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 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.)

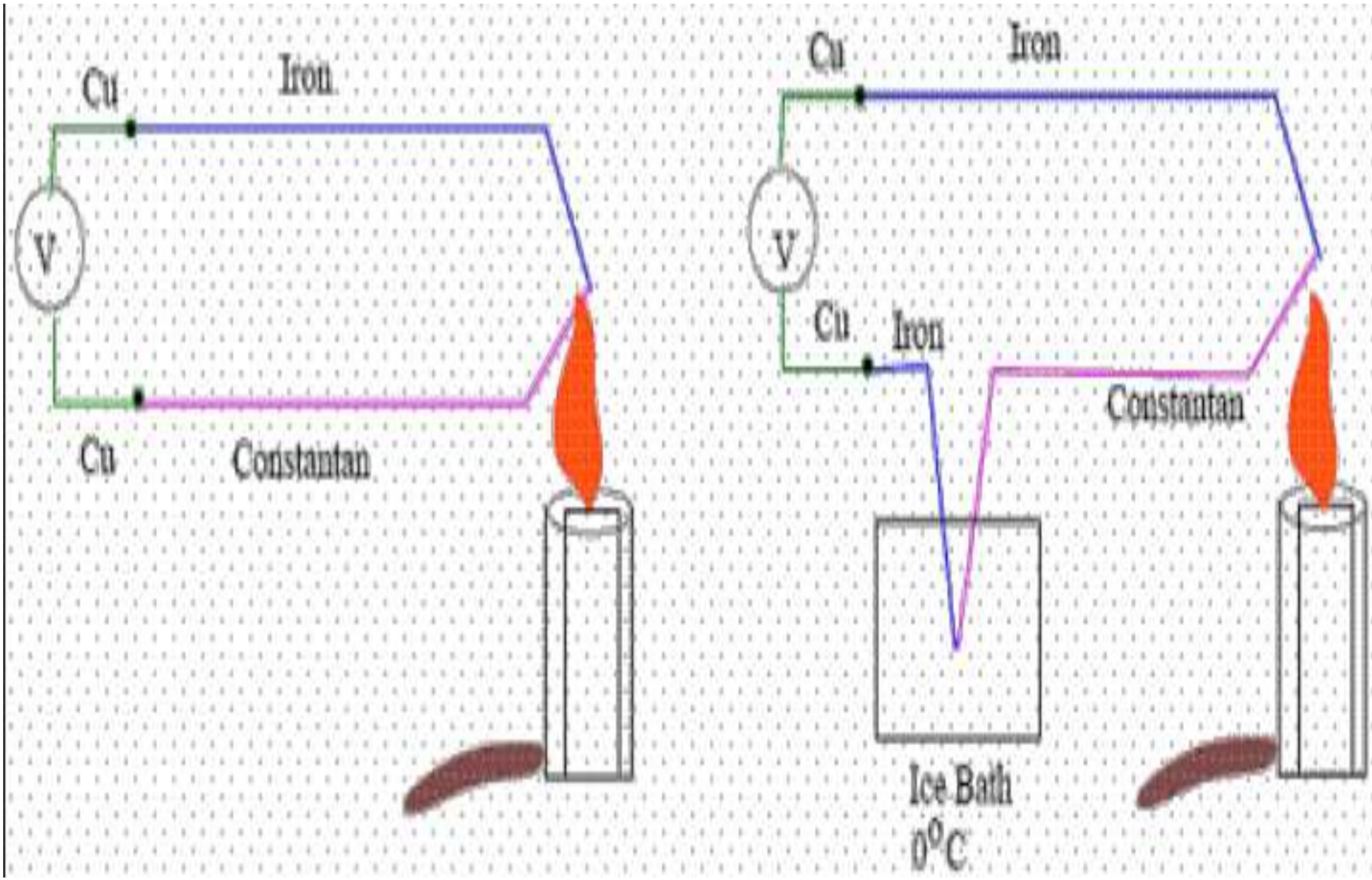
Introduction Thermoelectricity (CO4)

- 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)

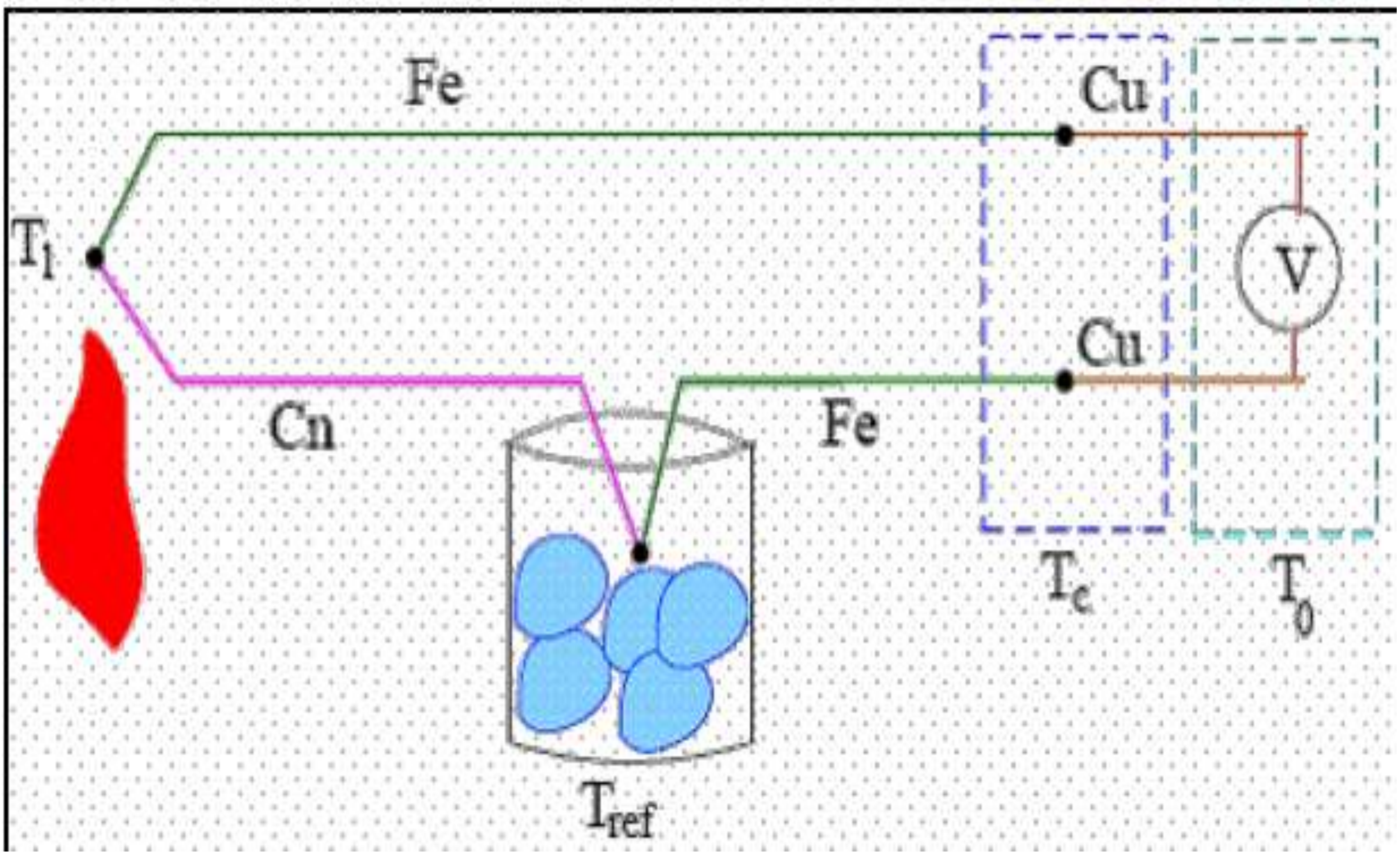
Law of Successive temperatures:

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.

