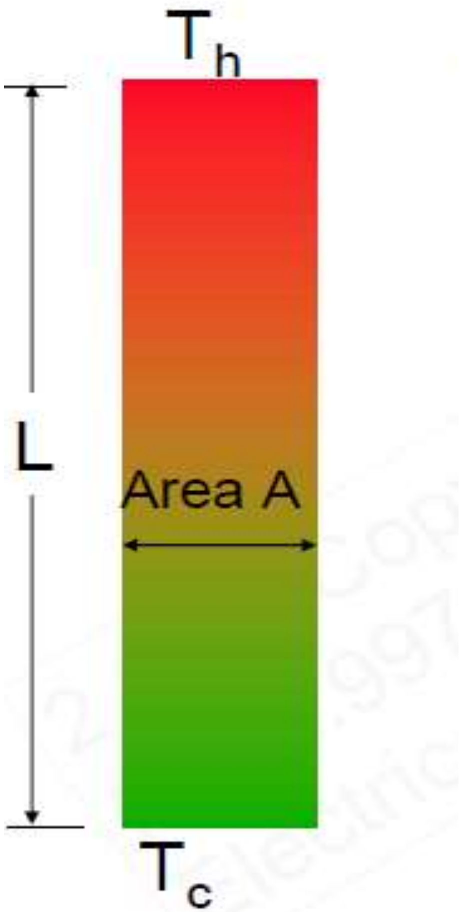
- Fourier law for heat conduction

$$q = -k\nabla T$$

Q= heat flux

K= thermal conductivity (W/mK)

T= temperature



- One dimensional heat conduction

$$Q = AK\left[\frac{T_h - T_l}{L}\right] = -k\nabla T$$

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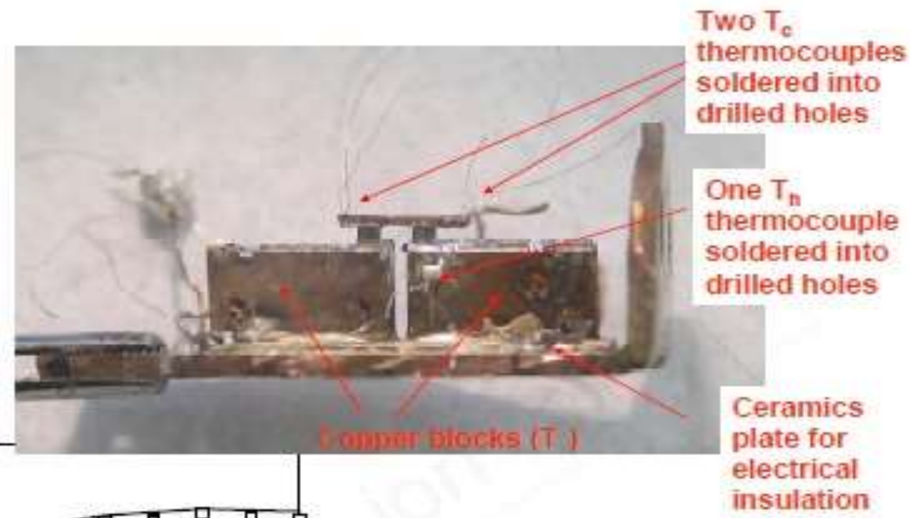
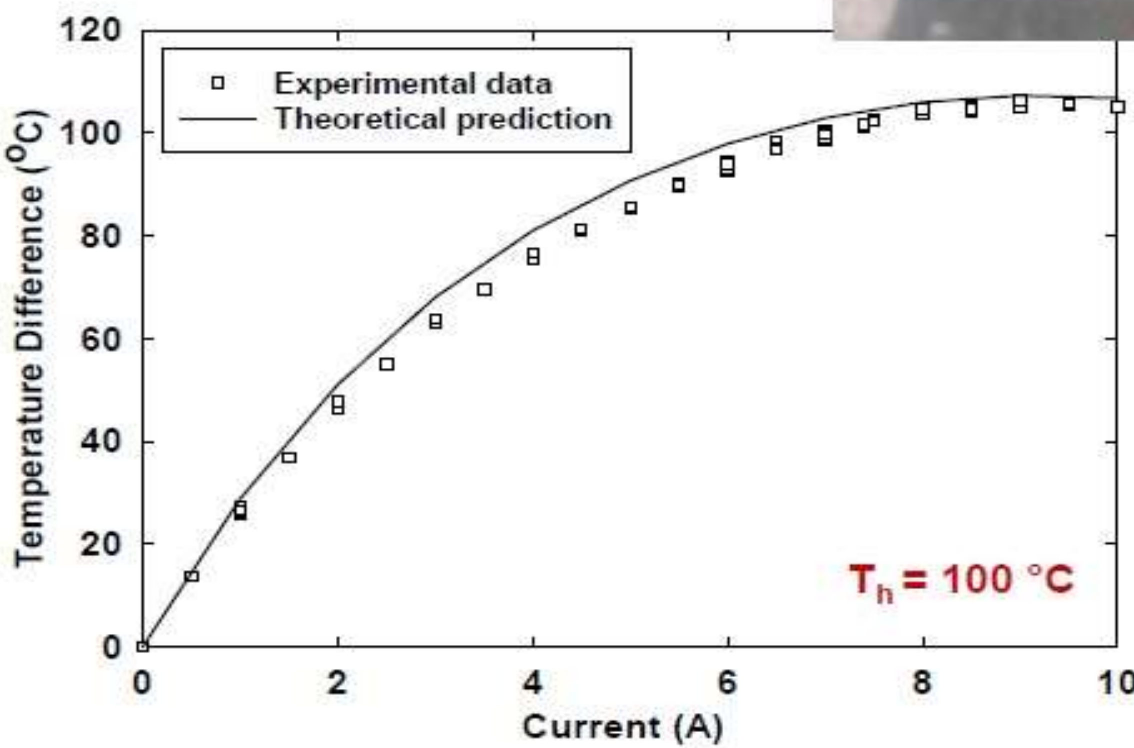
Performance (CO4)

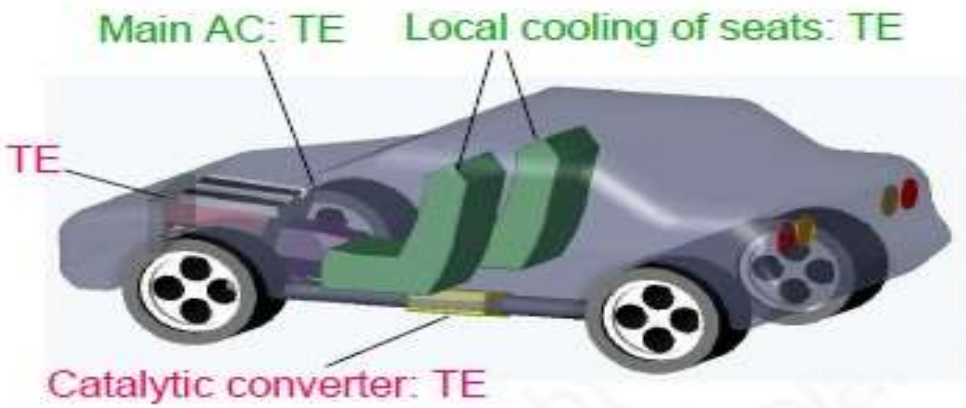




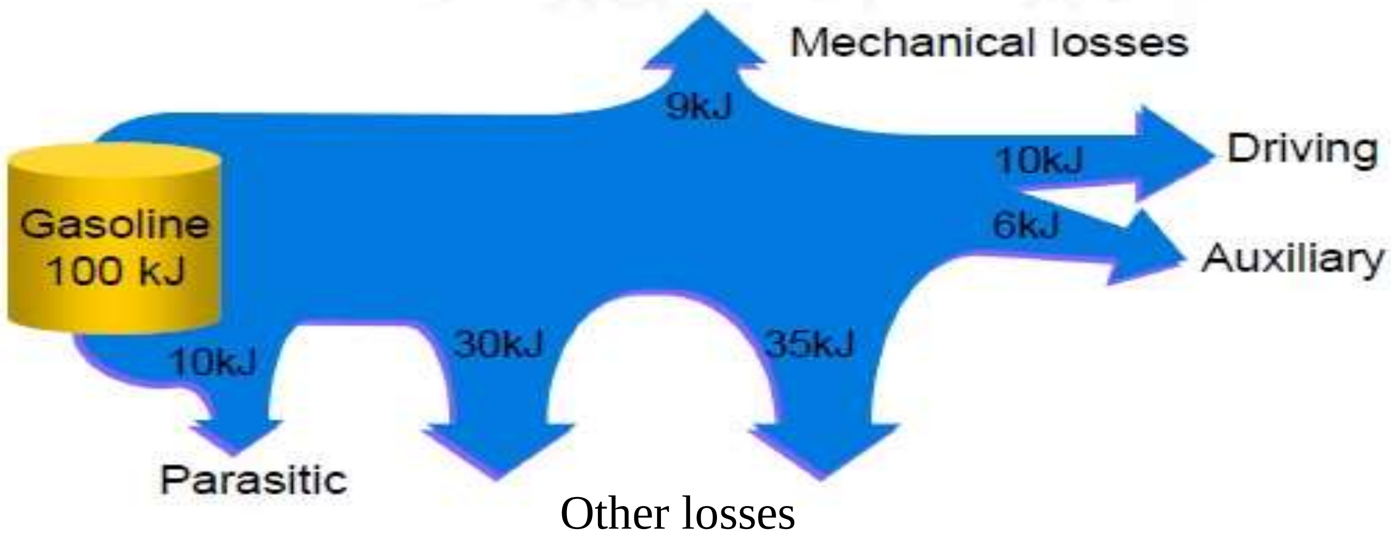
- Match two leg size
- Minimize contact resistance
- Optimize current

Example (CO4)

Vehicle Systems



In US, transportation uses ~26% of total energy.



