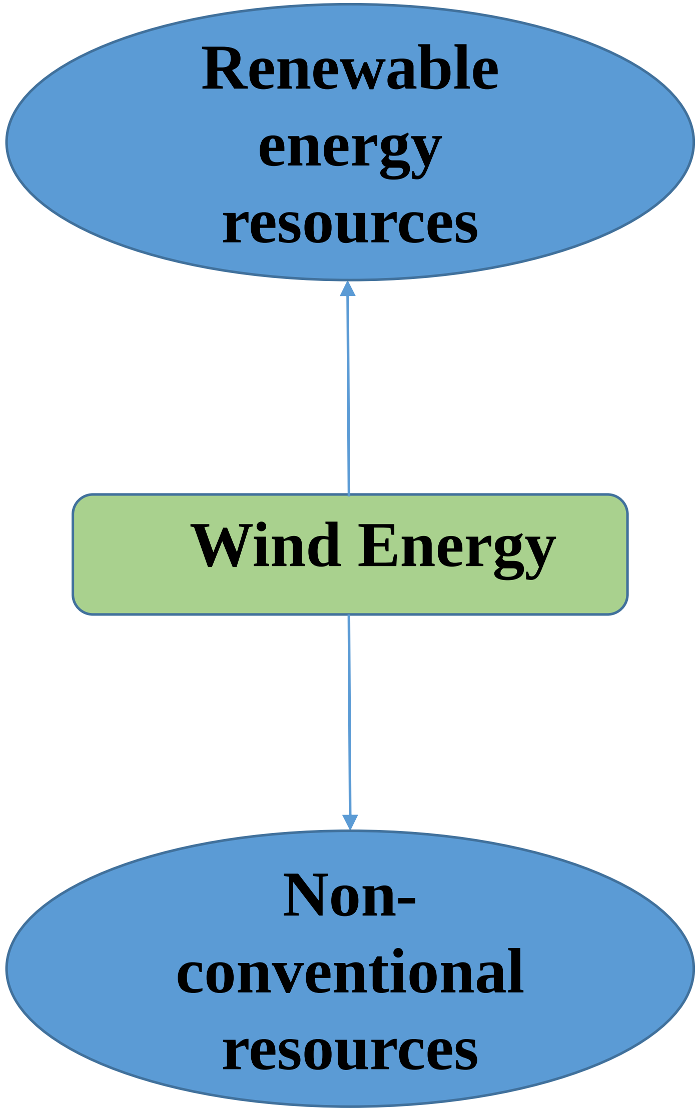
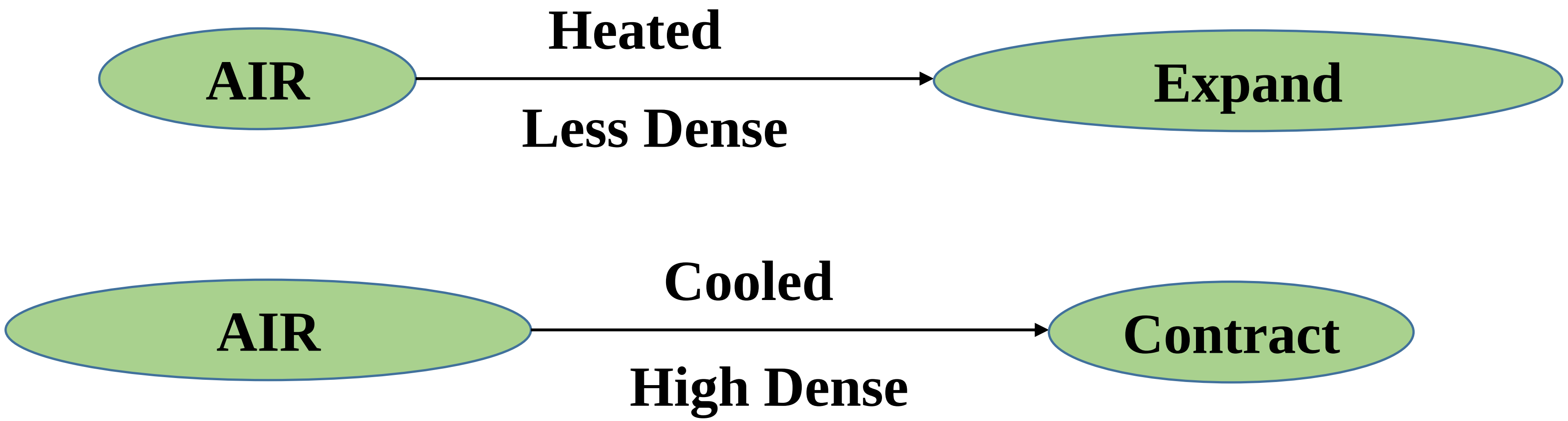
Wind Energy



It can be renew by nature again and again.

The Earth's Wind Systems

- **Like all gases, air expands when heated, and contracts when cooled.**
- **Thus warm air is less dense than cold air and will rise to high altitudes when strongly heated by solar radiation.**



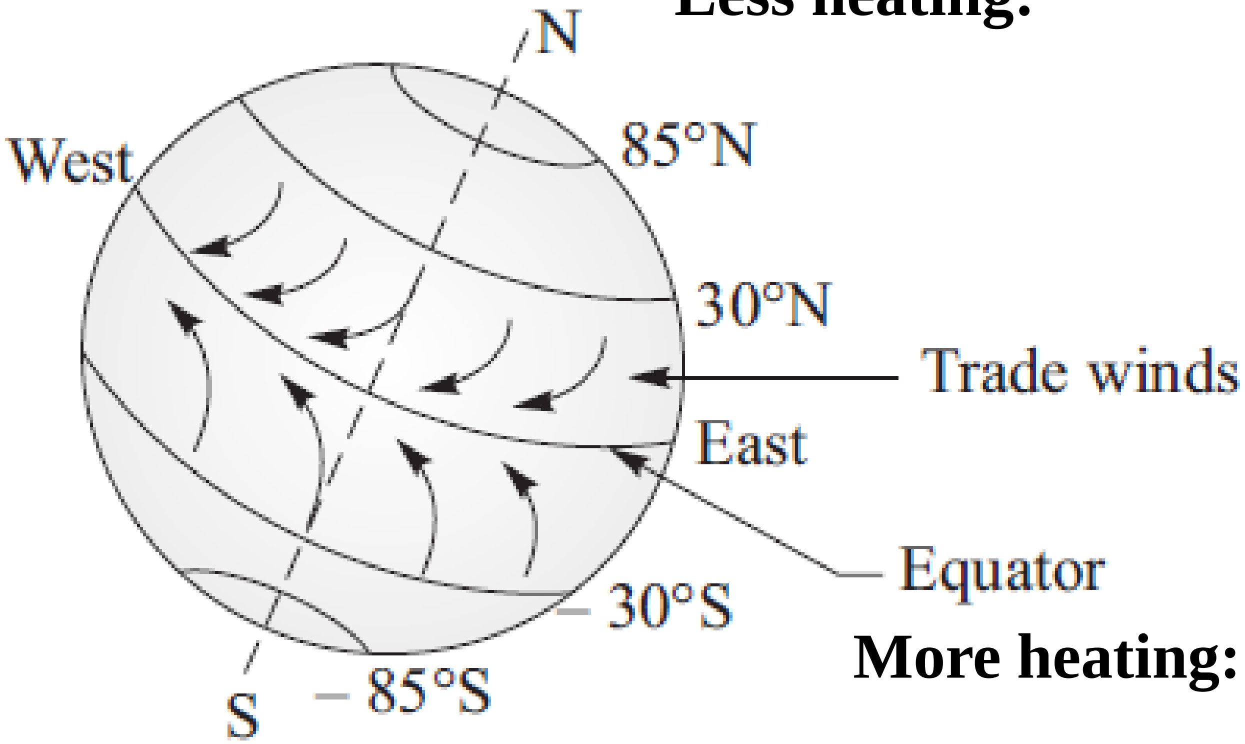
Origin of Winds

The winds can be classified as:

- Global winds
- Local winds

- **Global Winds:** **The primary force for global winds is produced due to differential heating of the earth surface at equator (0 degree longitudes) and polar regions (about $\pm 90\ degree\ longitude$).**
- **Cold winds move from polar to equatorial regions.**

Less heating:



More heating:

Figure: Global winds and their circulations.