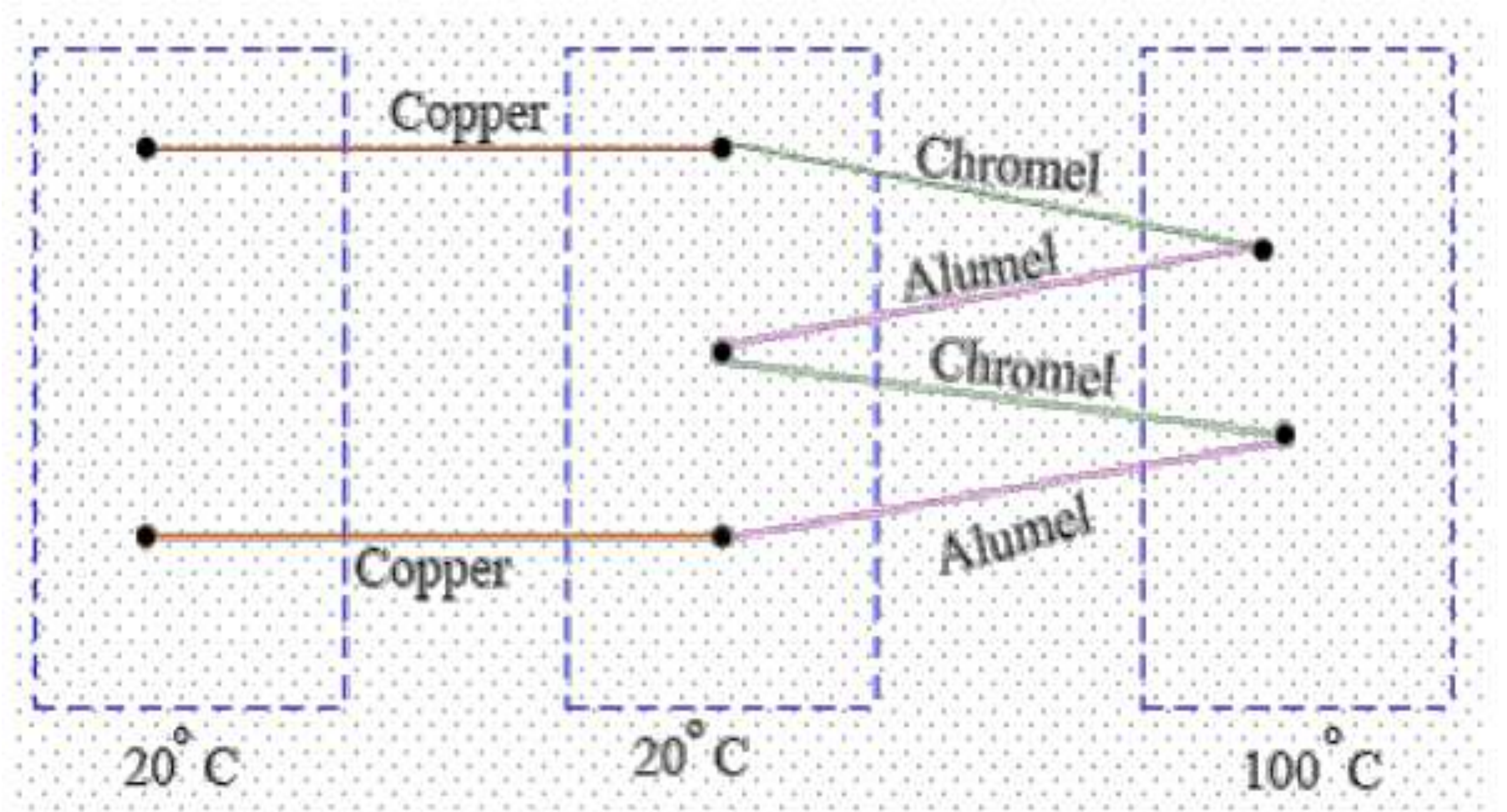
Law of Intermediate Metals:

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)



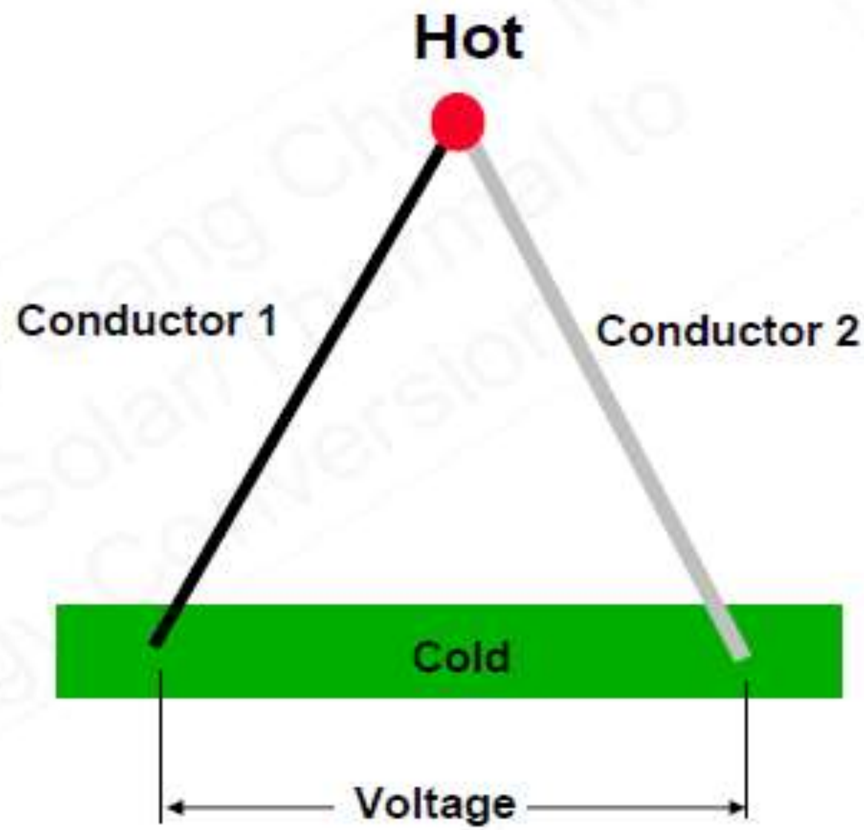
Application of Thermodynamics to Thermocouple (CO4)



Seeback Effect (CO4)

Seebeck Effect

Thomas Johann Seebeck
1770-1831

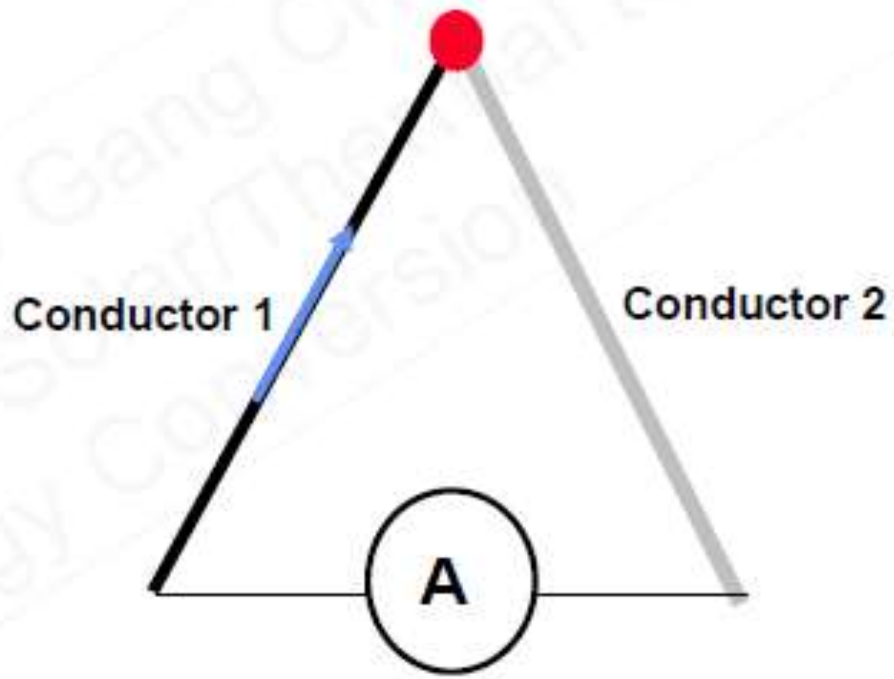


Seebeck effect: Discovered in 1821
Temperature difference generates voltage

Peltier effect (CO4)