Daily Quiz (CO4)

The biggest advantages of a thermoelectric power generator are

a) Cheap and compact

b) Cheap and bulky

c) Lowest maintenance and has ability to use high grade heat

d) Lowest maintenance and has ability to use low grade heat

The biggest disadvantages of a thermoelectric power generator are

a) Cheap and compact

b) Low cost and low efficiency

c) High cost high efficiency

d) High reliability and low cost

Daily Quiz (CO4)

The principle used to maintain cold and hot chamber in service cart used by an airhostess is

a) Seeback effect

b) Peltier effect

c) Avto effect

d) Tunneling

The space around the emitter can be greatly reduced by

a) Decreasing the gap between the electrodes

b) increasing the gap between the electrodes

c) Decreasing the temperature

d) Increasing the temperature

Daily Quiz (CO4)

For high temperature generated by combustion,

a) Both thermoelectric and thermionic generators are equally suited

b) Thermoelectric generators are more suited

c) Thermionic generators are more suitable

d) None of the two are suitable at high temperature.

Avto effect causes enhanced thermionic emission by

a) Increasing the gap between the electrodes

b) Increasing the voltage between electrodes

c) Choosing the appropriate material of cathode

d) Precise texturing of cathode surface at the nanoscale level.

Topic wise Recap (CO4)

Topic : Thermo-electrical and thermionic Conversions

Recap : In this topic we get to know about Thermo-electrical and Thermionic conversions, the difference between them. Also we understand the principle of working and It's performance and limitations.

Topic wise Objective (CO4)

Topic : Wind Energy

Objective : Objective is to understand what is wind. About the Wind power and its sources, Various parameters in site selection.

The momentum theory on which harvesting of wind energy is based upon. Also about the classification of rotors. We get to understand the wind characteristics.

CO 4. Solve the problems associated with Thermo-electrical and thermionic conversions and Wind Energy, wind characteristics, performance and limitations.

Prerequisite (CO4)

Topic : Wind Energy

Prerequisite: Concept of movement of air caused by the uneven heating of the Earth by the sun. Warm equatorial air rises higher into the atmosphere and migrates toward the poles. This is a low-pressure system.

Wind Energy (CO4)

Wind Energy is an indirect form of solar energy which can be used continuously unlike solar energy

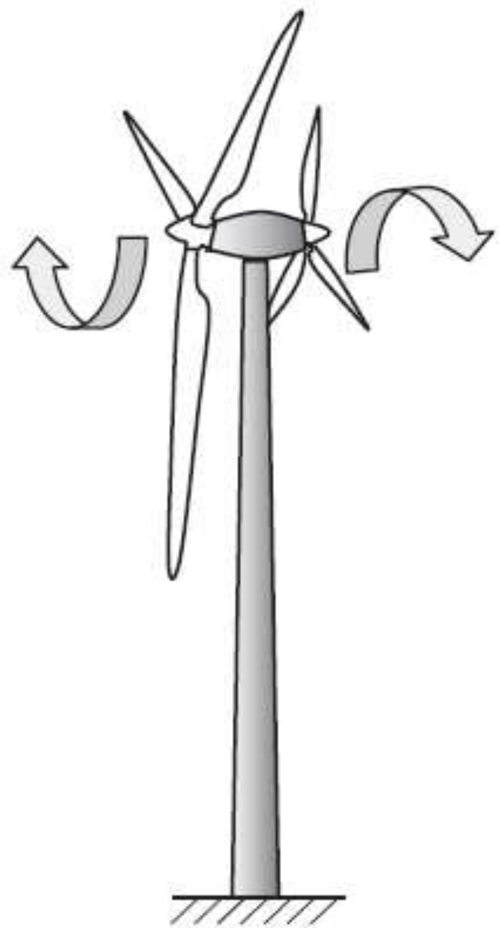


Illustration of a dual-blade set wind turbine.

Wind power (CO4)

Wind energy classified in two types

1.- Planetary winds

2.- Local winds.

- Planetary winds are cause due to greater heating of earth's surface near the equator as compared to solar heating near the south & north poles.
- Local winds are caused due to differential heating of land & water in coastal areas these are also caused due uneven heating in hill and mountains.

Wind power (CO4)

Site selection (CO4)

Four types of site are considered suitable. These are :

1.Plane land sites

2.Hill tops sites

3.Sea- shore sites

4.Off-shore shallow water sites.

Main considerations in selection of site (CO4)

The main considerations in selection of site for WECS(Wind Energy conversion system) are based on its technical feasibility, economics, social environment and other considerations some of the important criteria for selection of site are.

- Located where the high average wind velocities available are in the range of 6 m/s to 30 m/s throughout the year since power developed is proportional to cube of wind velocity.
- The WECS must be located for away from cities and forests since the buildings and forests offer resistance to the air movement. There should be no tall structures in 3 km radius from the installation.

Main considerations in selection of site (CO4)

b) The WECS must be located for away from cities and forests since the buildings and forests offer resistance to the air movement. There should be no tall structures in 3 km radius from the installation.

c) The wind farms are located in flat open areas, deserts , seas, shores and off shores site since wind velocities are of high in these locations.

Main considerations in selection of site (CO4)

d) Historical data of wind mean wind speed must be collected for average velocities during the year to select the site for availability of wind velocities needed for installation of wind farms.

e) Ground surface should have high soil strength to reduce the cost of foundation.

f) If small trees or vegetation exists at a particular location then it would need to increase the height of tower since any obstruction reduce the wind velocity. It causes the increase in cost of installation.

Main considerations in selection of site (CO4)

g) It should be installed away from localities so that the sound pollution caused by wind mills does not affect the habitants in near areas.

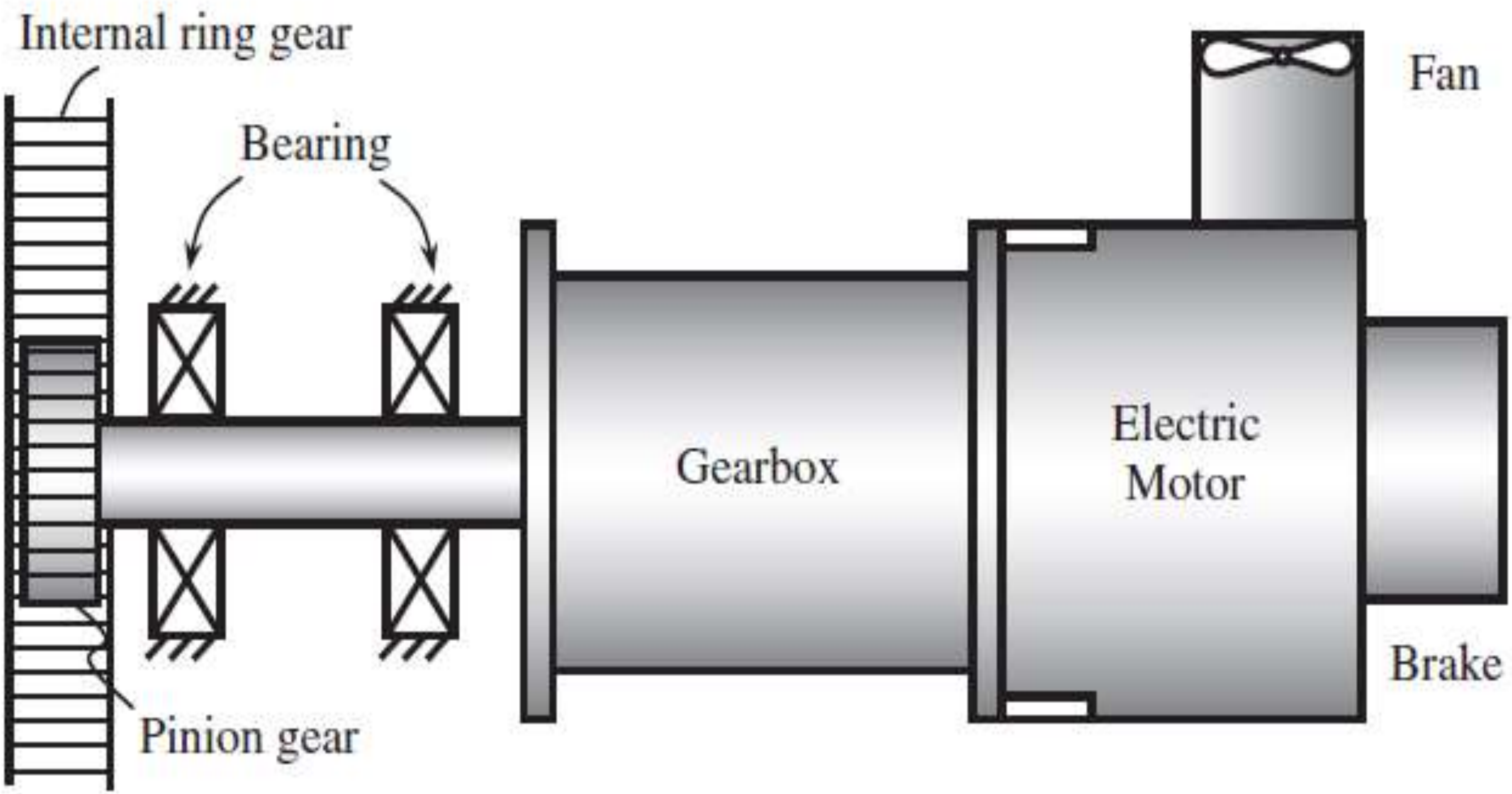
h) The minimum wind speeds at the selected site must be higher than 3.5 to 4.5 m/s which is the lower limit at which the present wind energy conversion system starts turning. It is called as cut-in-speed. Up to this speed no power will be generated by the system.