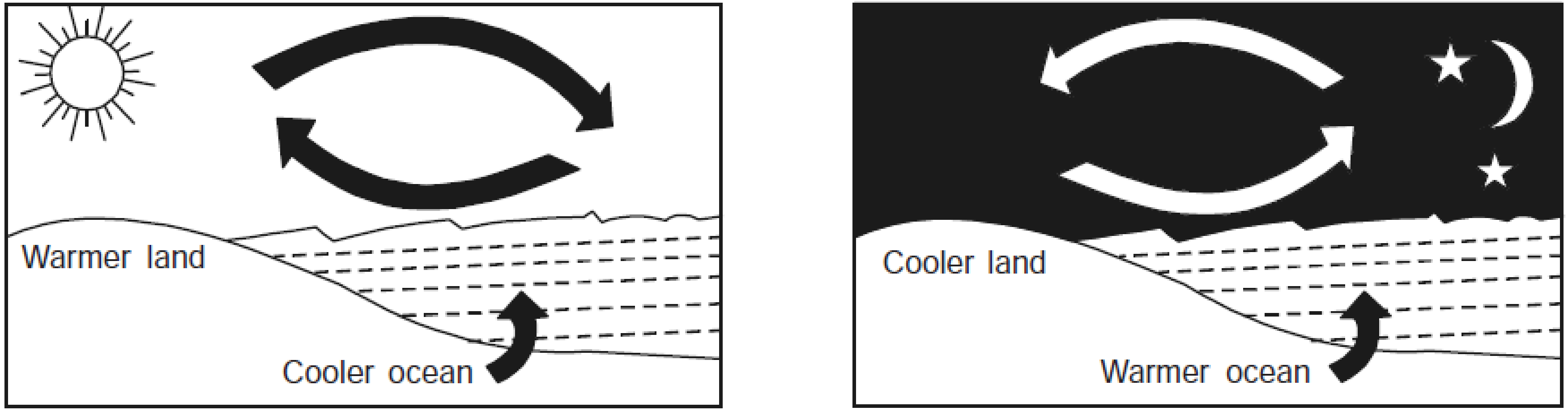
- **These air currents are also called *trade winds* as sailing ships in the past used these air currents for ship movement and trading.**

Origin of Winds cont.. Local Winds

- **Local winds are generated due to uneven heating.**
- **Uneven heating occurs on land surface and water bodies due to solar radiation.**

Wind Energy

- Sun is the main source of wind, and hence, wind is considered a form of solar energy.
- Winds are caused by the uneven heating of the atmosphere by the sun, the irregularities of the earth's surface, and rotation of the earth.
- Heating and cooling of the atmosphere which generates convection currents.
- The wind flow or motion energy is 'harvested' by modern wind turbines.



Due to different heat capacities of land and ocean.

(a) Wind from ocean to land during daytime, and (b) Wind from land to ocean during night.

Wind Energy cont.

- **During daytime, the air over the land mass heats up faster than the air over the oceans.**
- **Hot air expands and rises while cool air from oceans rushes to fill the space, creating local winds.**
- **At night the process is reversed as the air cools more rapidly over land than water over off-shore land, causing breeze.**

Advantages of Wind Energy

- ✓ Freely and abundantly available in nature.
- ✓ It is a renewable energy source.
- ✓ It does not cause pollution to environment.
- ✓ It require minimal maintenance and operating cost.

Disadvantages of Wind Energy

- ✓ It can not produce steady and consistent power.
- ✓ It can generate only low power.

Renewable:-Resources which can be renewed by nature again and again so that their supply is not adversely affected by the rate of their consumption. Examples are:

- ✓ Wind
- ✓ Solar
- ✓ Hydel
- ✓ Geothermal

Wind Energy Conversion System (WECS)

- **If the mechanical energy is used directly by machinery, such as for a pump or grinding stones, the machine is usually called a *windmill*.**
- **Wind turbines are also sometimes referred to as WECS.**

Wind mills

Wind turbines

Wind Energy Conversion System (WECS) cont.

- **Wind turbines deliver their power through a revealing shaft, and in this respect, they are similar to other prime movers such as diesel engine and stream turbines.**
- **A generator can be coupled to this shaft and the electrical power delivered can be used to serve the multitude of different purposes for which electricity is required today.**
- **In practice, an important difference between the wind turbine and the power delivered by engines and stream turbines is that *<u>the power delivered by wind turbines to the same extent uncontrolled and unpredictable over very short periods of time.</u>***
- **In most applications for electricity, power is normally required on demand and not whenever available. Therefore, it is important to have some storage or reserve supply. This requirement has been one of the main limitations.**
- **If the mechanical energy is then converted to electricity, the machine is called a wind generator.**

Air Mass Density

From the universal gas equation, $$\rho = \left[\frac{P}{(R.T)}\right]$$

Where,

ρ is the density of in kg/m^3

P is the air pressure in Pascal i.e., N/m^3

R is the specific gas constant for air i.e., 287 J/kg.K

T is the air temperature in degree Kelvin (K = $C^{\circ} + 273$)

An approximate value of ρ based on altitude only is given by $\rho = 1.225 - [1.194 \times$

Energy and Power in the Wind

- The energy contained in the wind is its kinetic energy.

- Kinetic energy = $\frac{1}{2}mV^2$ (1)

Where, m = Mass of the air , kilograms

V = Velocity of the air, m/s

$$Mass\ (m)\ of\ air\ per\ second = air\ density\ \times volume\ of\ air\ passing\ per\ second$$
$$= air\ density\ \times area \times length$$
$$= air\ density\ \times area \times velocity$$

That is: $m = \ \rho AV$

Substituting for m in (1) above gives:

Kinetic energy per second = 0.5 ρAV^3 (joules per second)

Energy and Power in the Wind cont..

Density of air (ρ) = 1.2256 kgm^{-3} $at\ sea\ level$

$$Power = \frac{Energy}{time}(watts) \Rightarrow 0.5\rho AV^3$$

The power in the wind is proportional to:

- **The density of the air**
- **The area through which the wind is passing (i.e. through a wind turbine rotor),**
- **The cube of the wind velocity.**

$$\frac{Power}{A} = 0.5\rho V^3 \Rightarrow Wind\ power\ density\ i.e, wind\ power\ over\ a\ unit\ area$$

Energy and Power in the Wind cont..

Energy is defined as (power x time)