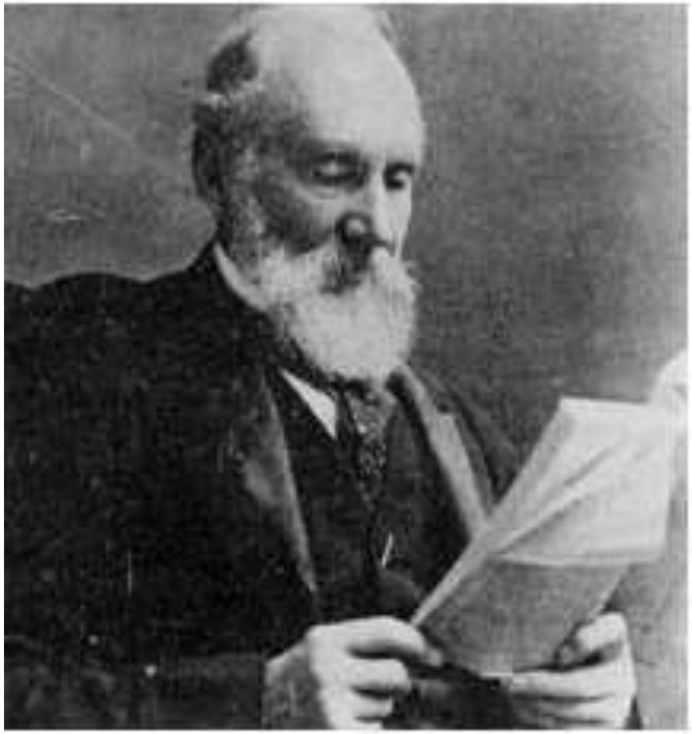
Jean Charles Athanase Peltier
1785-1845

Heating or Cooling

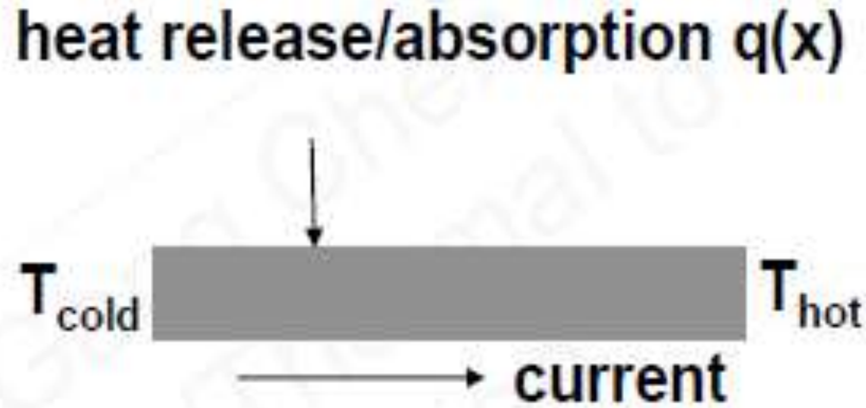


Peltier Effect: Discovered in 1834
An electrical current creates a cooling or heating effect at the junction depending on the direction of current flow.

Thomson Effect (CO4)

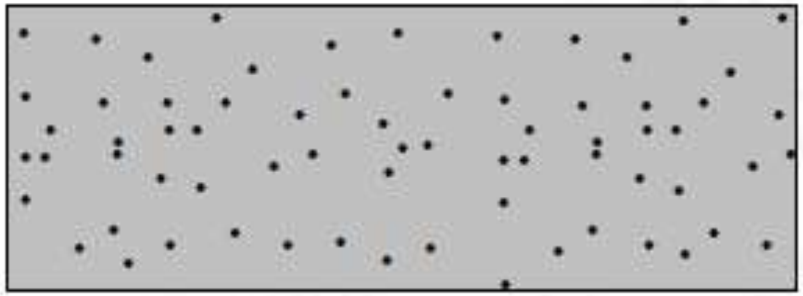


William Thomson
(Lord Kelvin)
1824 – 1907



Thomson effect predicted, 1855

Current Flow in an Isothermal Conductor (CO4)



Electrical Field [V/m]

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

Electrical Resistivity [Ωm]

Electron Charge [C]

Electron Density [1/m^3]

Drift Velocity [m/s]

Mobility [m^2/s.V]

Electrical Conductivity [1/Ωm]

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

Heat Per Charge [J]

Peltier Coefficient [J/A]

Other Basic Relations: Heat Conduction (CO4)

- Fourier law for heat conduction

$$q = -k\nabla T$$

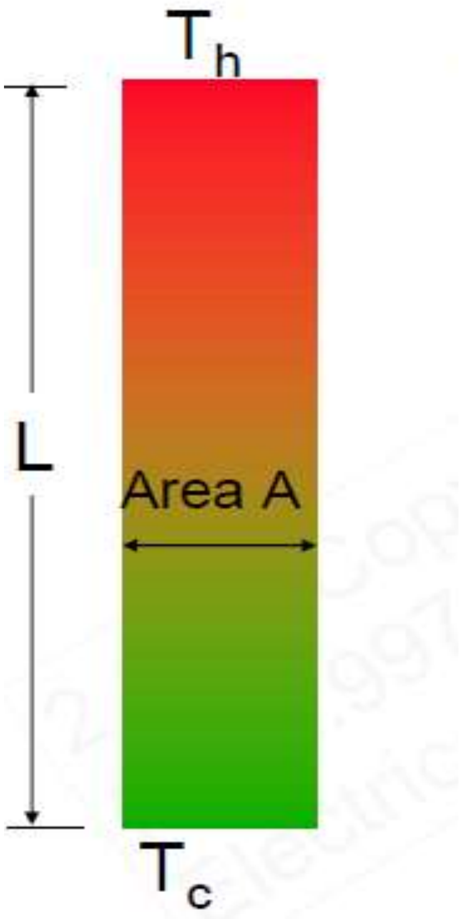
Q= heat flux

K= thermal conductivity (W/mK)

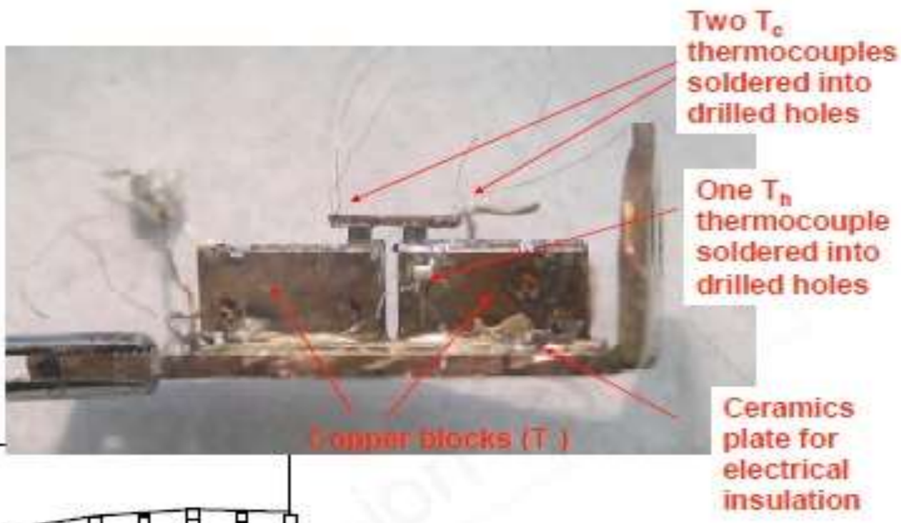
T= temperature

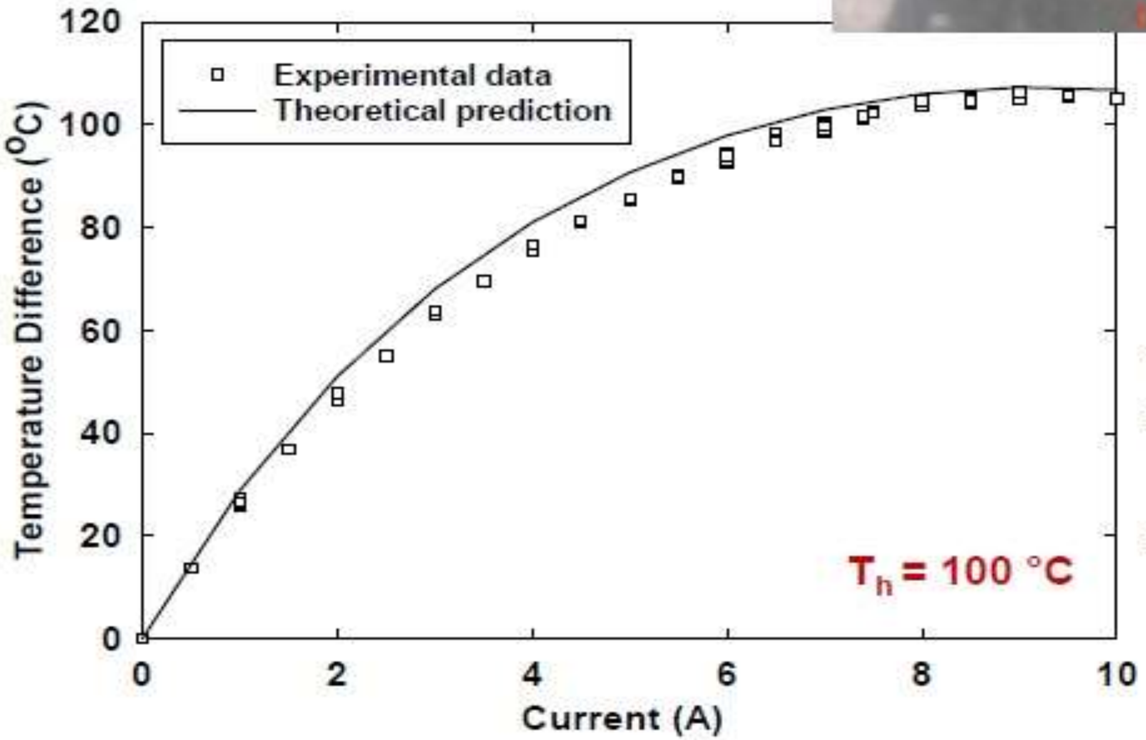
- One dimensional heat conduction

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



Performance (CO4)