How Wind Power is Generated (CO4)

The terms "wind energy" or "wind power" describe the process by which the wind is used to generate mechanical power or electricity. Wind turbines convert the kinetic energy in the wind into mechanical power.

- This mechanical power can be used for specific tasks (such as grinding grain or pumping water) or a generator can convert this mechanical power into electricity to power homes, businesses, schools, and the like.

Wind Power Generation and Wind Turbine Design (CO4)



Coriolis force (CO4)

- The earth's self-rotation is another important factor to affect wind direction and speed.
- The Coriolis force, which is generated from the earth's self-rotation, deflects the direction of atmospheric movements.
- In the north atmosphere wind is deflected to the right and in the south atmosphere to the left.
- The Coriolis force depends on the earth's latitude; it is zero at the equator and reaches maximum values at the poles.
- In addition, the amount of deflection on wind also depends on the wind speed; slowly blowing wind is deflected only a small amount, while stronger wind deflected more.

Coriolis force (CO4)

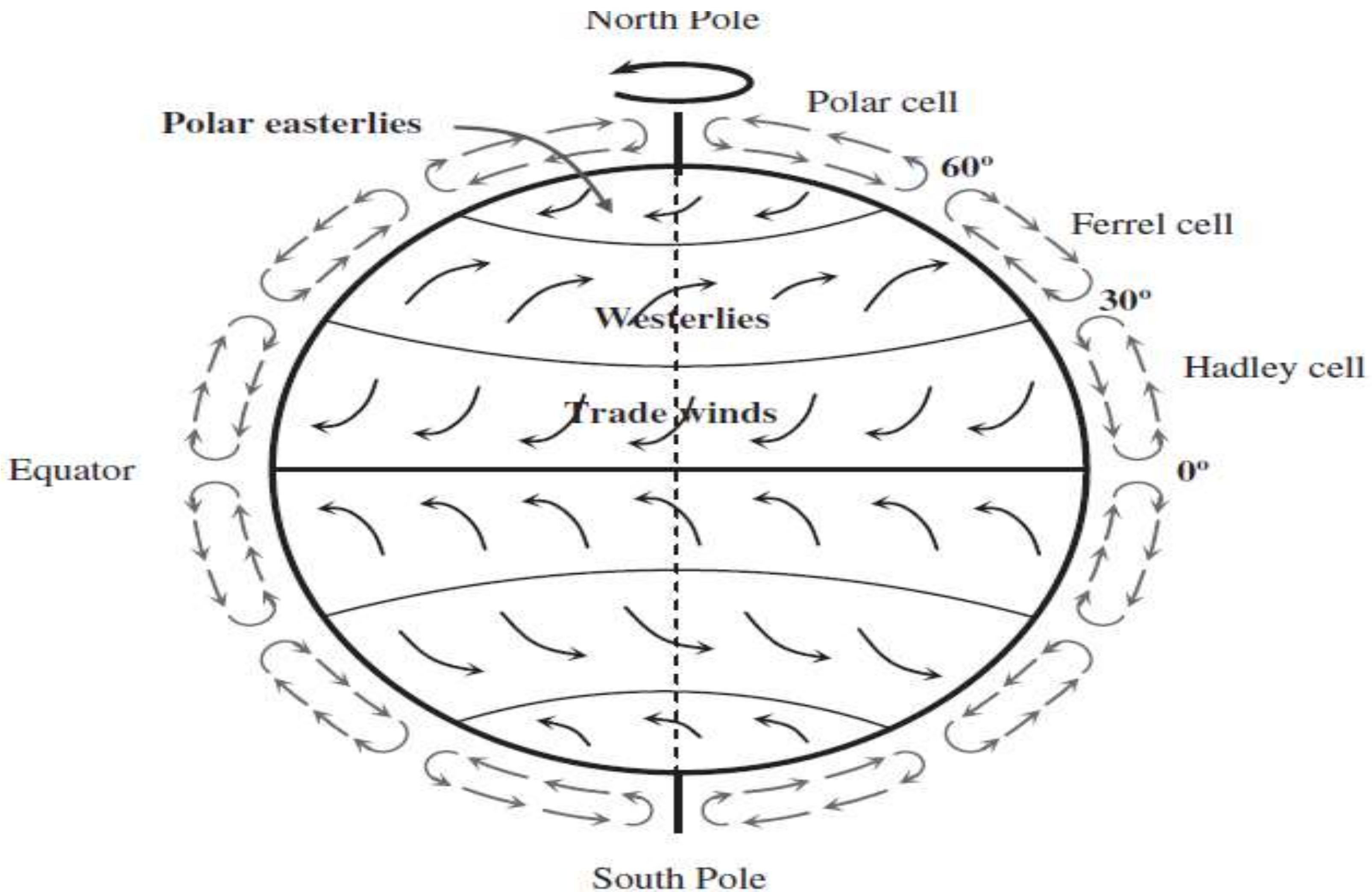


Figure 1: Idealized atmospheric circulations.

Blade swept area (CO4)

$$A = \pi l(l + 2r)$$

where l is the length of wind blades and r is the radius of the hub.

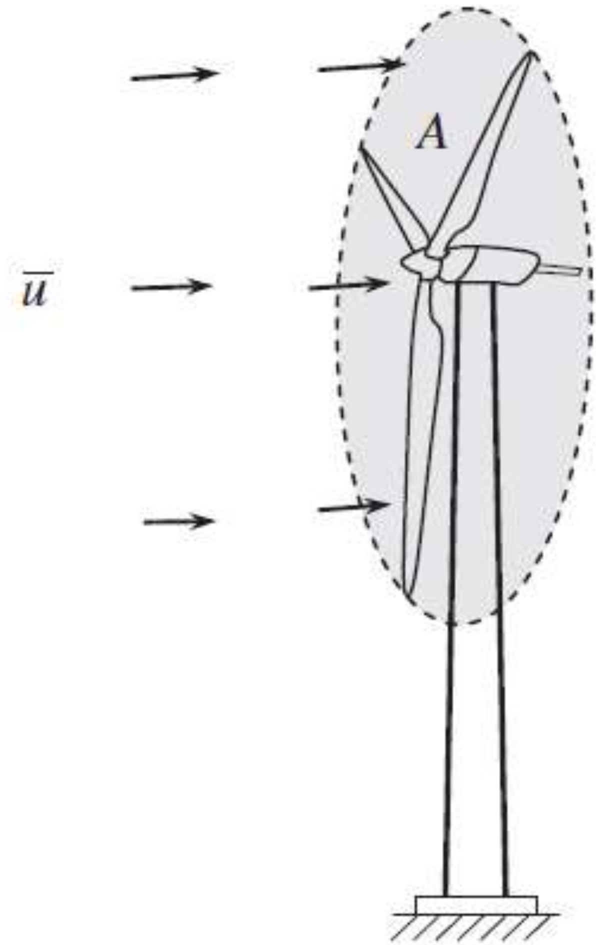


Figure 3: Swept area of wind turbine blades.