$$Power = \frac{Energy}{time}(watts) \Rightarrow 0.5\rho A V^3$$

Wind energy density over time 0 to t,

$$\frac{E_w}{A} = \int_0^t \left(\frac{P_w}{A}\right).dt$$

$$\frac{E_w}{A} = 0.5\rho \int \left[V^3\right]dt$$

$$\boxed{\frac{E_w}{A} = 0.5\rho \sum V^3.\Delta T}$$

ΔT indicates time in hours

Wind Potential

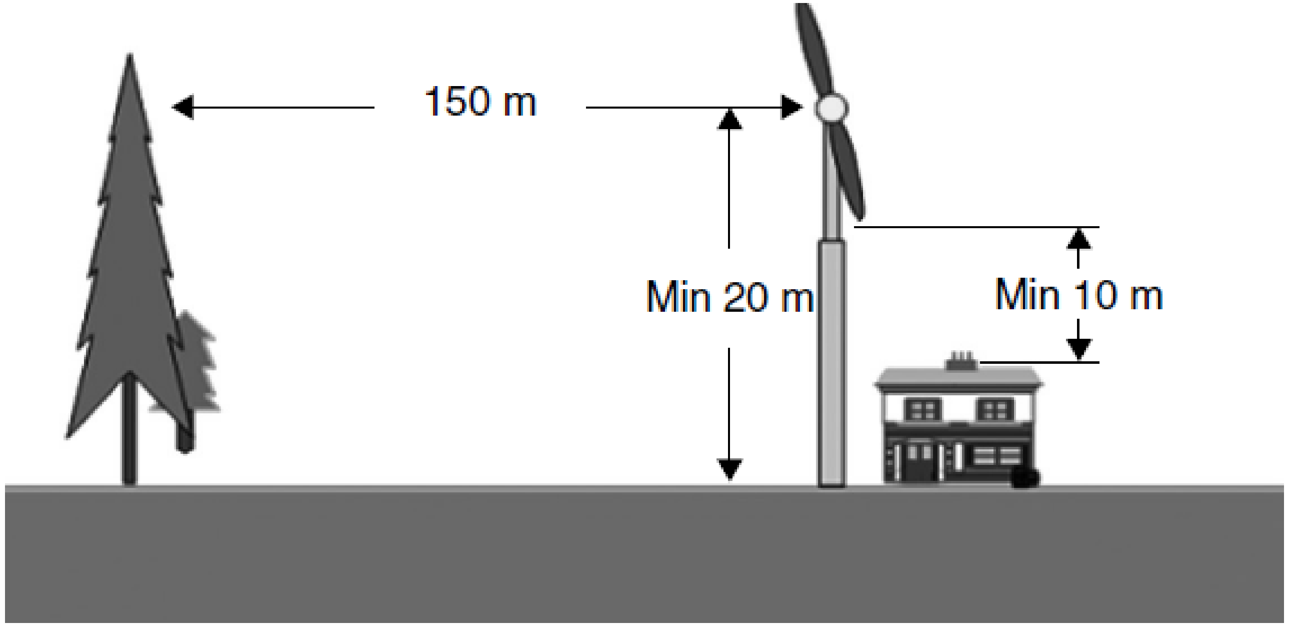
- **In order for a wind energy system to be feasible, there must be an adequate wind supply.**
- **A wind energy system usually requires an average annual wind speed of at least 15 km/h.**
- **Table represents a guideline of different wind speeds and their potential in producing electricity.**
- **A wind generator will produce lesser power in summer than in winter at the same wind speed as air has lower density in summer than in winter.**
- **Similarly, a wind generator will produce lesser power in higher altitudes—as air pressure as well as density is lower—than at lower altitudes.**

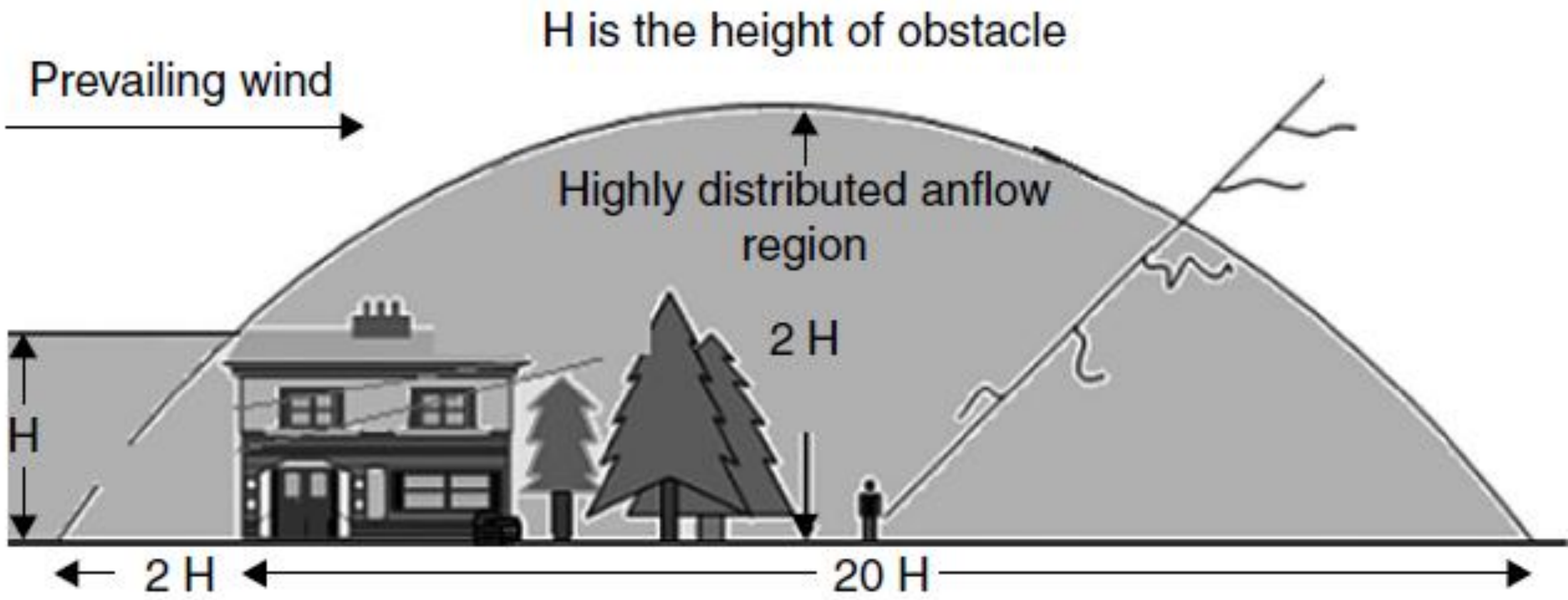
Wind Turbine Performance with Wind Speed

Average Wind Speed Suitability (km/h)	Wind Turbine Performance
Up to 15	Extremely poor
18	Poor
22	Moderate
25	Good
29	Excellent

- **Obstructions such as trees or hills can interfere with the wind supply to the rotors. To avoid this, rotors are placed on top of towers to take advantage of the strong winds that blow high above the ground.**
- **The towers are generally placed 100 m away from the nearest obstacle. The middle of the rotor is placed 10 m above any obstacle that is within 100 m.**

Installation of wind turbine (simple rule of thumb)





Wind Turbine Siting

The main considerations for selecting a site for wind generator are as follows:

(i) **High annual mean wind speed.** A basic requirement for a successful use of a windmill or farm is an adequate supply of wind and good wind speeds. The wind power is proportional to the cubic power of wind speed.

(ii) **No obstruction.** There should not be any high structure to obstruct wind for a distance of 3 km to the windmilll.

(iii) **Open plain.** The site should be the open plain such as open sea shoreline where strong winds prevail.

(iv) **Height.** The wind speed increases with height, which can be obtained when the windmill is located on a hill or a ridge with gentle slope.

(v) **Near lake or ocean.** Differential heating of water and land generates wind of sufficient speeds.

(vi) **Topography.** Topography such as mountain gap helps to channelise and speed up winds.

(vii) **Favourable land cost.** It helps in restriction or reducing the cost of project.

(viii) **Nearness to load centre.** It reduces the cost of transmission of the generated power.

(ix) **Nearness to road or rail link.** It helps in installation of windmill.

(x) **Availability of wind rose.** It helps in designing of windmill as wind data of the site can be determined.

Numerical Problem on Wind power density i.e, wind power over a unit area

Q. **Wind speed is 10 m/s at the standard atmospheric pressure. Calculate (i) the total power density in wind stream, (ii) the total power produced by a turbine of 100 m diameter with an efficiency of 40%.**

Solution: **(i) Total Power density** $= \dfrac{Total\ Power}{Area} \Rightarrow \dfrac{{}^{1}/{}_{2}\rho A V^3}{A} = \dfrac{1}{2}\rho V^3$

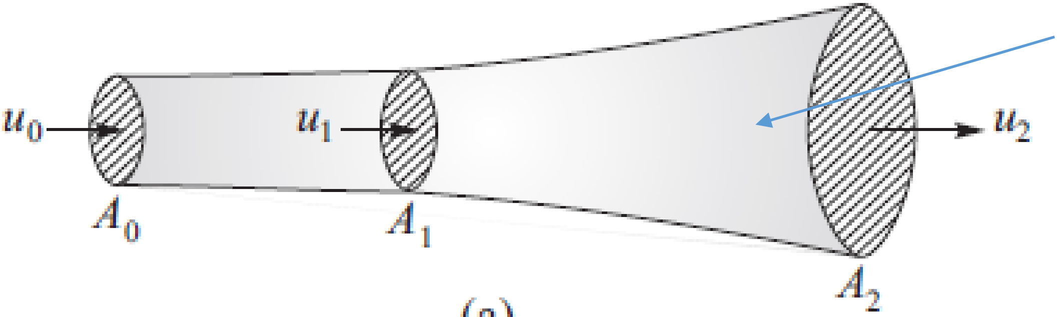
$$= 0.5 \times 1.226 \times 10^3 \Rightarrow 613\ {}^{W}/{}_{m^2}$$