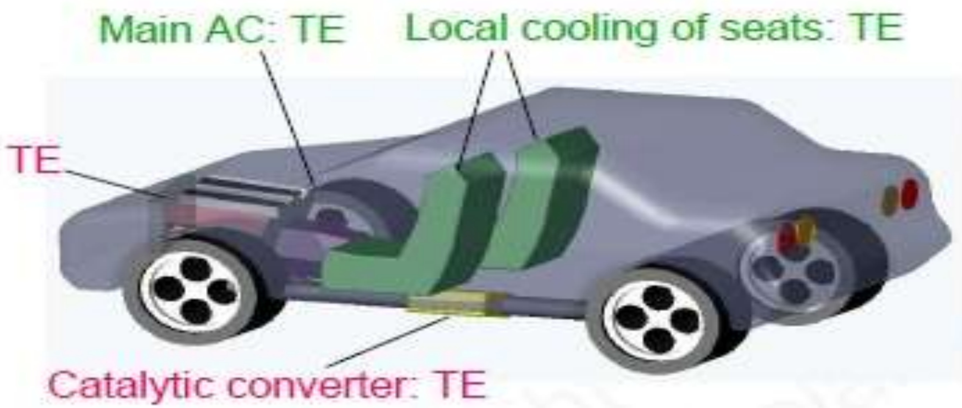




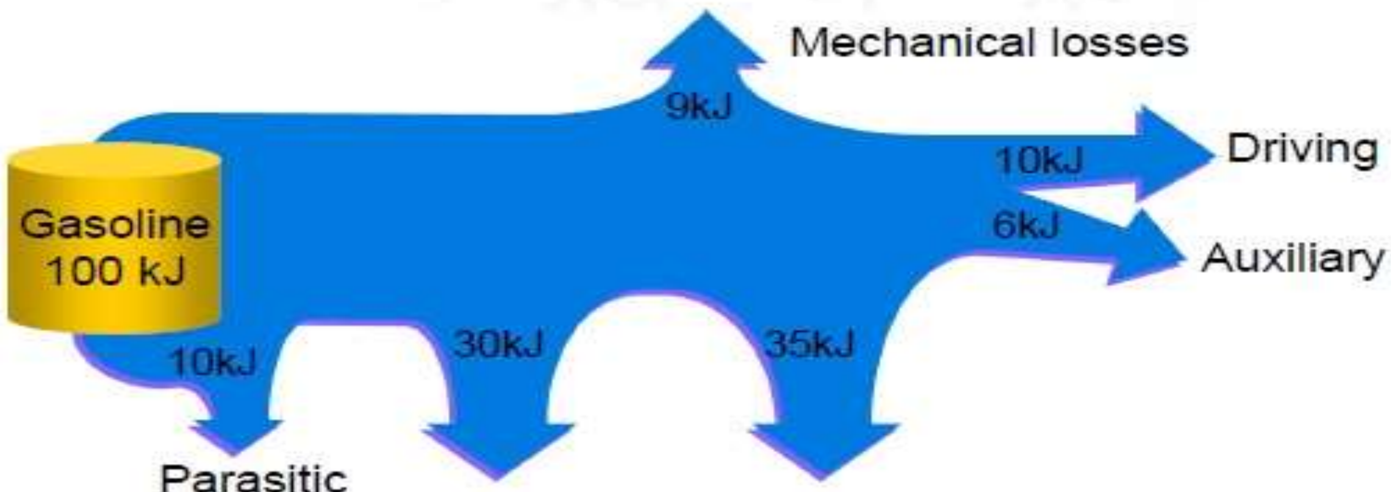
- Match two leg size
- Minimize contact resistance
- Optimize current

Example (CO4)

Vehicle Systems



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



Other losses

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

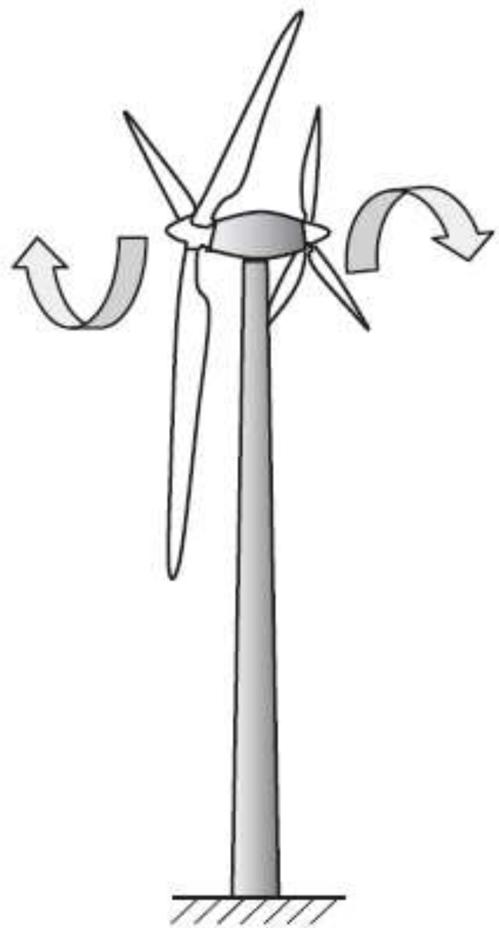


Illustration of a dual-blade set wind turbine.

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.

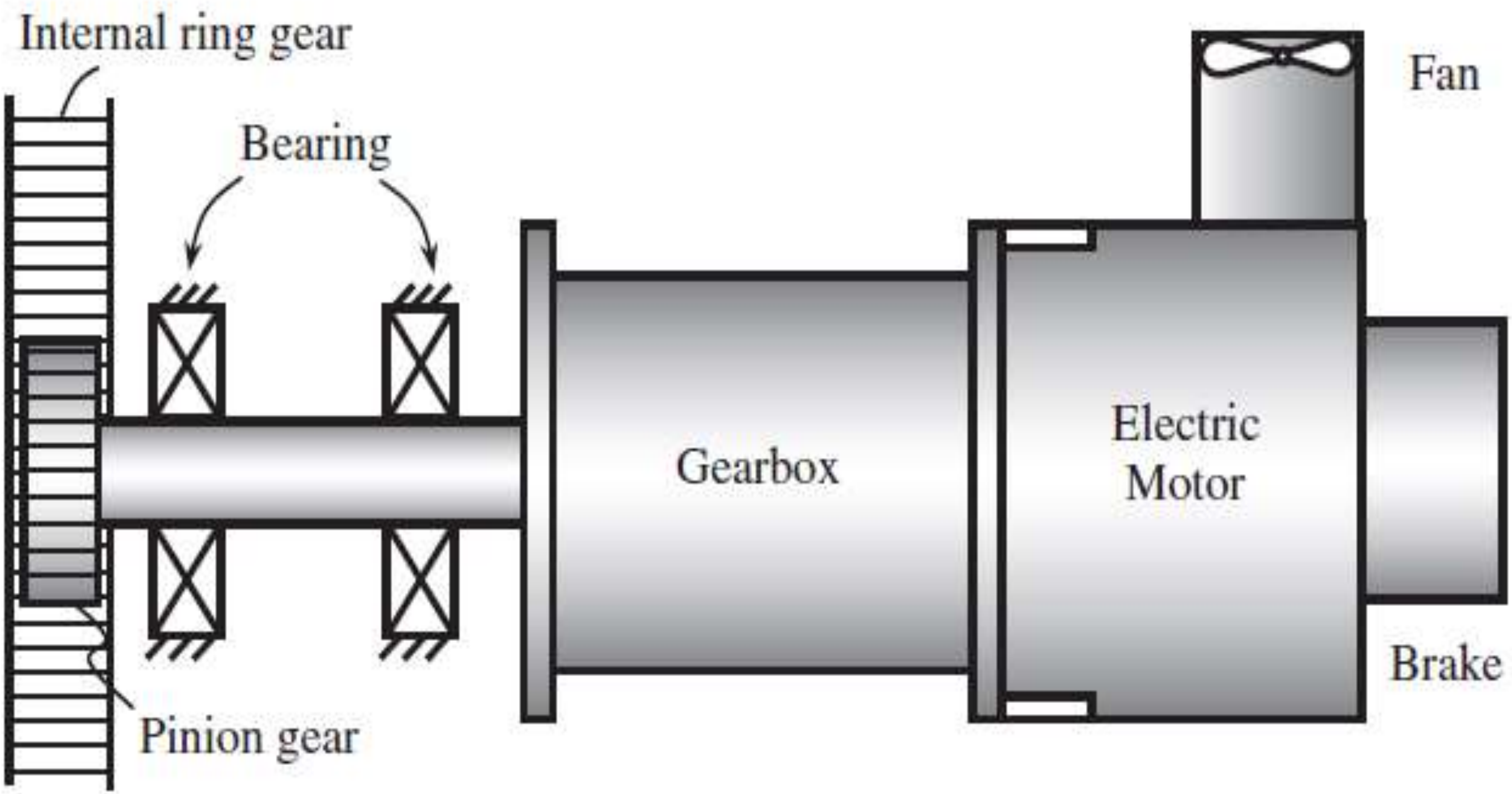
h) The minimum wind speeds at the selected site must be higher than 3.5 to 4.5 m/s which is the lower limit at which the present wind energy conversion system starts turning. It is called as cut-in-speed. Up to this speed no power will be generated by the system.