Wind characteristics (CO4)

Wind varies with the geographical locations, time of day, season, and height above the earth's surface, weather, and local landforms. The understanding of the wind characteristics will help optimize wind turbine design, develop wind measuring techniques, and select wind farm sites.

- Wind speed
- Weibull distribution
- Wind turbulence
- Wind gust
- Wind direction
- Wind shear

Wind speed (CO4)

- Wind speed is one of the most critical characteristics in wind power generation.

- In fact, wind speed varies in both time and space, determined by many factors such as geographic and weather conditions.

- Because wind speed is a random parameter, measured wind speed data are usually dealt with using statistical methods.

Weibull distribution (CO4)

Weibull distribution

- The variation in wind speed at a particular site can be best described using the Weibull distribution function, which illustrates the probability of different mean wind speeds occurring at the site during a period of time. The probability density function of a Weibull random variable *u*:

$$f(\overline{u},k,\lambda)=\begin{cases}\dfrac{k}{\lambda}\left(\dfrac{\overline{u}}{\lambda}\right)^{k-1}\exp\left(-\left(\dfrac{\overline{u}}{\lambda}\right)^{k}\right) & \overline{u}\geq 0\\ 0 & \overline{u}<0\end{cases}$$

Wind turbulence (CO4)

- Wind turbulence is the fluctuation in wind speed in short time scales, especially for the horizontal velocity component.
- The wind speed *u* (*t*) at any instant time *t* can be considered as having two components: the mean wind speed *u*– and the instantaneous speed fluctuation *u* ′(*t*), i.e.:

$$\boldsymbol{u(t) = \bar{u} + u' t}$$

Wind turbulence (CO4)

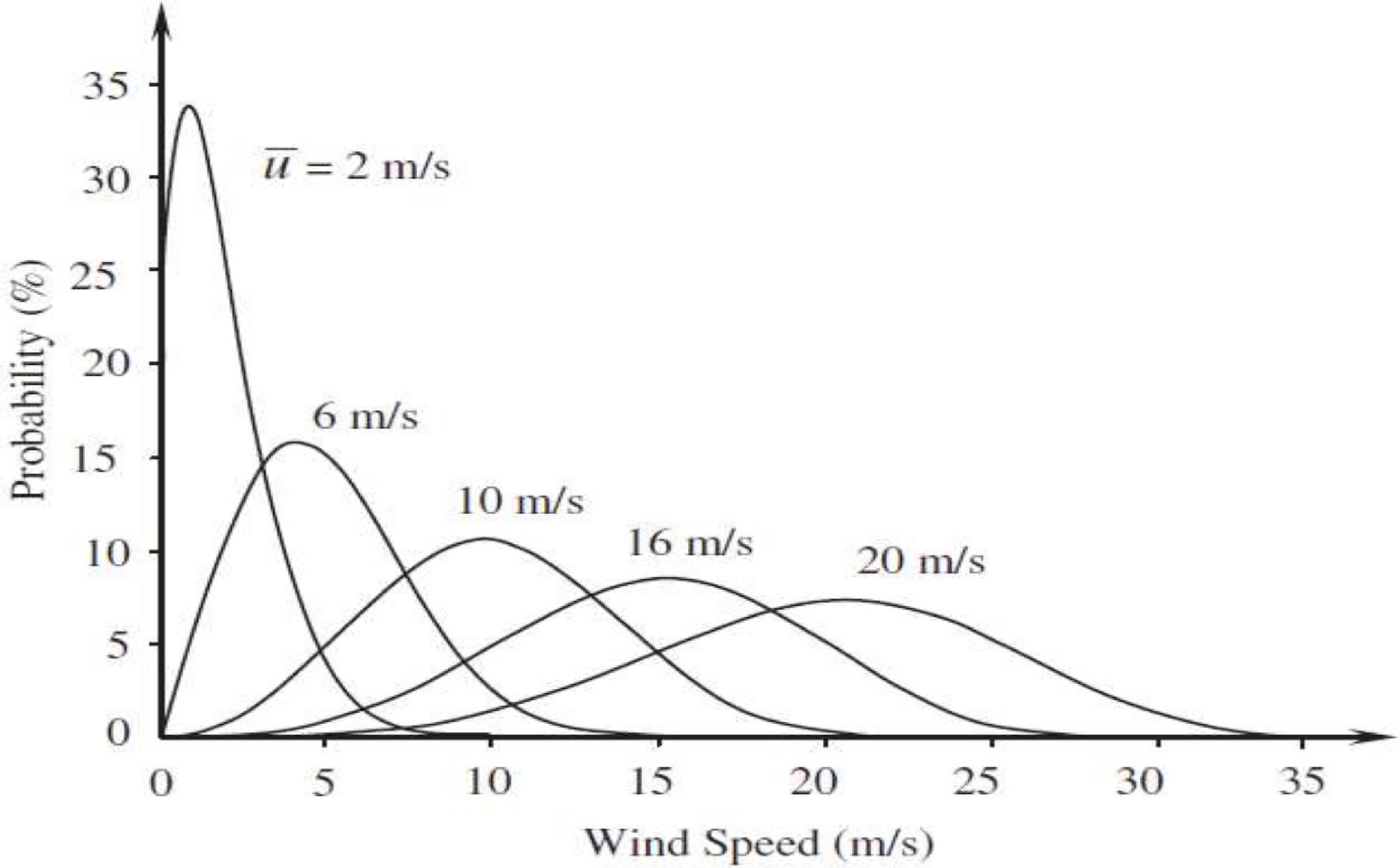


Figure 4: Weibull distributions for various mean wind speeds.

Wind direction (CO4)

- Wind direction is one of the wind characteristics. Statistical data of wind directions over a long period of time is very important in the site selection of wind farm and the layout of wind turbines in the wind farm.

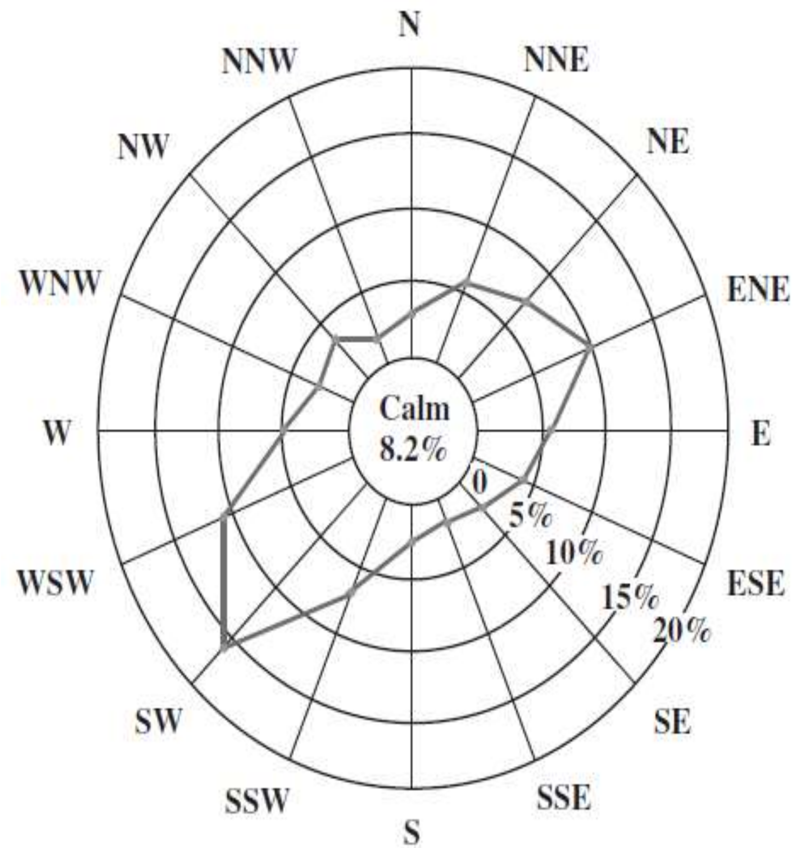


Figure 5: Wind rose diagram for wind directions.

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Wind shear (CO4)

- Wind shear is a meteorological phenomenon in which wind increases with the height above the ground.
- The effect of height on the wind speed is mainly due to roughness on the earth's surface and can be estimated using the Hellmann power equation that relates wind speeds at two different heights

$$\boldsymbol{u(z) = u(z_0)\ \{z|z_0\}^{a}}$$

- where z is the height above the earth's surface, z_0 is the reference height for which wind speed $u\,(z_0\,)$ is known, and a is the wind shear coefficient.