(ii) Efficiency $= \dfrac{Desired\ output}{Required\ input}$

$$0.40 = \frac{Power\ produced}{613 \times \frac{\pi}{4} \times 100^2}$$

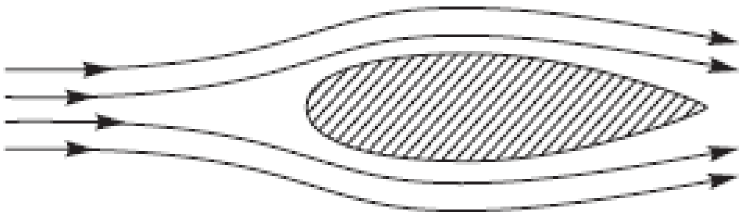
Power produced = 1924820 W ⇒1924.82 kW

Principle of Power Generation or Betz model of expanding airstream tube

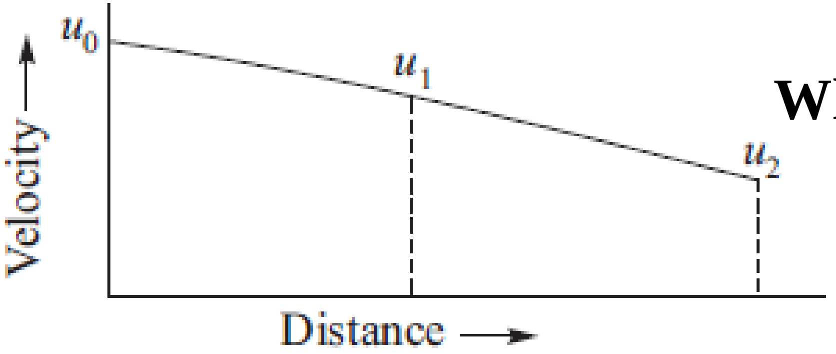


(a)

Airstream tube



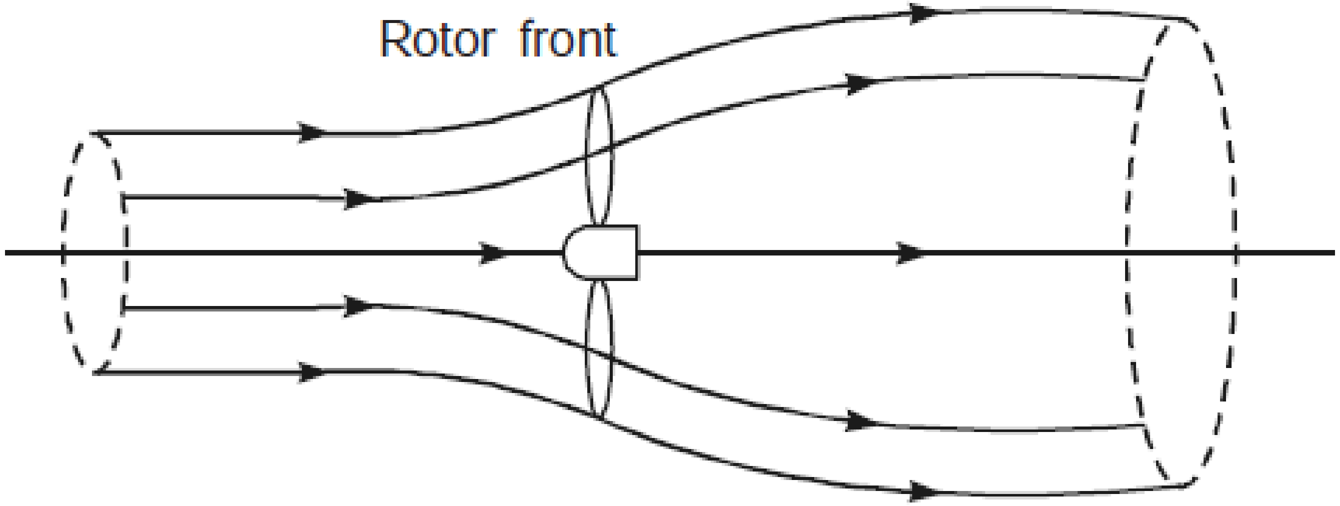
(b)



(c)

Law of continuity

$$Q \Rightarrow \ A_0u_0 = A_2u_2 = constant$$



Where,

$u_0 = Wind\ velocities\ at\ upstream\ direction$

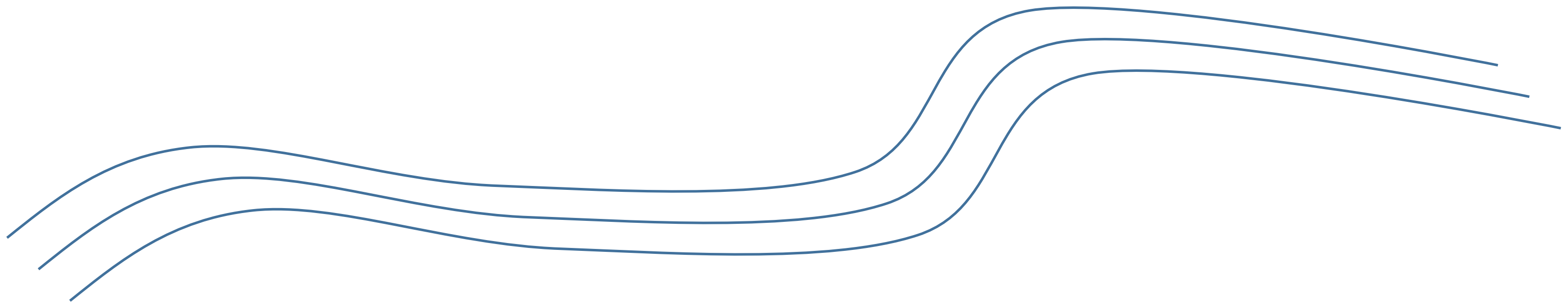
$u_1 = Wind\ velocities\ while\ passing\ through\ rotor\ blade$

$u_2 = Wind\ velocities\ at\ downstream\ direction$

- ***The rotor of the wind turbine collects wind from the whole area swept by the rotor.***
- ***Air mass flow rate should be same everywhere within the stream tube.***

Bernoulli's Principle

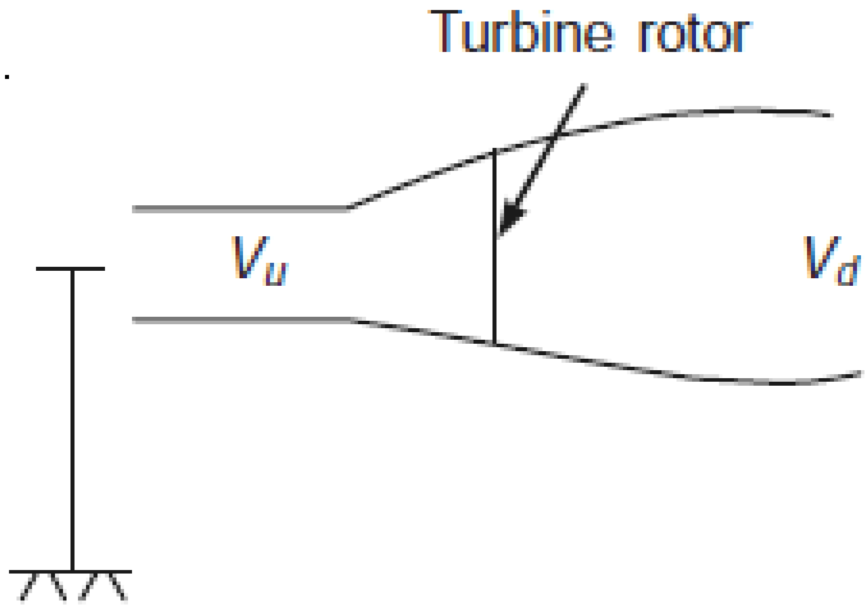
- **It is based on the *principle of conservation of energy*.**
- **In a steady flow the sum of all forms of mechanical energy in a fluid *along a streamline* is the same at all points on that streamline.**