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)

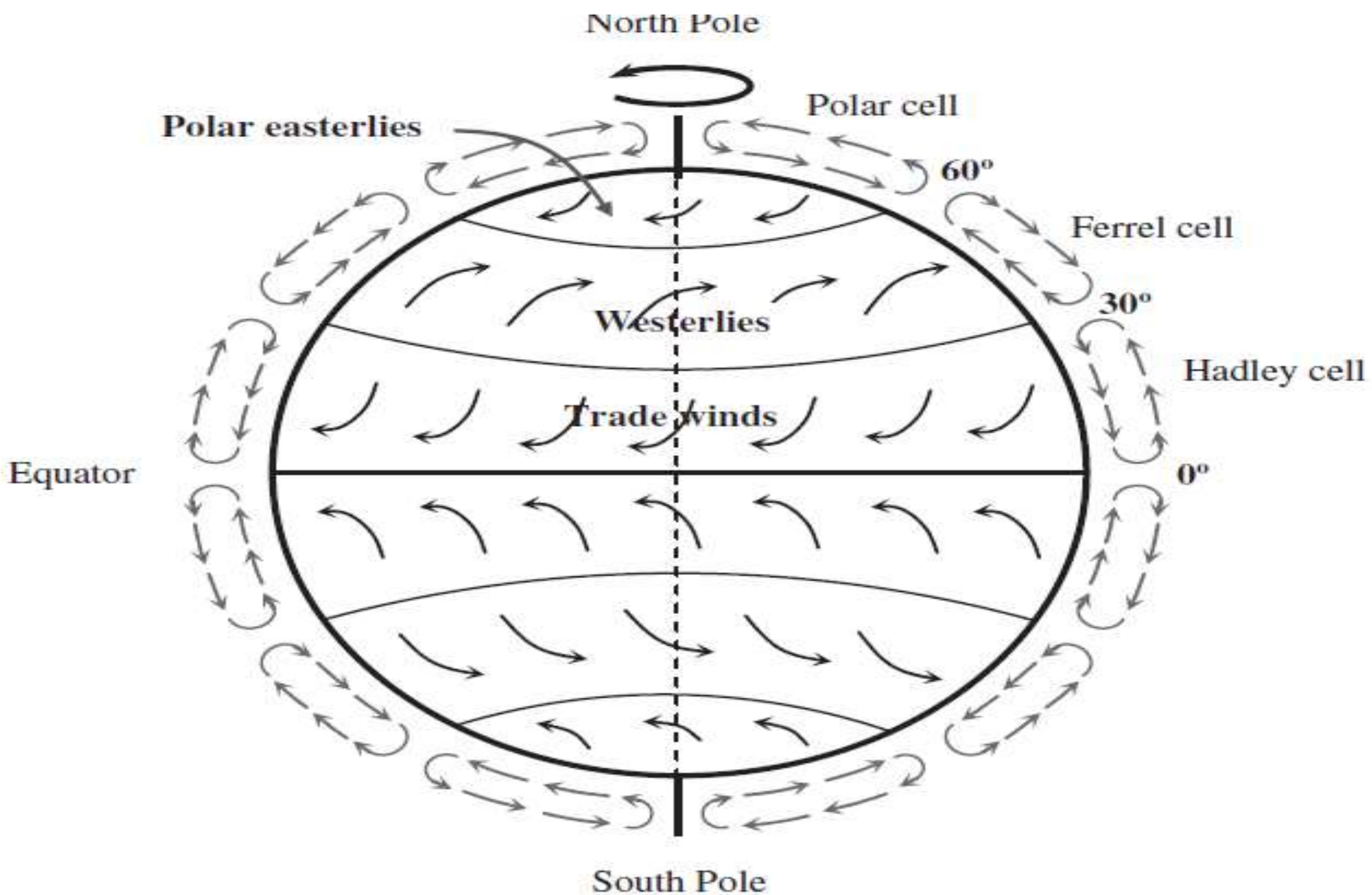


Figure 1: Idealized atmospheric circulations.

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.

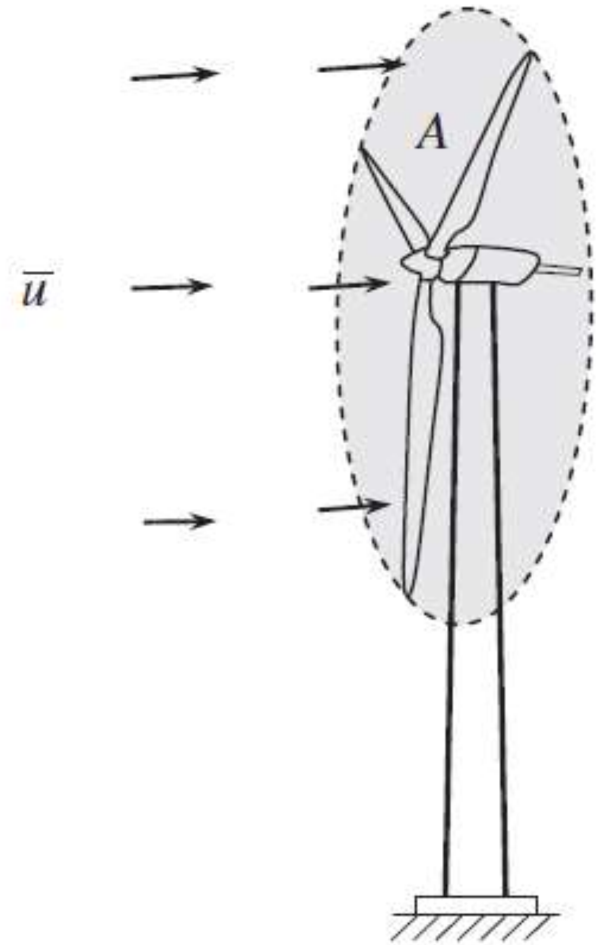


Figure 3: Swept area of wind turbine blades.

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*:

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

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)

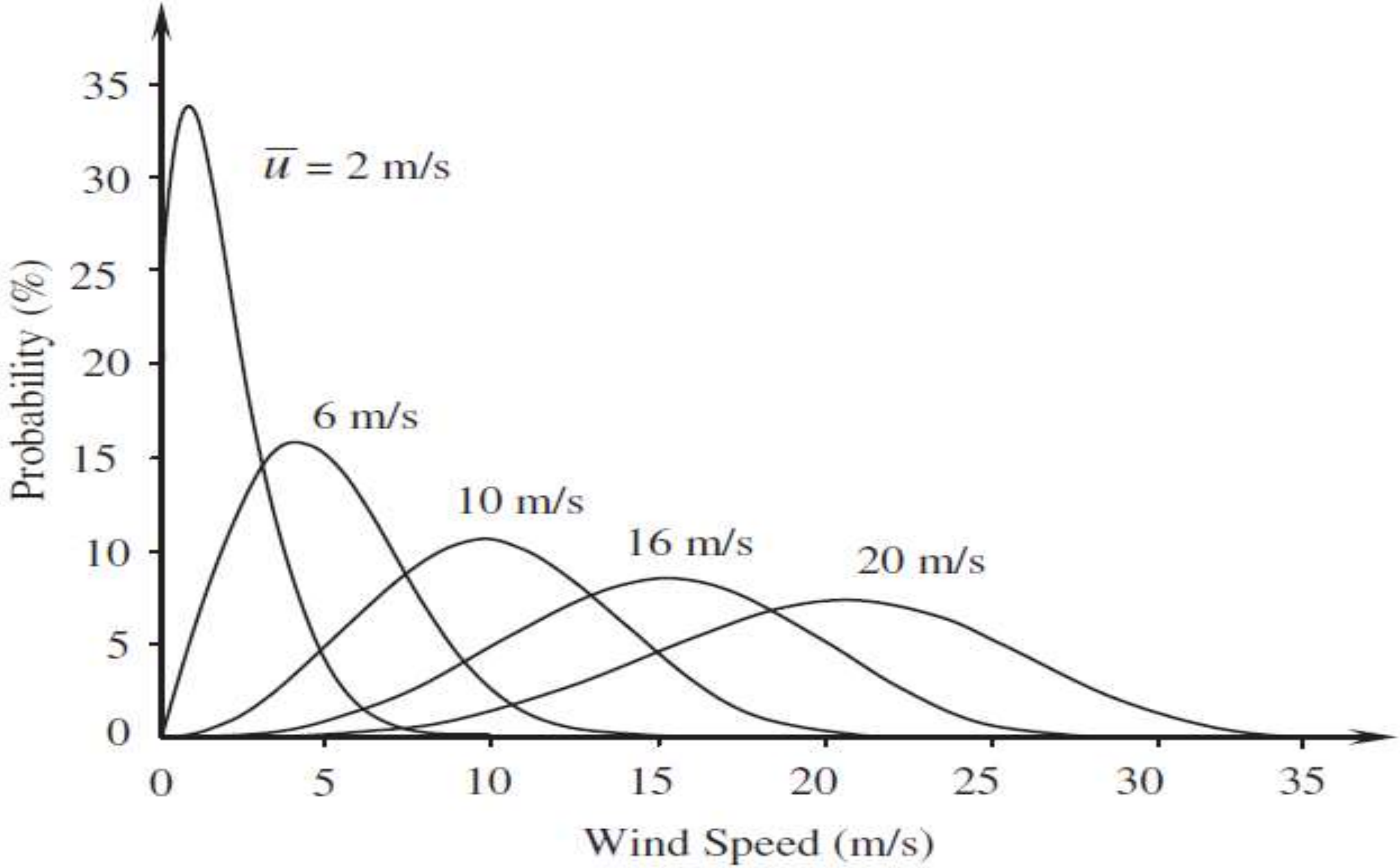


Figure 4: Weibull distributions for various mean wind speeds.