Daily Quiz (CO4)

Favorable wind for small scale applications exist

a) Everywhere on earth surface
b) 75% on earths surface
c) 50% on earths surface
d) 25 of the earths surface

There is little wind in the

a) North pole
b) South pole
c) Tropical
d) Around equator

The range of wind speed suitable for wind power generator is

a) 0 to 5m/s
b) 5 to 25 m/s
c) 25 to 50 m/s
d) 50 to 75 m/s

Daily Quiz (CO4)

Windmill typically capture all of the energy in the wind as long as the wind speeds are more than 20 kph

A)True B)False

For a given velocity for away from and after the windmill the belt limit is constant regardless of the velocity of the incoming wind

A)True B)False

Bernoulli's equation is representation of conservation of energy associated with fluid flow

A)True B)False

Wind fully dropped by the wind mill enables the extraction of all of the energy in the blowing windhover a long period of time

A)True B)False

Rotor blades are often made of glass fibber reinforced plastic

A)True B)False

Topic wise Recap (CO4)

Topic : Wind Energy

Recap : In this topic we get to understand about wind, Wind power and its sources, Various parameters in site selection.

The momentum theory on which harvesting of wind energy is based upon and classification of rotors.

Topic wise Objective (CO4)

Topic : Wind turbine

Objective : objective of this topic is to know about wind turbine which rotates and its various types.

Objective is to know about the performance and limitations of wind energy conversion systems.

CO.4. Solve the problems associated with Thermo-electrical and thermionic conversions and Wind Energy, wind characteristics, performance and limitations.

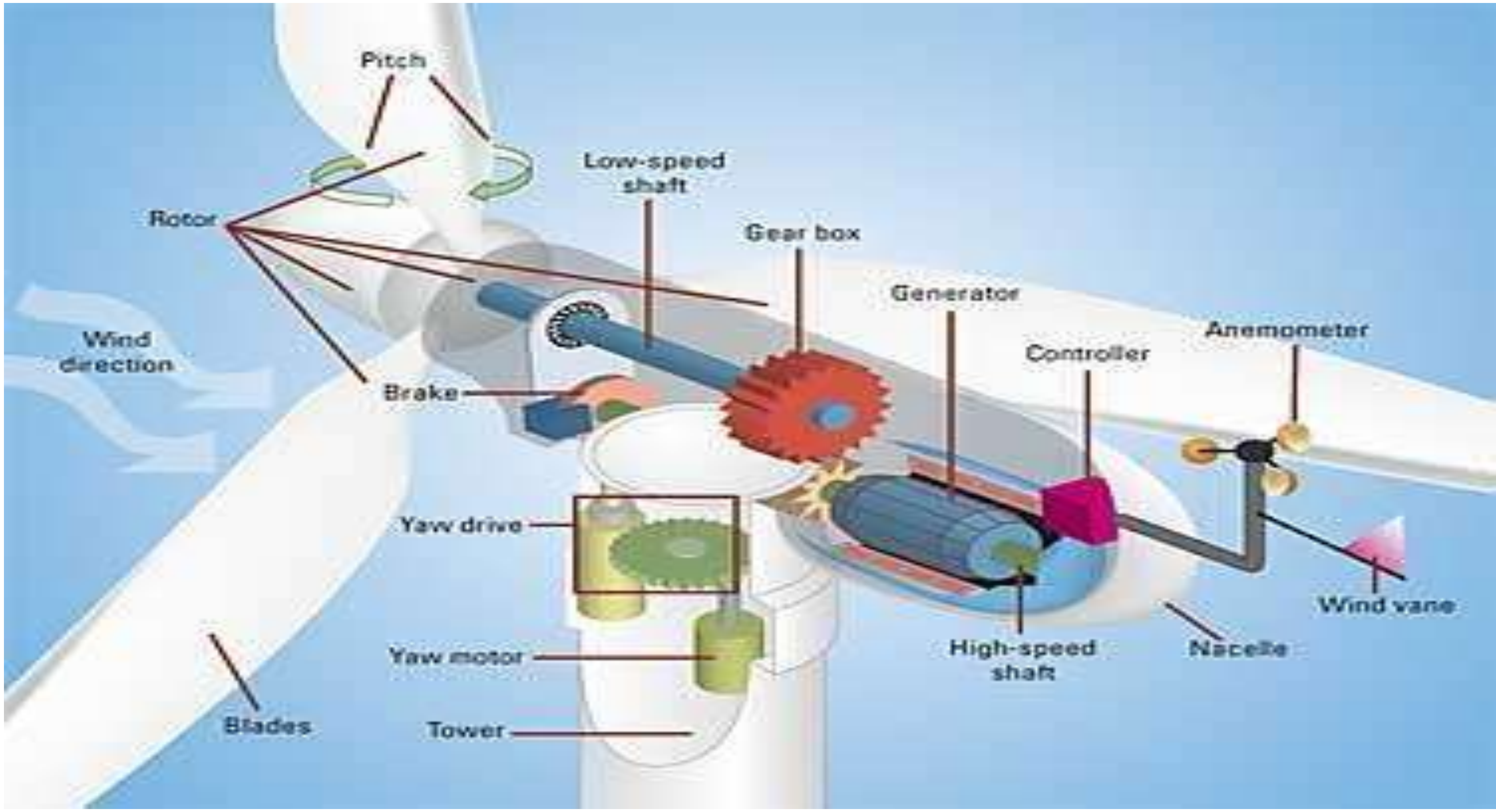
Prerequisite (CO4)

Topic : Wind turbine

Prerequisite : Some concepts kinetic energy of wind energy and rotational theory which will be applied when the turbine rotates due to kinetic energy of wind.

Wind Turbine (CO4)

Wind turbines, like aircraft propeller blades, turn in the moving air and power an electric generator that supplies electric current.



Wind Turbine (CO4)

- Unlike windmills which are used directly to do work such as water pumping or grain grinding, wind turbines are used to convert wind energy to electricity.
- The first automatically operated wind turbine in the world was designed and built by Charles Brush in 1888.
- This wind turbine was equipped with 144 cedar blades having a rotating diameter of 17 m.
- It generated a peak power of 12 kW to charge batteries that supply DC current to lamps and electric motors

Wind turbine classification (CO4)

Wind turbines can be classified according to the turbine generator configuration, airflow path relatively to the turbine rotor, turbine capacity, the generator-driving pattern, the power supply mode, and the location of turbine installation.

- Horizontal-axis and vertical-axis wind turbines
- Upwind and downwind wind turbines
- Wind turbine capacity
- Direct drive and geared drive wind turbines
- On-grid and off-grid wind turbines
- Onshore and offshore wind turbines

Horizontal-axis Wind Turbine(CO4)

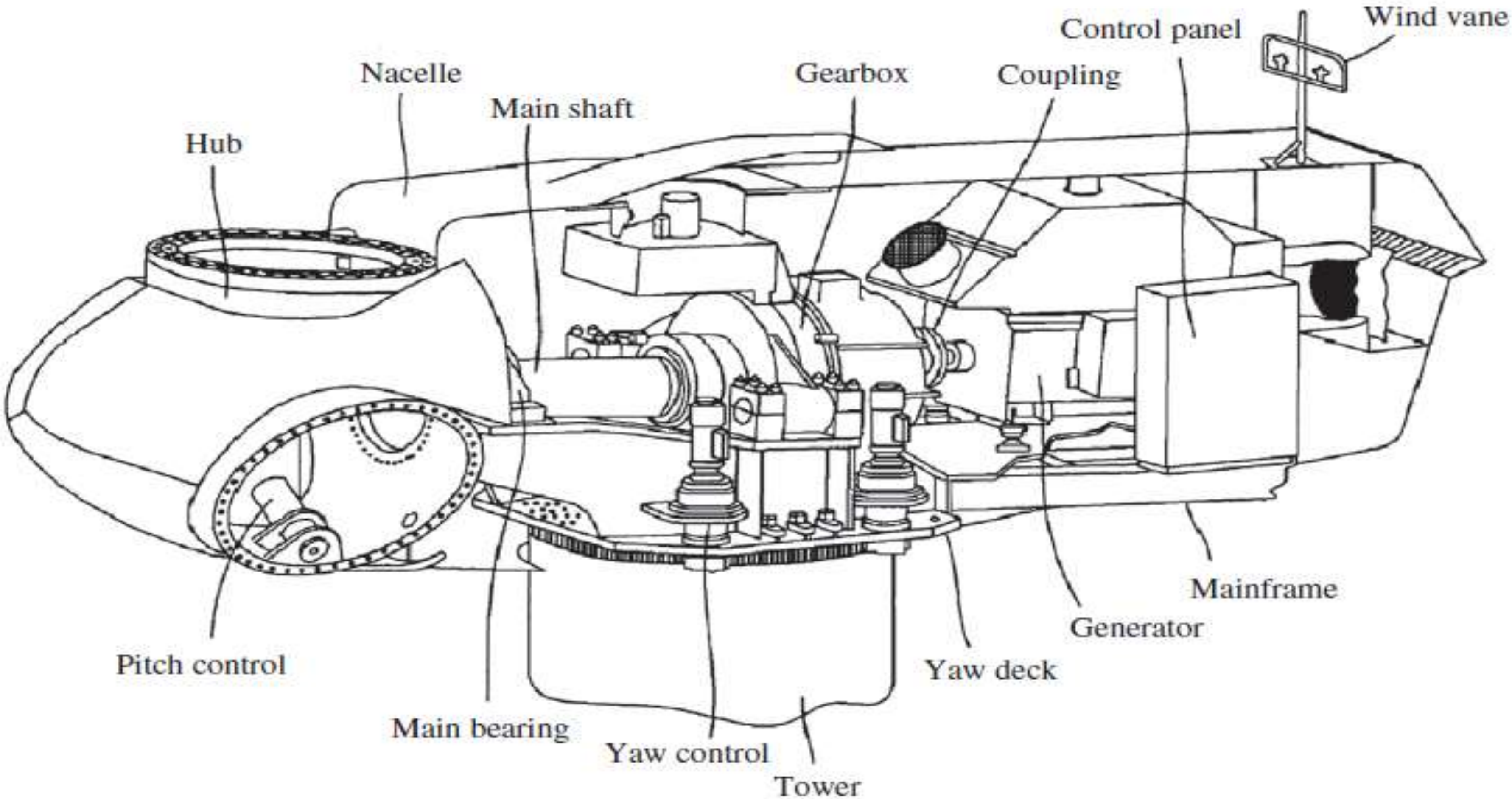


Figure 7: A horizontal-axis wind turbine configuration. Courtesy of the US Patent & Trademark Office.