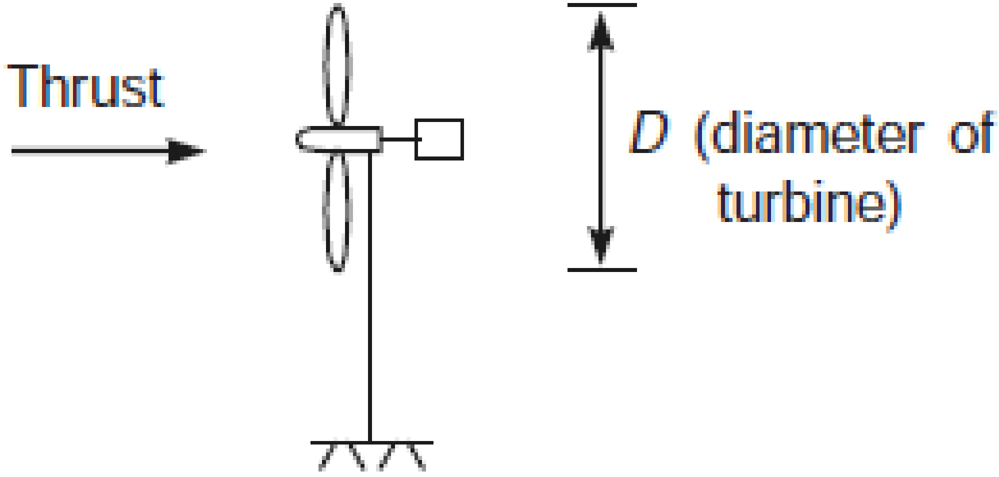


DESIGN OF WIND TURBINE ROTOR

Two forces that operate on the blades of a propeller type wind turbine

- **Axial Thrust** — Acts in the same direction as that of the flowing wind stream.
- **Circumferential force** — Acting in the direction of wheel rotation that provides the torque.





Mechanical Power

$$Mechanical\ Power = Torque\ imparted\ by\ the\ wind\ \times Angular\ velocity$$

$$\boldsymbol{P_T = T \times \omega}$$

$$\boldsymbol{T = F \times R}$$

Numerical Problems

Q1. ***Wind at one standard atmospheric pressure and 15°C has a speed of 10 m/s. A 10-m diameter wind turbine is operating at 5 rpm with maximum efficiency of 40%. Calculate***

(i) The total power density in wind stream,

(ii) The maximum power density,

(iii) The actual power density,

(iv) The power output of the turbine, and

(v) The axial thrust on the turbine structure.

Numerical Problems

Q2. ***A WEG generates 1500 watts at rated speed of 24 kmph at the atmospheric pressure and temperature of 20°C. Calculate the change in output if the wind generator is operated at an altitude of 1800 m, temperature 10°C, wind speed 30 kmph, and air pressure 0.88 atmosphere.***

AERODYNAMIC OPERATION OF WIND TURBINES

Aerodynamics deals

↓

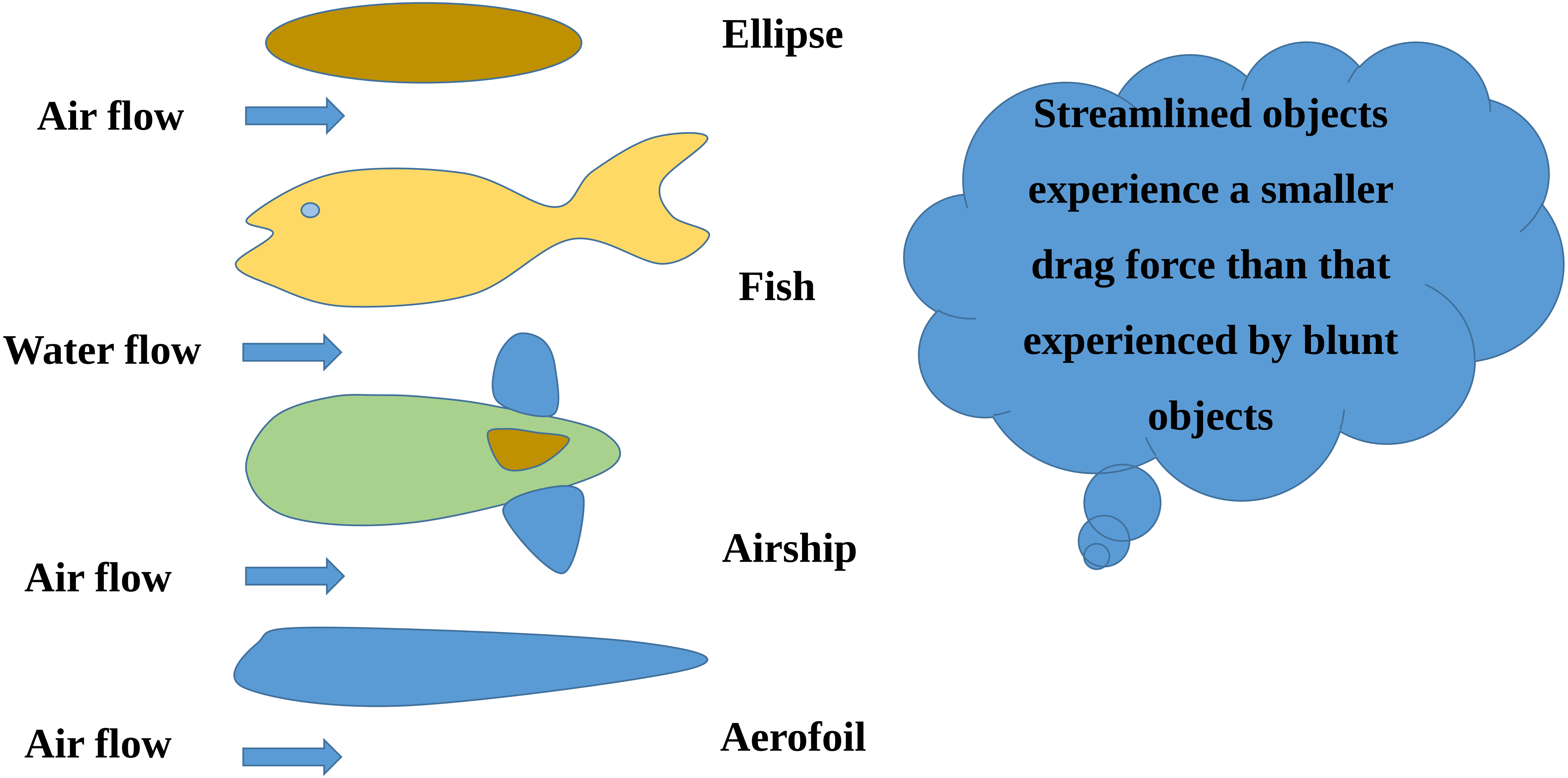
Movement of solid bodies through the air