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.

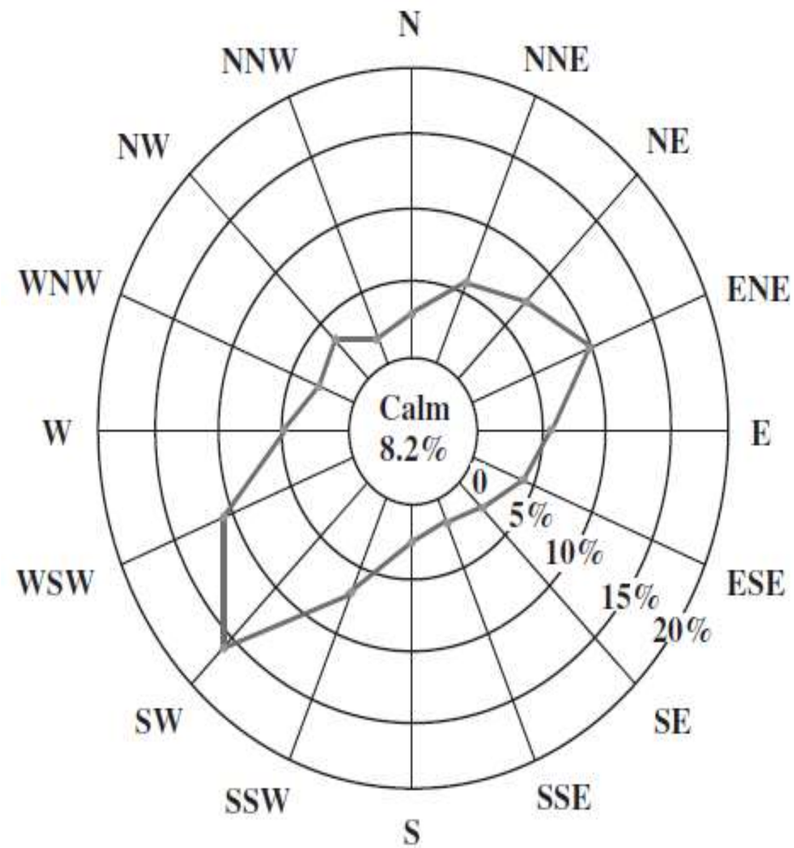


Figure 5: Wind rose diagram for wind directions.

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.

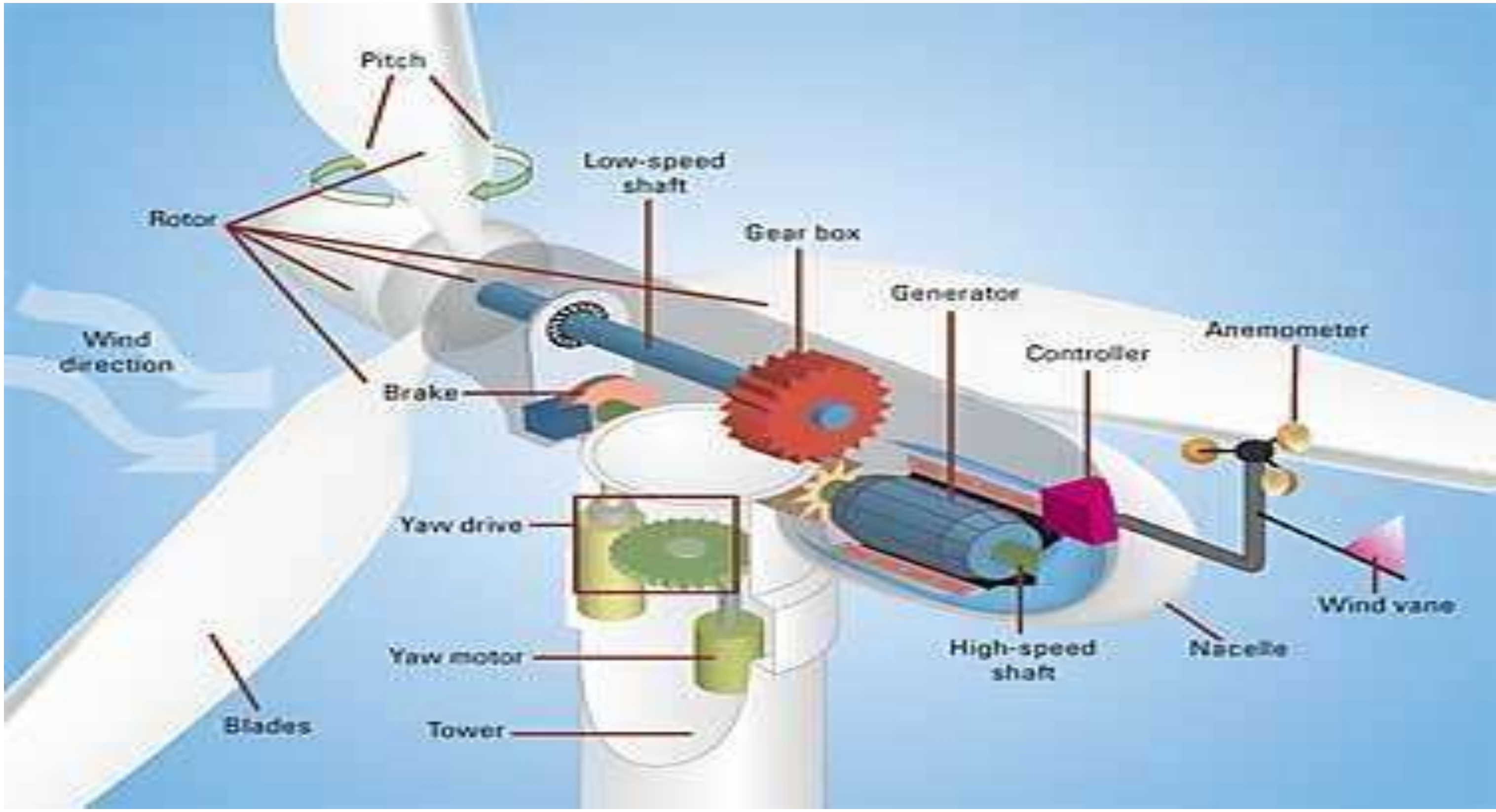
Prerequisite (CO4)

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)