Vertical-axis wind turbines (CO4)

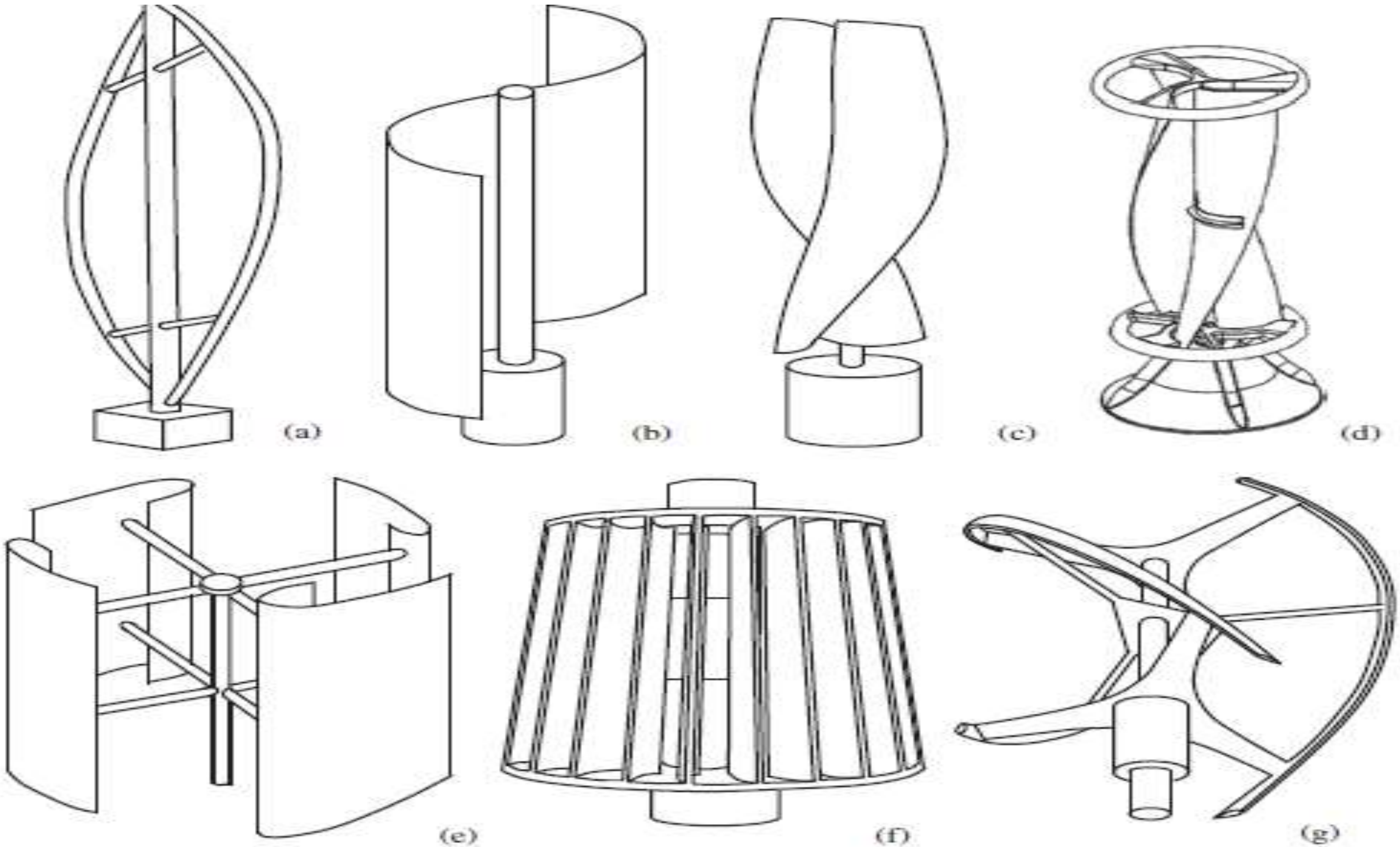


Figure 6: Several typical types of vertical-axis wind turbines: (a) Darrius; (b) Savonius; (c) Solarwind™ [36]; (d) Helical [37]; (e) Noguchi [38]; (f) Maglev [39]; (g) Cochrane [40].

Performance and limitations of energy conversion systems. (CO4)

Power coefficient

- The power coefficient C p deals with the converting efficiency in the first stage, defined as the ratio of the actually captured mechanical power by blades to the available power in wind.

$$C_p = \frac{P_{output}}{(1/2)\rho A\bar{u}^3}$$

- Because there are various aerodynamic losses in wind turbine systems, for instance, blade-tip, blade-root, profile, and wake rotation losses, etc., the real power coefficient C p is much lower than its theoretical limit, usually ranging from 30 to 45%.

Total power conversion coefficient and effective power output (CO4)

- the total power conversion efficiency from wind to electricity ηt is the production of these parameters, i.e

$$\eta = C_p \eta_{gear} \eta_{gen} \eta_{ele}$$

The effective power output from a wind turbine to feed into a grid becomes

$$P_{eff} = C_p \eta_{gear} \eta_{gen} \eta_{ele} P_w$$

Power curve (CO4)