↓

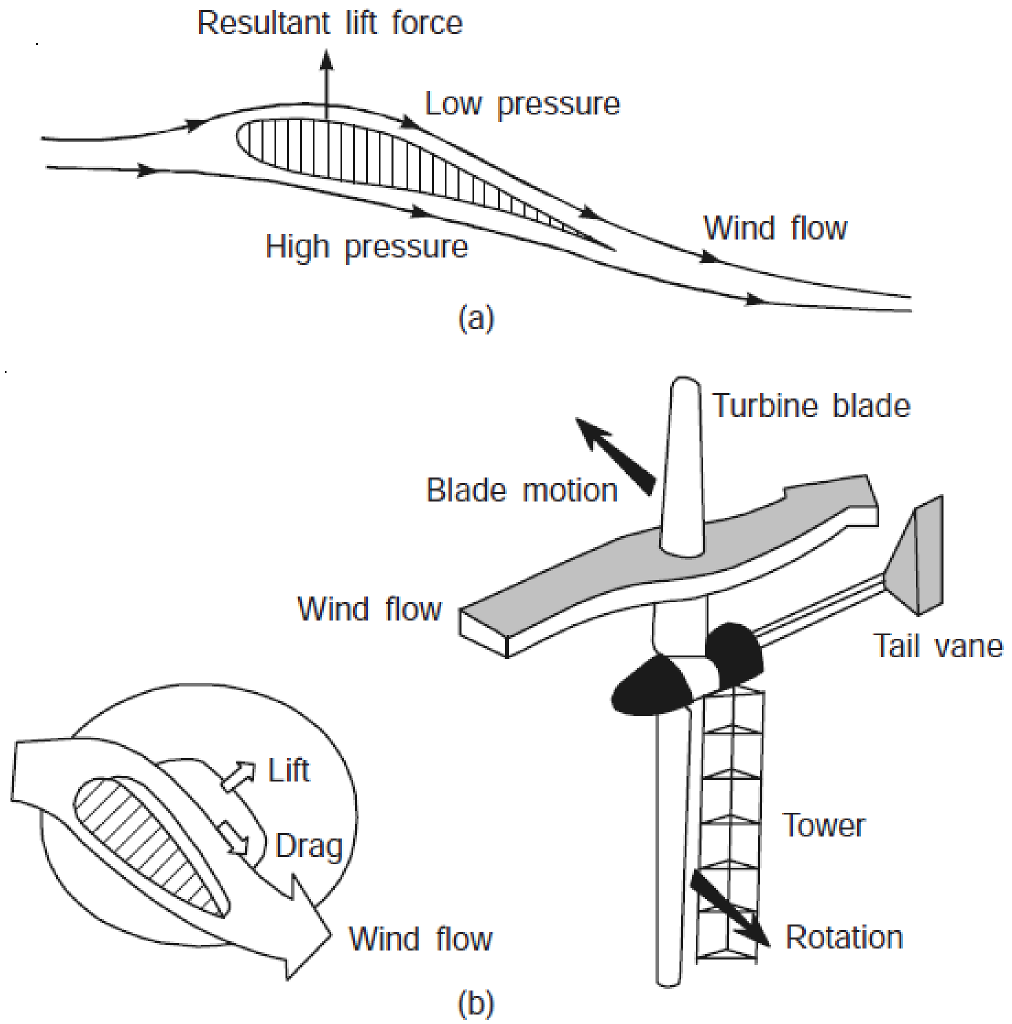
In wind turbines,
aerodynamics provides a method to explain the relative motion between airfoil and air

Airfoil is the cross-section of the wind turbine blade.

Some Examples of Streamlined Shapes



PRINCIPLES OF WIND ENERGY CONVERSION (AERODYNAMICS) cont..



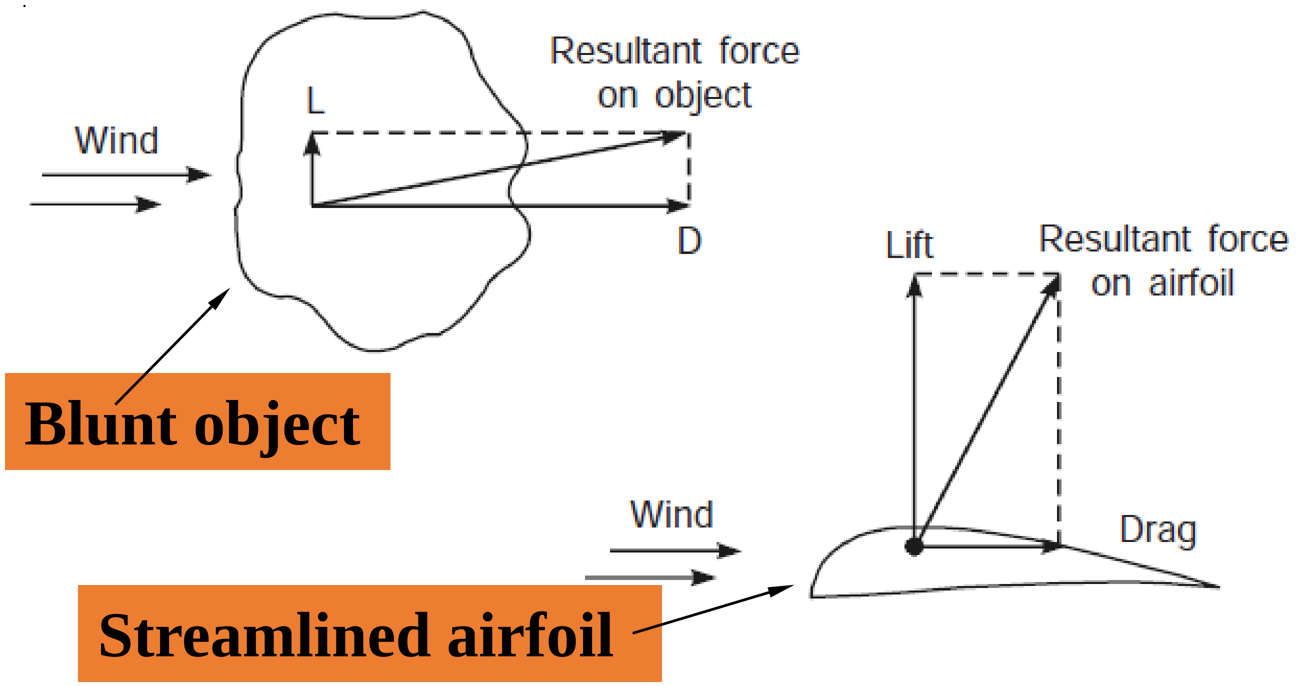


Figure: **Relative magnitudes of lift and drag forces on a blunt object and a streamlined airfoil.**

Figure: **(a) Aerodynamic lift force on blade cross-section of wind turbine, and (b) the basic operating principle of wind turbine aerodynamic lift.**

Drag force

- **Drag : It is the resistance which a body experiences when a fluid moves over it.**
- **The force that a flowing fluid exerts on a body in the direction of flow is called ‘drag force’.**
- **Streamlined objects experience a smaller drag force than that experienced by blunt objects.**
- **Generation of lift always creates a certain amount of drag force.**
- **Friction acts to help us as a ‘life saver’ in brakes of automobiles. Similarly, the drag force is useful in safe landing with a parachute.**
- **Reduction of drag is the basic engineering approach, associated with the reduction in fuel consumption in automobiles, aircraft and submarines.**

Lift force

- When a body is immersed in a standstill fluid, only the normal pressure force is exerted on it.
- A flowing fluid in addition exerts tangential shear forces on the surface. Both these forces have two components, one is drag in the flow direction, the other is perpendicular to the fluid flow called 'lift'.
- It causes the body to move in the upward direction. The relative magnitudes of drag and lift forces depend completely on the shape of the object.
- Airfoils of a wind turbine are especially shaped to produce lift force on coming in contact with the moving air.
- It is achieved by fabricating the top surface of the airfoil as curved and the bottom surface nearly flat.