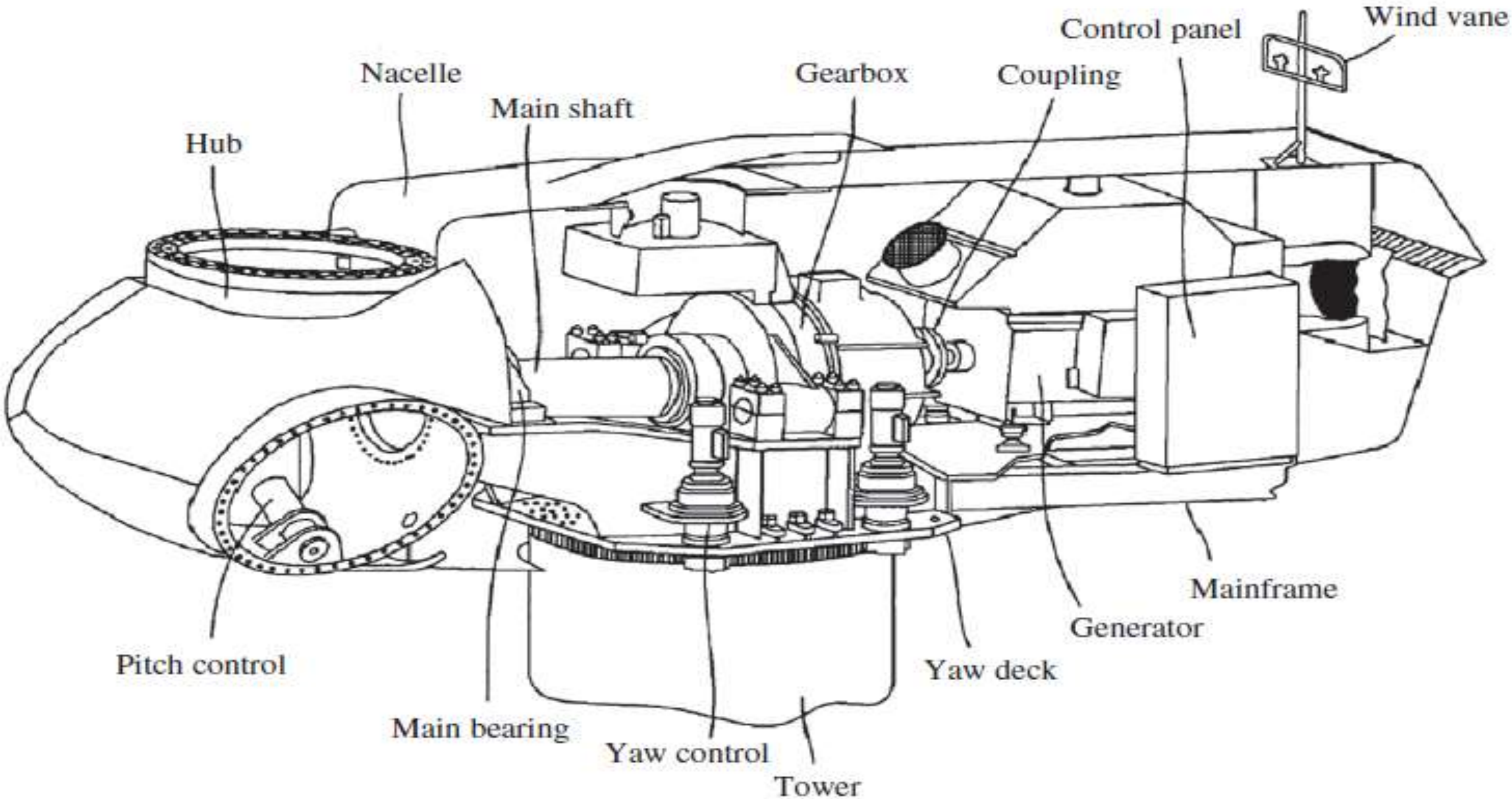


Figure 7: A horizontal-axis wind turbine configuration. Courtesy of the US Patent & Trademark Office.

Vertical-axis wind turbines (CO4)

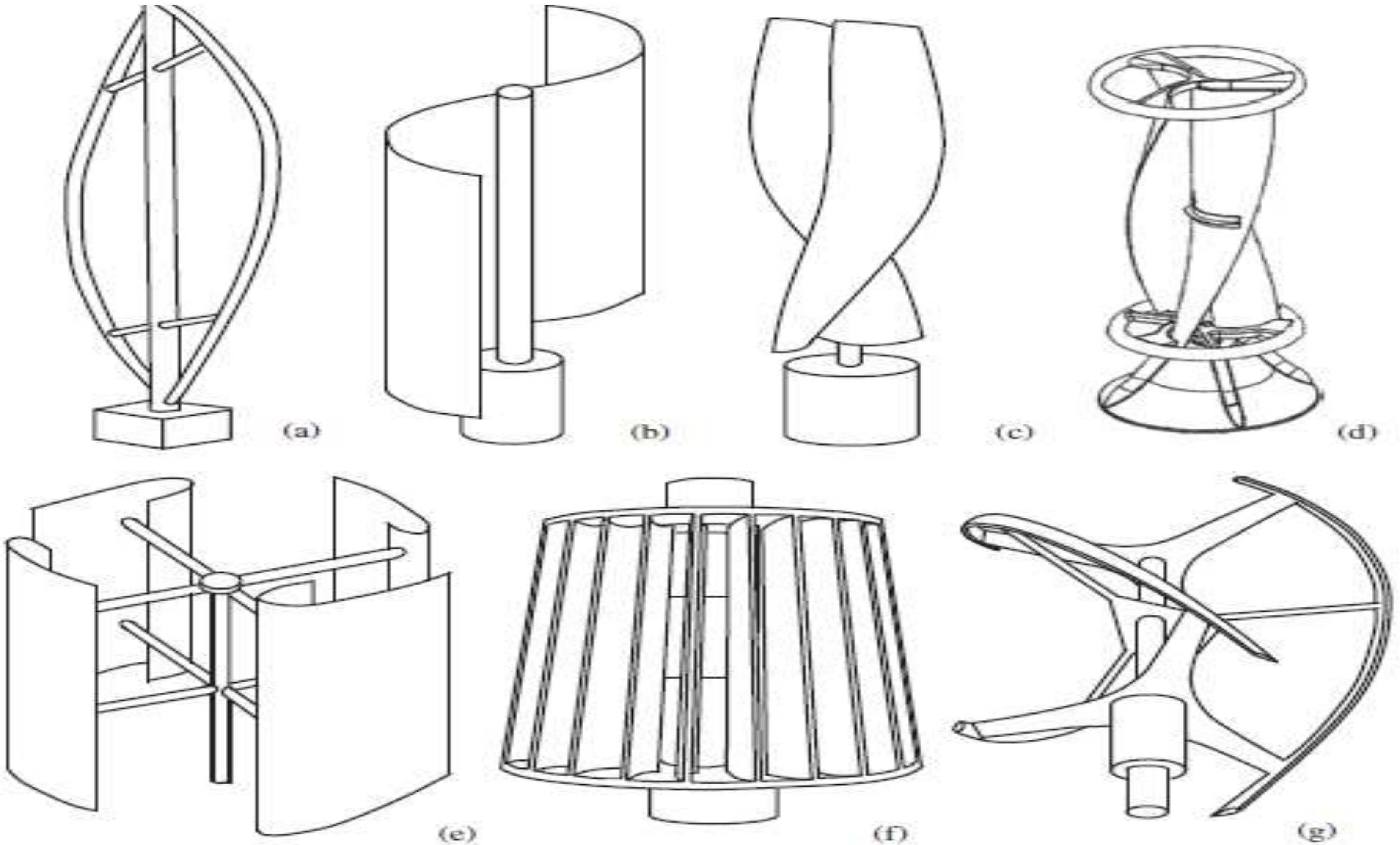


Figure 6: Several typical types of vertical-axis wind turbines: (a) Darrius; (b) Savonius; (c) Solarwind™ [36]; (d) Helical [37]; (e) Noguchi [38]; (f) Maglev [39]; (g) Cochrane [40].

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)