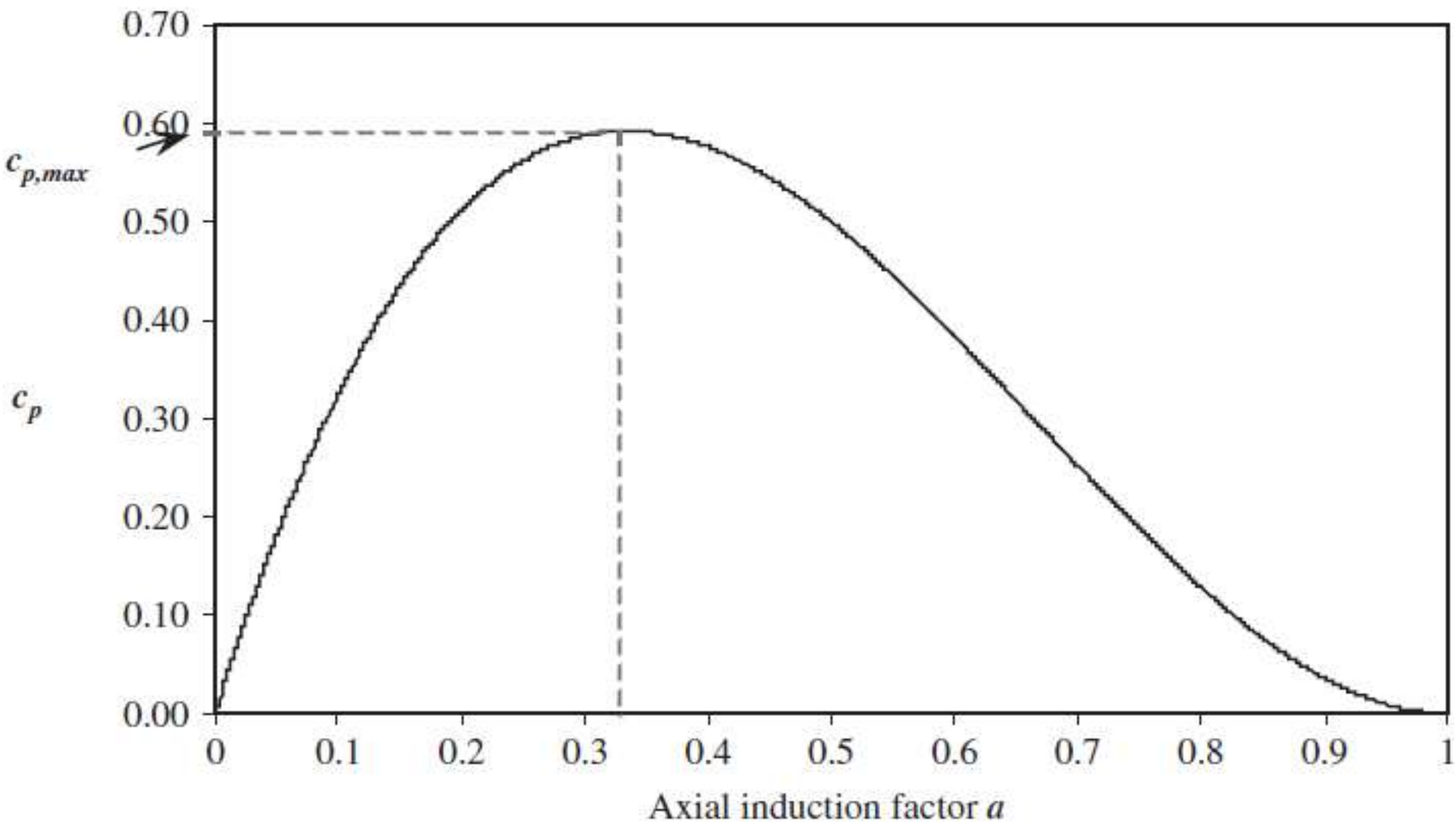


Figure 9: Power coefficient as a function of axial induction factor *a*.

Power curve (CO4)

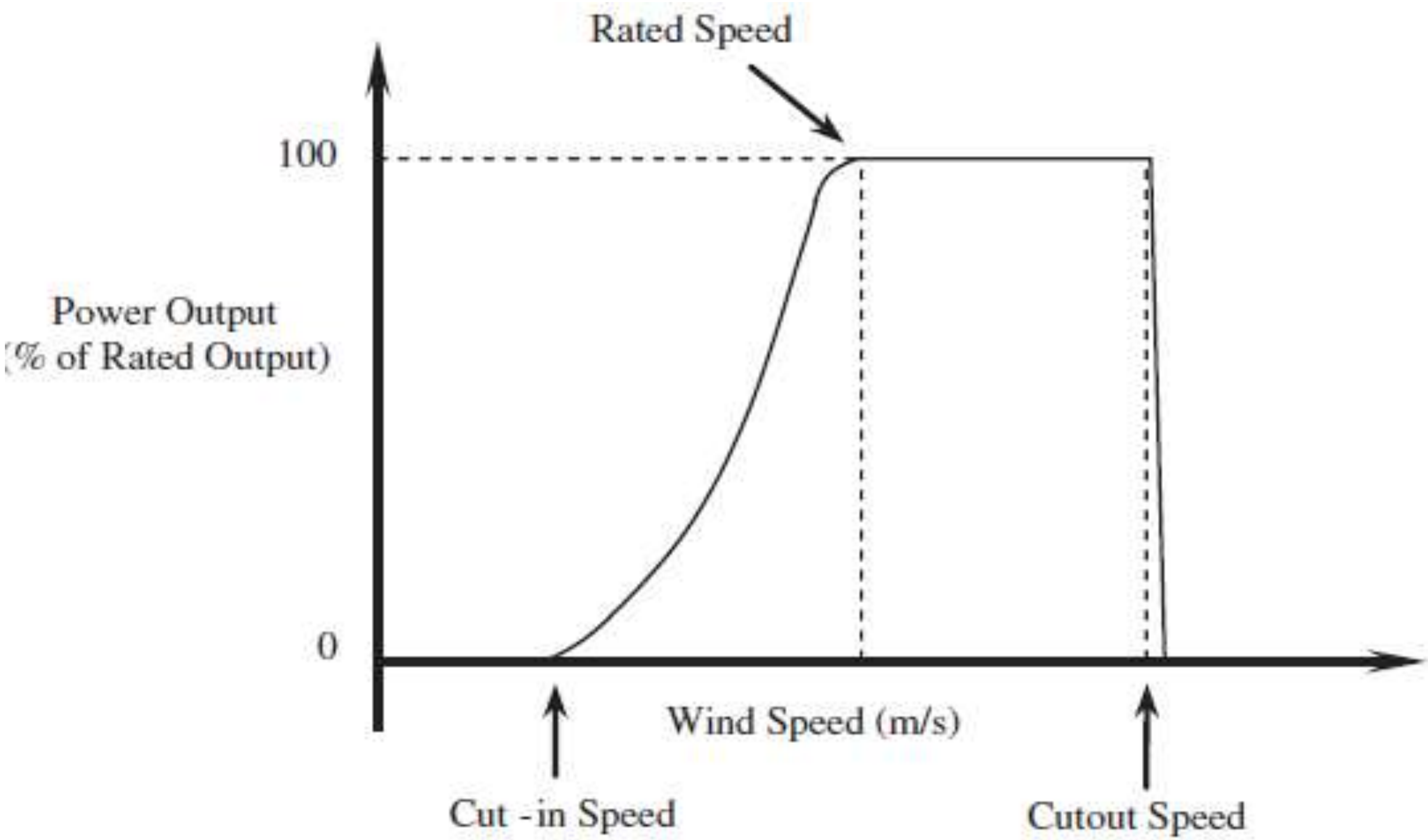


Figure 10: Typical wind turbine power curve.

Tip speed ratio (CO4)

- The tip speed ratio is an extremely important factor in wind turbine design, which is defined as the ratio of the tangential speed at the blade tip to the actual wind speed, i.e

$$\lambda = \frac{(l + r)w}{u}$$

- where *l* is the length of the blade, *r* is the radius of the hub, and *w* is the angular speed of blades.

Wind–solar hybrid system (CO4)

- Both wind and solar energy are highly intermittent electricity generation sources.
- Time intervals within which fluctuations occur span multiple temporal scales, from seconds to years.
- These fluctuations can be subdivided into periodic fluctuations (diurnal or annual fluctuations) and non-periodic fluctuations related to the weather change.

Wind–solar hybrid system (CO4)

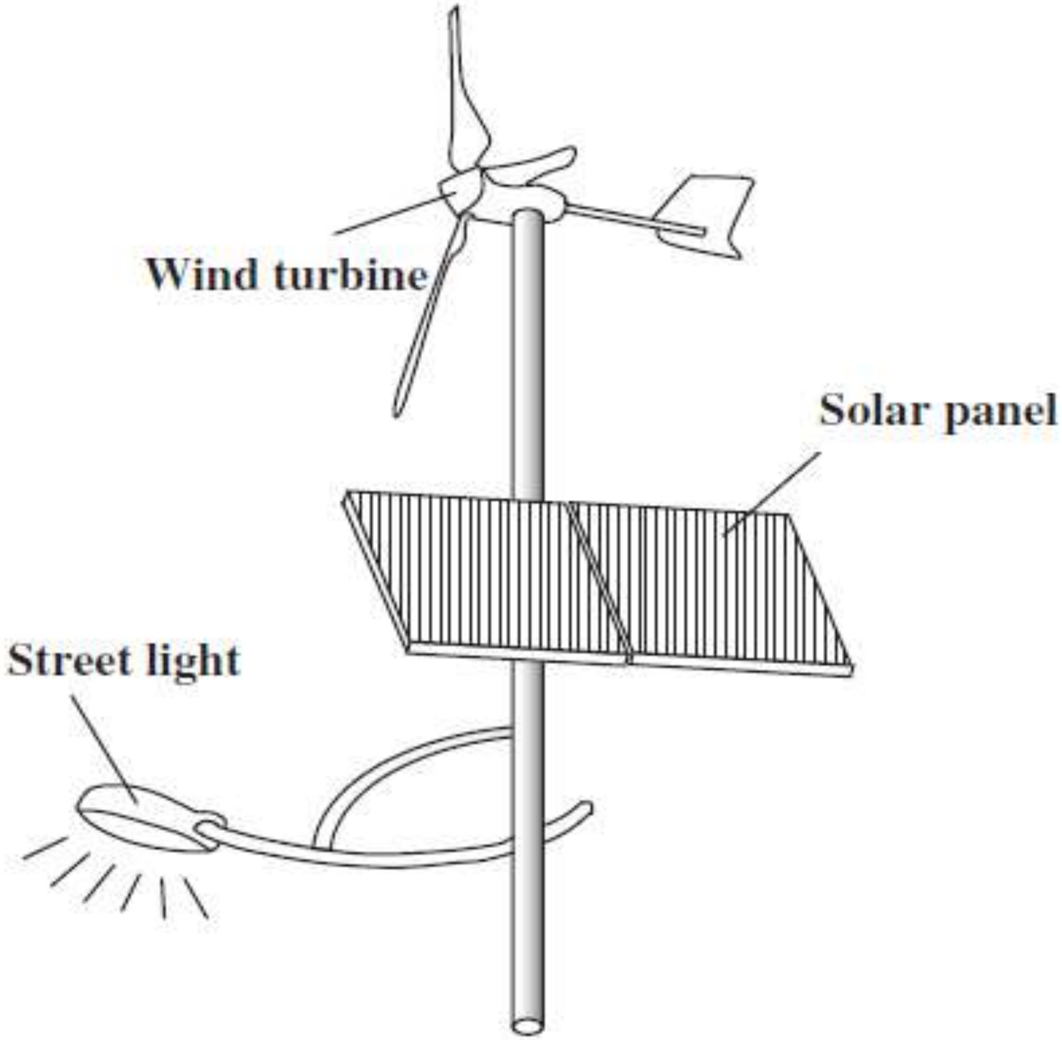


Figure 16: Wind–solar hybrid system for street lights.