PRINCIPLES OF WIND ENERGY CONVERSION (AERODYNAMICS)

- **There are two primary physical principles by which energy can be extracted from the wind.**
- **These are through the *creation of either lift or drag force* (or through a combination of the two), as shown in Figure.**

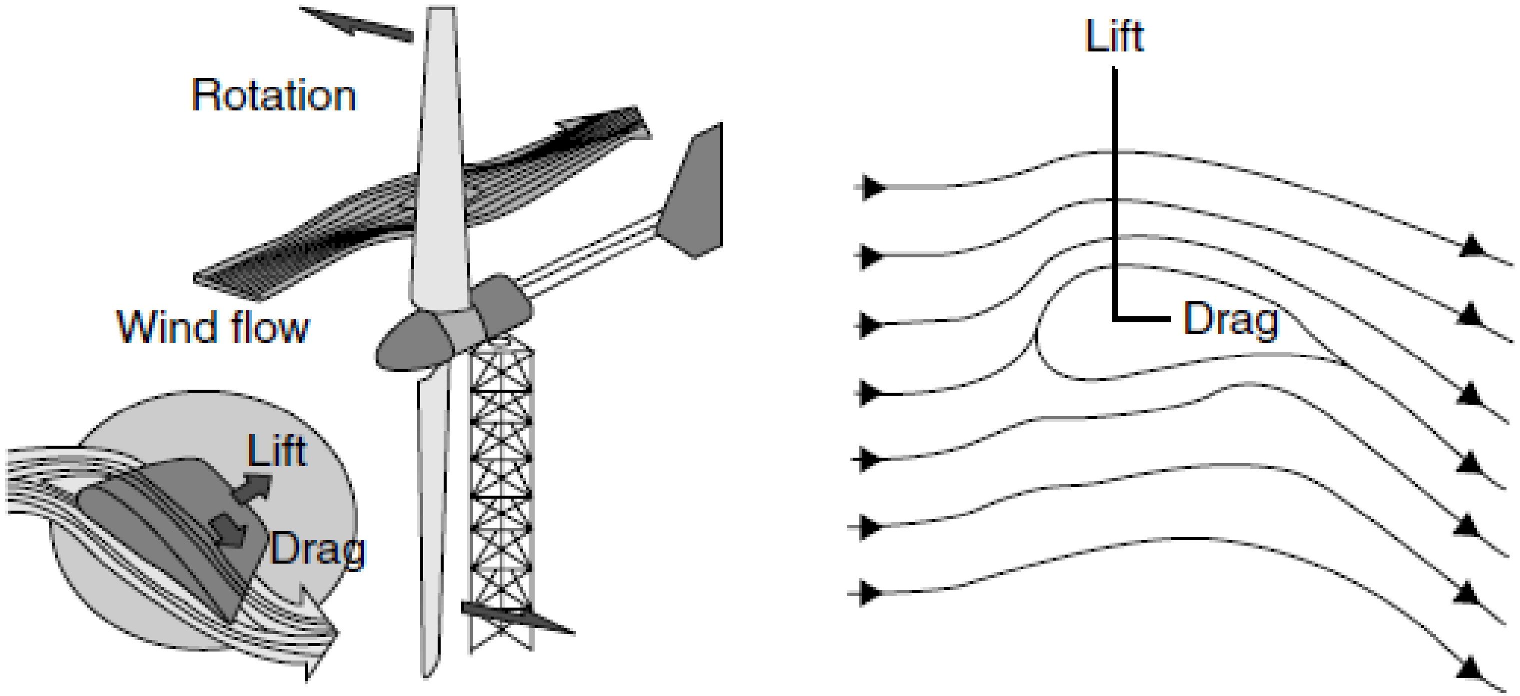
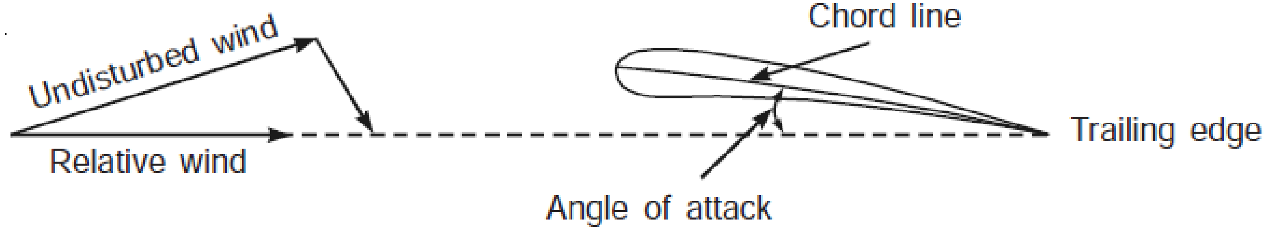


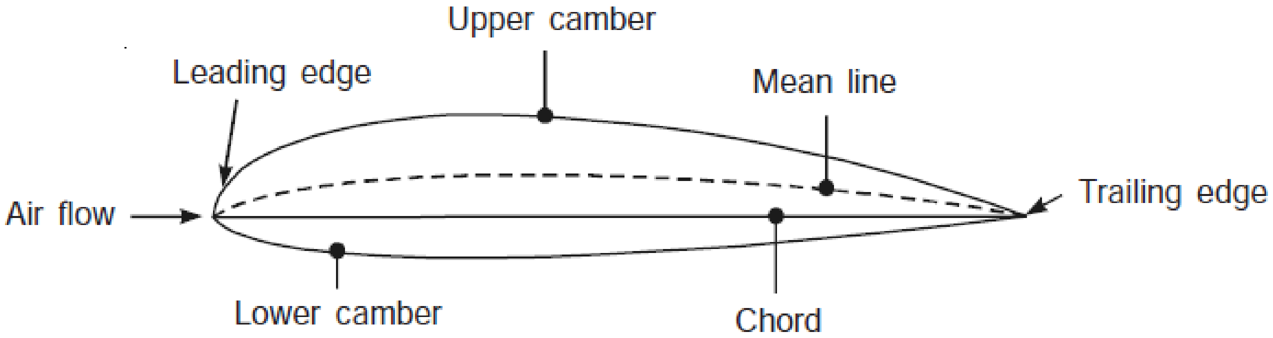
Figure: Principles of wind turbine aerodynamics

TERMS USED IN WIND ENERGY

Airfoil (Aerofoil): A streamlined curved surface designed for air to flow around it in order to produce low drag and high lift forces.

Angle of attack: It is the angle between the relative air flow and the chord of the airfoil.



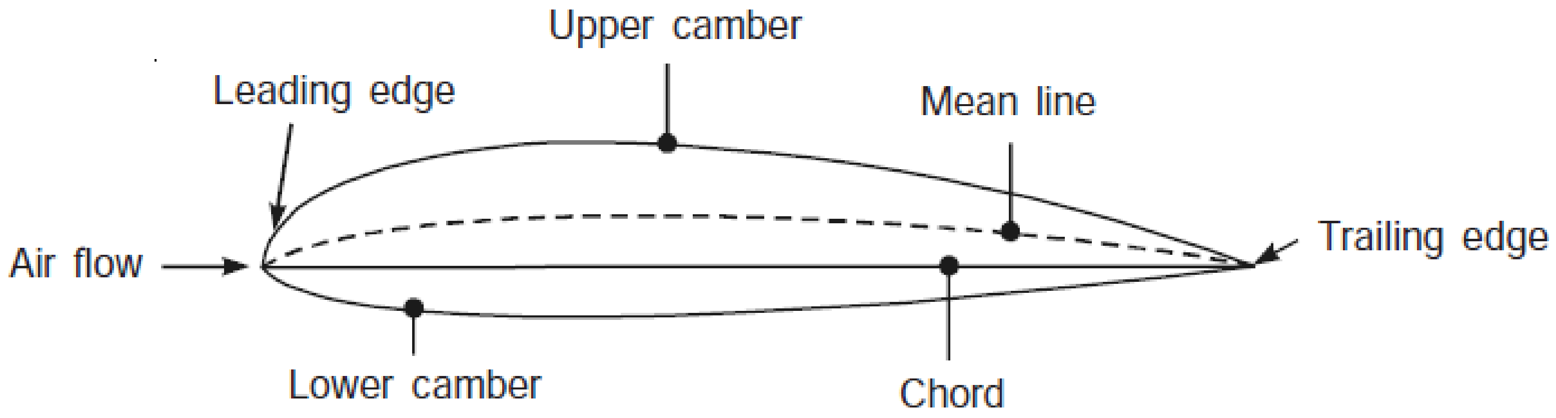


Blade: An important part of a wind turbine that extracts wind energy.

Leading edge: It is the front edge of the blade that faces towards the direction of wind flow [Figure].

Trailing edge: It is the rear edge of the blade that faces away from the direction of wind flow [Figure].

TERMS USED IN WIND ENERGY cont.



Mean line: A line that is equidistant from the upper and lower surfaces of the airfoil.

Camber: It is the maximum distance between the mean line and the chord line, which measures the curvature of the airfoil.

Rotor: It is the prime part of the wind turbine that extracts energy from the wind. It constitutes the blade-and-hub assembly.