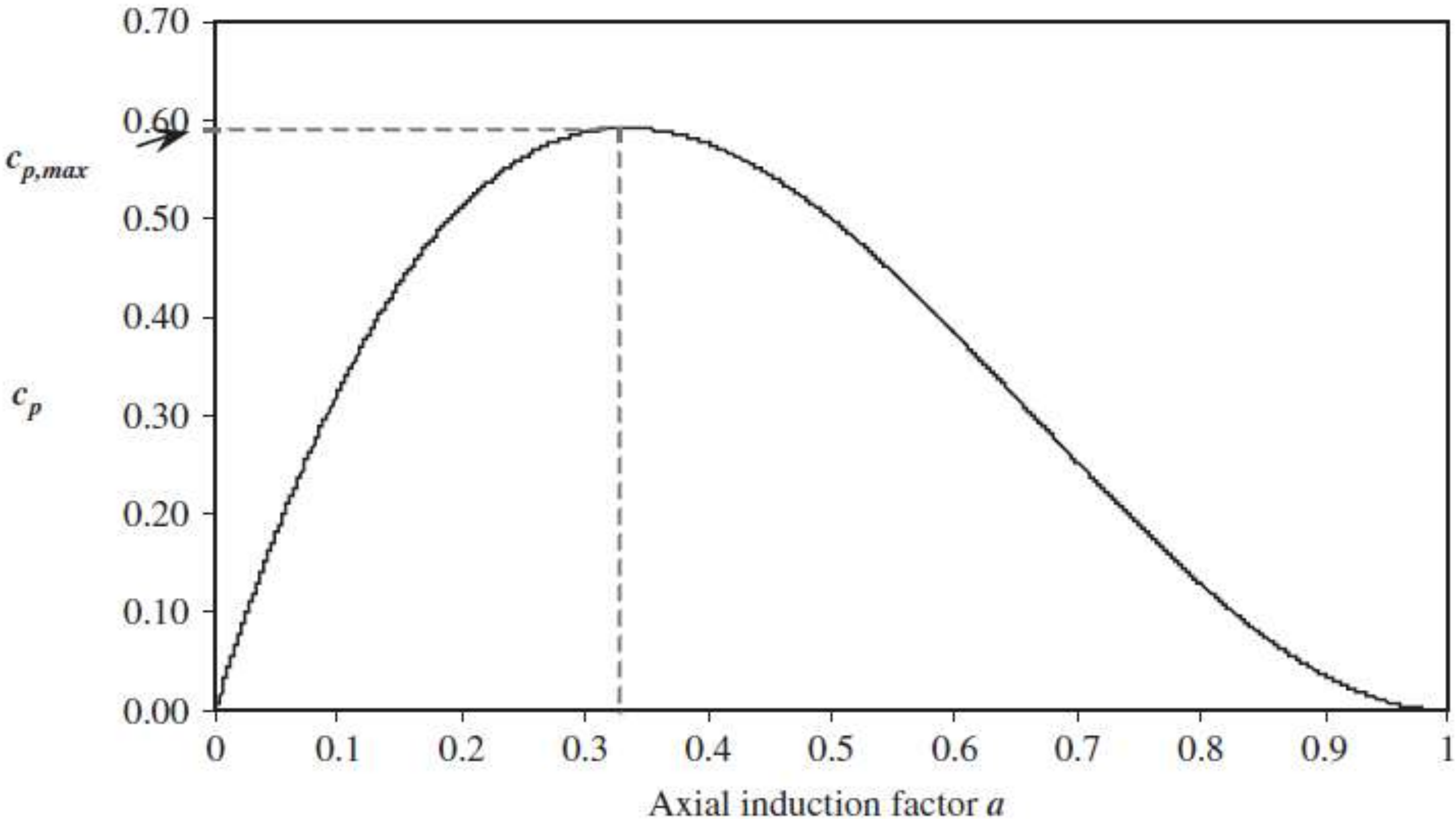


Figure 9: Power coefficient as a function of axial induction factor *a*.

Power curve (CO4)

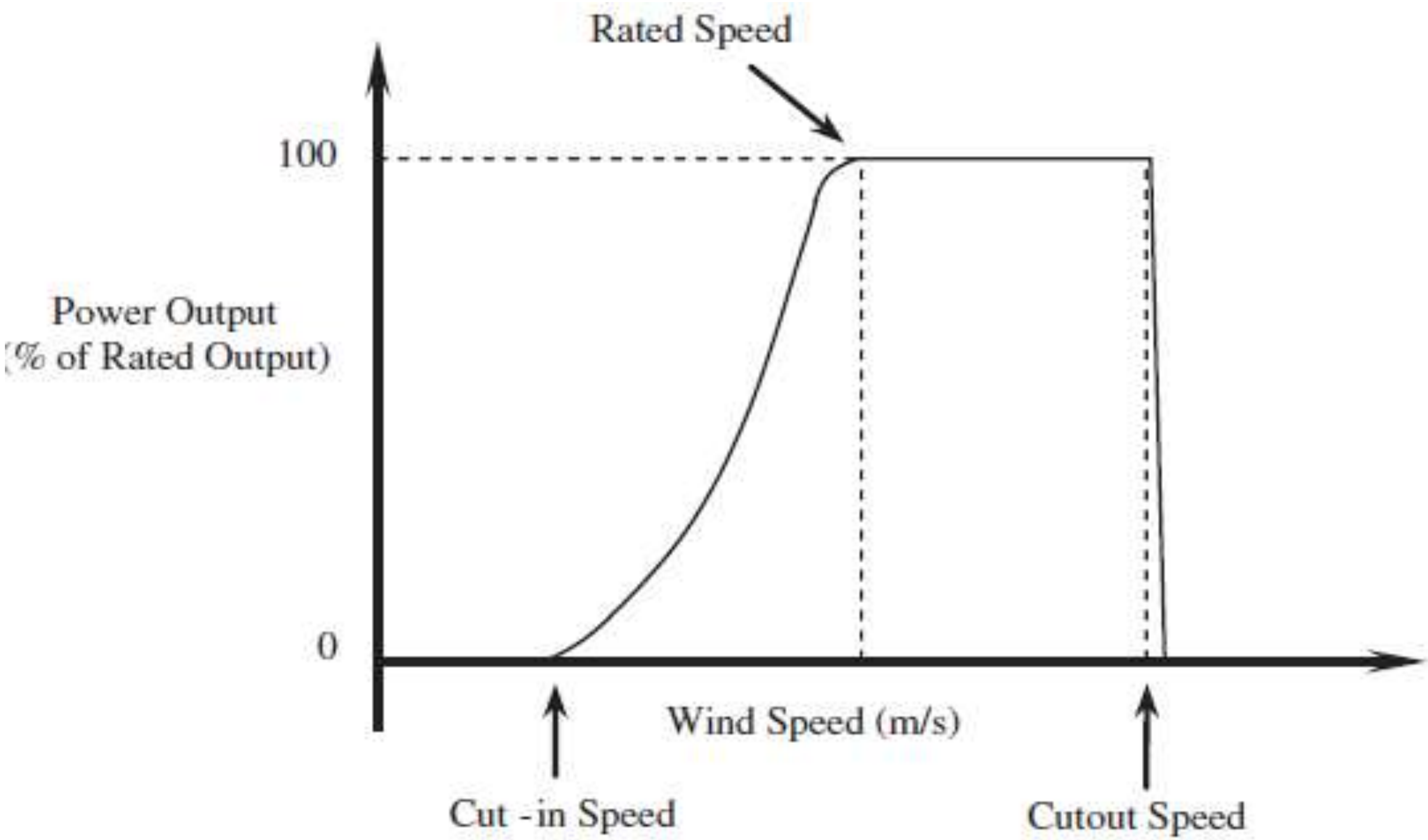


Figure 10: Typical wind turbine power curve.

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)

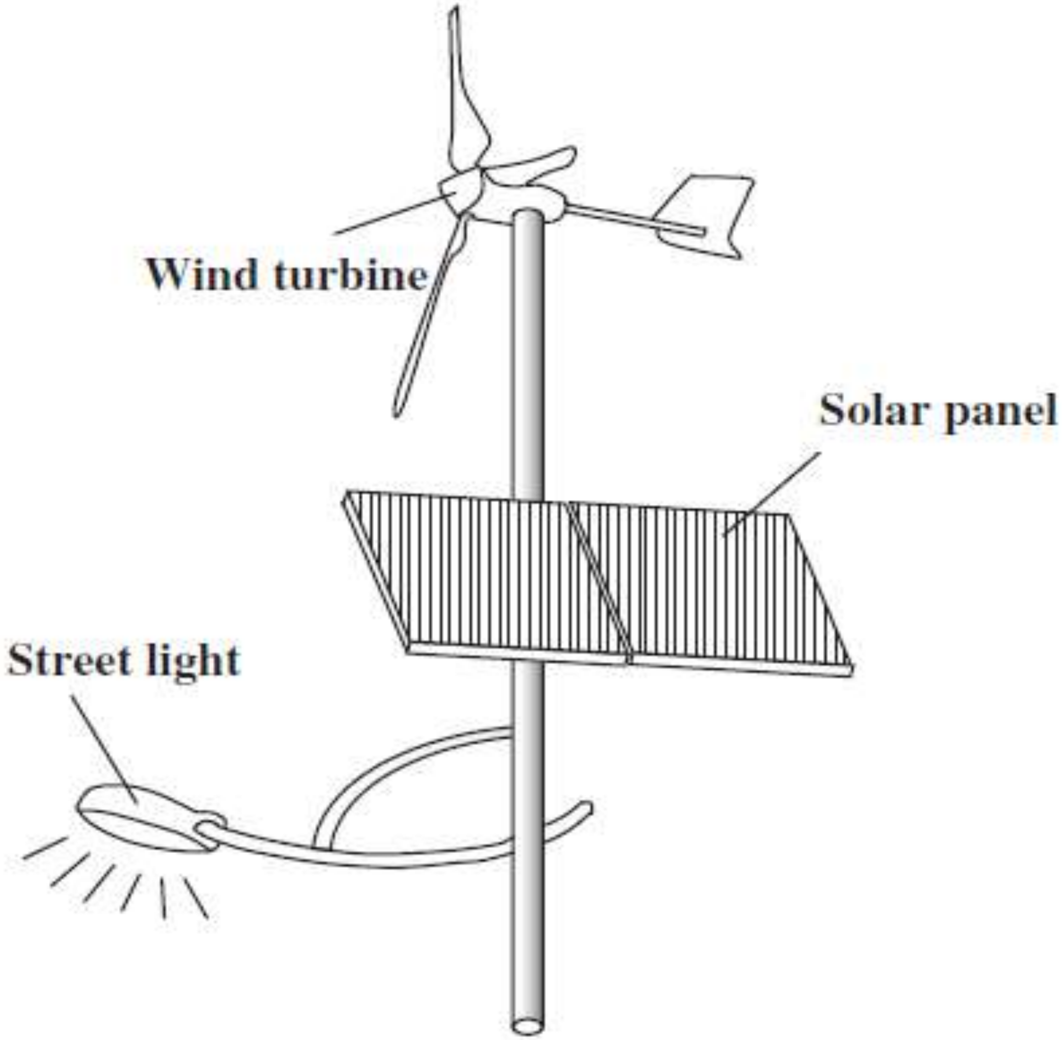


Figure 16: Wind–solar hybrid system for street lights.

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