Performance and Limitations of Energy conversion systems (CO4)

Advantages :-

- It is available free and is inexhaustible.
- It is clean and Non-Polluting.
- Have low maintenance cost.
- Has low cost of power generation of about Rs.2.25/KWH.

Performance and Limitations of Energy conversion systems (CO4)

Disadvantages :-

- At present capital cost is high. it is about Rs.3.5 Crores/MW.
- Wind energy available is dilute and fluctuating in nature both in magnitude direction.
- Large variation in wind speed during cyclones, hurricanes, tornadoes may cause damage to installation .
- Design of system is difficult aue to large variation of wind speed from time to time and season to seasons.
- These problems also require the provision of suitable storage device to ensure continuous power supply.
- It causes sound pollution. A large unit can be heard few kilometers away.

Limitations of energy conversion systems. (CO4)

While wind power generation offers numerous benefits and advantages over conventional power generation, there are also some challenges and problems need to be seriously addressed.

- Environmental impacts
- Wind turbine noise
- Integration of wind power into grid
- Thermal management of wind turbines
- Wind energy storage
- Wind turbine lifetime
- Cost of electricity from wind power

Daily Quiz (CO4)

Wind turbine extract maximum power from wind when the downstream wind speed reduces to

a) One third of upstream

b) Half of upstream

c) Two third of upstream

d) Zero

Stalled flow occurs when the value of the incident angle is

a) 0 degree

b) 180 degree

c) 0 to 16 degree

d) More than 16 degree

Daily Quiz (CO4)

The maximum axial thrust occurs when interference factor a is

a) 0

b) 0.33

c) 0.5

d) 1

The wind turbine rotor having a low value of solidity

a) Runs slower

b) Runs faster

c) Produces high torque

d) Has low efficiency

Daily Quiz (CO4)

Windmill shaft cannot be connected to the generator without a gear

A)True B)False

Pressurised concrete is often used in the construction of the towers associated with wind turbines

A)True B)False

Based on the design the Tip Speed ratio can be less than 1 or greater than 1

A)True B)False

Savona's wind turbines are based on the drag principle

A)True B)False

The number of blades in a horizontal axis wind turbine must be 3

A)True B)False

Topic wise Recap (CO4)

Topic : Wind Turbine

Recap : In this topic we get to understand about wind turbine blades and their various types.

We learnt about the wind characteristics and the performance and limitations of energy conversion systems.

Summary

- Considerable interest in tapping wind energy both internationally as well as in India
- Geographical locations play an important role in planning windmill installations
- Various designs of wind mills considered historically
- The power available in Wind is proportional to the third power of wind velocity
- There are practical aspects that limit the range of wind velocities that can be effectively tapped
- There is a theoretical limit to the extent to which energy available in the wind, can be captured

Faculty Video Links, Youtube & NPTEL Video Links and Online Courses Details

YouTube/other Video Links

Thermoelectric conversion

https://www.youtube.com/watch?v=uOgzOHW1ip8

https://www.youtube.com/watch?v=0jOHce18AXM&t=55s

https://www.youtube.com/watch?v=9YLJ-Wrye8Q

https://www.youtube.com/watch?v=G9NgoxHMPwk

https://www.youtube.com/watch?v=FrRijaNfFbo

Faculty Video Links, Youtube & NPTEL Video Links and Online Courses Details

YouTube/other Video Links

Wind energy

https://www.youtube.com/watch?v=qSWm_nprfqE

https://www.youtube.com/watch?v=4kW1y9xZOZM

https://www.youtube.com/watch?v=_pngOp-8KiU

https://www.youtube.com/watch?v=LjZwF4JpeoU

https://www.youtube.com/watch?v=xy9nj94xvKA

https://www.youtube.com/watch?v=f3hgB-0rPOI

https://www.youtube.com/watch?v=GExTwRNkQBg

https://www.youtube.com/watch?v=AckRAYQ8N48

Weekly Assignment

1. What factors led to accelerated development of wind power?
2. Comment on the environment impacts of wind energy
3. Explain the major applications of wind power.
4. Explain the variation of power output of a wind turbine with tip speed of the rotor
5. What are the potential applications of thermionic converters?
6. Comment on the type of materials required in a thermionic converter?
7. What range of wind speed is considered favorable for wind power generation?
8. What are the types of wind turbine available?
9. Write the expression for energy available in the wind?
10. What do you understand by gust?

MCQ s

.______ force is responsible for forcing the global winds towards westerly direction.

A)corollas B)gravitational

C) centripetal D)Centrifugal

Global winds towards we sternly direction are know as

A)Trade winds B)western winds

C)Eastern winds C)none of the above

Uneven heating occurs on land surface and water bodies are due to____

A)air currents B)solar radiation

C)Lunar eclipse D)none of the above

.

The following factors affects the distribution of wind energy .

A)mountain chains B)The hills , ,trees and buildings

C)frictional effect of the surface D)the all of the above

The amount of energy available in the wind at any instant is proportional to ___ of the wind speed.

A) Square root power of two (B) Square root power of three (C) Square power (D) Cube power

MCQ s

The amount of energy available in the wind at any instant is proportional to ___ of the wind speed.

A Square root power of two

B Square root power of three

C Square power

D Cube power

Wind energy is harnessed as ______ energy with the help of windmill or turbine.

A Mechanical

B Solar

C Electrical

D Heat

The following is (are) the classification of winds

A Global wind

B Local wind

C Both (A) and (B)

D None of the above

MCQ s

Winds having following speed are suitable to operate wind turbines.

A)5 -25m/sec B)10-35m/sec

C)20-45m/sec D)30-55m/sec

The following is (are) the classification of winds

A)Global wind B)local wind

C)Both (A)and(B) D) none of the above

Global called wind move from

A)Polar to equatorial region B)equatorial to polar region

C) equatorial to oceanic region D) Oceanic to equatorial region

Global called wind generated from ocean moves to

A)mountains B)equator

C) plain areas D)Poles

Old Question Papers

1. Attempt any two out of the following 2*10=20

(a) Discuss renewable forms of energy. Highlight their merits and demerits.

(b) With the aid of block diagram explain autonomous solar power plant and combined solar power plant.

(c) Describe principle of solar photovoltaic conversion. Discuss the limitations of solar photovoltaic energy conversion.

2. Attempt any two out of the following 2*10=20

(a) Describe the construction of solar flat plate collector. How is its performance evaluated?

(b) Classify various energy storage system. Describe steam storage system for solar thermal energy.

(c) Describe solar absorption refrigeration system for space cooling.

Old Question Papers

3. **Attempt any two out of the following** **2*10=20**

(a) Explain a vapor dominated geothermal power plant. What are the environmental constraints in design of geothermal power plant.

(b) How are MHD system classified? Describe them in brief.

(c) Describe the principle of working of a fuel cell with reference to hydrogen oxygen cell. Discuss advantages and disadvantages of fuel cell.

4. **Attempt any two out of the following** **2*10=20**

(a) Explain principle of power generation in windmills. Derive an expression for maximum efficiency.

(b) Describe main consideration in selecting a site for a wind farm. Discuss merits and demerits of wind energy.

(c) Describe the principle of operation and constructional details of a basic generator.

Old Question Papers

5. Attempt any two out of the following **2*10=20**

(a) Classify biomass conversion technologies. Explain anaerobic digestion process for production of methane.

(b) Discuss the technology of OTEC. What are the environmental effects of OTEC.

(c) What are tidal waves? How can power be produced in single tidal system.

Expected Question

1. Discus various types of drive schemes used in wind turbines.
2. Explain the terms: wind shear, gradient height, free atmosphere, planetary boundary, surface layer and Ekman layer.
3. Evaluate the suitability of various types of generators for wind-power generation
4. Mention the merits of a thermionic converter. On what parameters do the output voltage and current depend?
5. Explain the heating and cooling applications of a thermoelectric system. Comment on the type of materials used for low and high-temperature applications
6. What are the various factors which effect the site selection for wind turbine.
7. Difference between thermionic conversion and thermoelectric conversion.
8. Define Seeback and Peltier effect.
9. Why three blades are used in wind turbine
10. Discuss vertical axis turbine blade of wind turbine.

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Thank You