Hub: Blades are fixed to a hub which is a central solid part of the turbine.

TERMS USED IN WIND ENERGY cont.

Propeller: It is the turbine shaft that rotates with the hub and blades and is called the propeller. Blades are twisted as per design. The outer profile of the blades conforms to aerodynamic performance while the inner profile meets the structural requirements.

Tip speed ratio: It is the ratio of the speed of the outer blade tip to the undisturbed natural wind speed.

Swept area: This is the area covered by the rotating rotor.

Solidity: It is the ratio of the blade area to the swept area.

- A windmill has rotor of 6 m with 30 blades. Each blade has width of 0.30 m, find the solidity. What is the implication of solidity?

$$\text{Solidity} = \frac{\text{Projected area of blades}}{\text{Swept area}}$$

$$\text{Solidity} = \frac{30 \times 0.30}{\pi \times 6^2} \times 100\%$$

$$= 7.96\%$$

The fraction of the swept area that is solid.

TERMS USED IN WIND ENERGY cont.

The greater is the solidity of a rotor, the slower it needs to turn to intercept the wind. When windwill has a lesser number of blades, it needs to rotate fast to intercept the wind so that wind should not be lost through the large gap existing between two blades without importing a part of wind power.

- **Find the tip-speed ratio if a 6 m diameter rotor has rotation of 20 rpm and the wind speed is 4 m/s. What is the implication of tip speed ratio?**

$v = \omega R$

$= \text{Linear velocity}$

$$\text{Tip speed ratio} = \frac{W.R}{u_0}$$

$$\text{Tip speed ratio} = \frac{\frac{\pi R N}{60}}{4}$$

$$= \frac{\pi \times 6 \times 20}{60 \times 4} = 1.6$$

$$\omega = \frac{2\pi \times 20}{60} \text{ Rad/sec} \Rightarrow 2.09\ Rad/sec$$

$$Ratio = \frac{2.09 \times 3}{4} = 1.57$$

The windmill rotating fast has tip speed ratio greater than 1. Two or three-bladed rotors rotate faster, thereby having tip speed ratio ranging from 3 to 10. More bladed rotors rotate move slowly, thereby having tip speed ratio between 1 and 2.

Drag force: **It is the force component which is in line with the velocity of wind.**

Lift force: **It is the force component perpendicular to drag force.**

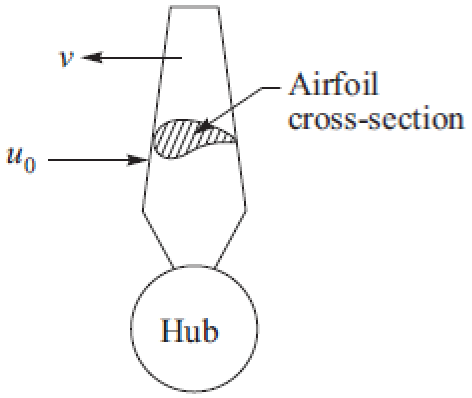
TERMS USED IN WIND ENERGY cont.

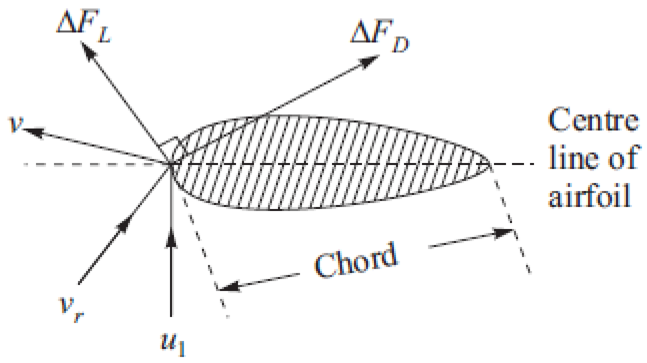
Yaw control: **As the direction of the wind changes frequently, the yaw control is provided to steer the axis of the turbine in the direction of the wind.**

- **It keeps the turbine blades in the plane perpendicular to the wind, either in the upward wind direction or in the downward wind direction.**

Lift Type and Drag Type Wind Turbines

- Two important aerodynamic principles are used in wind turbine operations, i.e., lift and drag.
- Wind can rotate the rotor of a wind turbine either by lifting (lift) the blades or by simply passing against the blades (drag).
- Wind turbines can be identified based on their geometry and the manner in which the wind passes over the blades.
- Drag force: It is the force component which is in line with the velocity of wind.
- Lift force: It is the force component perpendicular to drag force.





Chord:- Width of the blade from one edge to the other edge.

Parts of a Wind Turbine

1. The nacelle contains the key components of the wind turbine, including the gearbox and the electrical generator.

2. The tower of the wind turbine carries the nacelle and the rotor. Generally, it is an advantage to have a high tower, since wind speeds increase farther away from the ground.

3. The rotor blades capture wind energy and transfer its power to the rotor hub.

4. The generator converts the mechanical energy of the rotating shaft to electrical energy.

5. The gearbox increases the rotational speed of the shaft for the generator.

CLASSIFICATION AND DESCRIPTION OF WIND MACHINES

- **The basic wind energy conversion device is the wind turbine.**
- **Although various designs and configurations exist, these turbines are generally grouped into two types depending on the *position of the rotor axis*.**
- **Figure illustrates the two types of turbines and typical subsystems for an electricity generation application.**

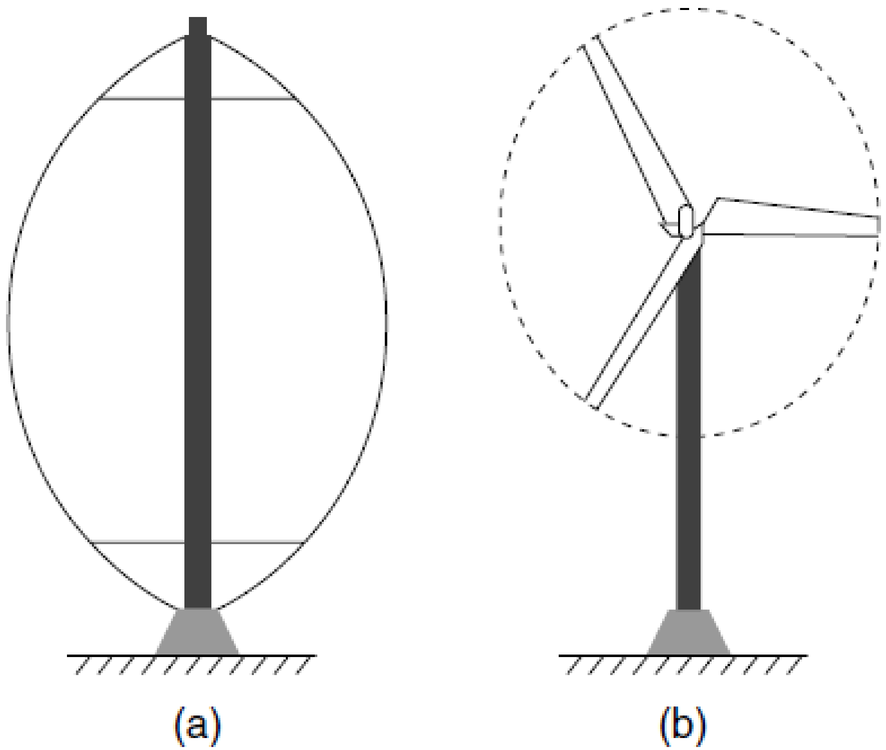


Figure : Wind rotor configurations (a) Vertical axis (b) Horizontal axis

CLASSIFICATION AND DESCRIPTION OF WIND MACHINES cont..

- **For a <u>horizontal-axis turbine</u>, *the rotor axis is kept horizontal* and aligned parallel in the direction of the wind stream.**
- **In a <u>vertical-axis turbine</u>, *the rotor axis is vertical* and fixed, and remains perpendicular to the wind stream.**

Parts of a Wind Turbine cont.

Gearbox

Increases the rotational speed of the shaft

Nacelle

Electrical generator

Nacelle and the Rotor

Tower of the wind turbine

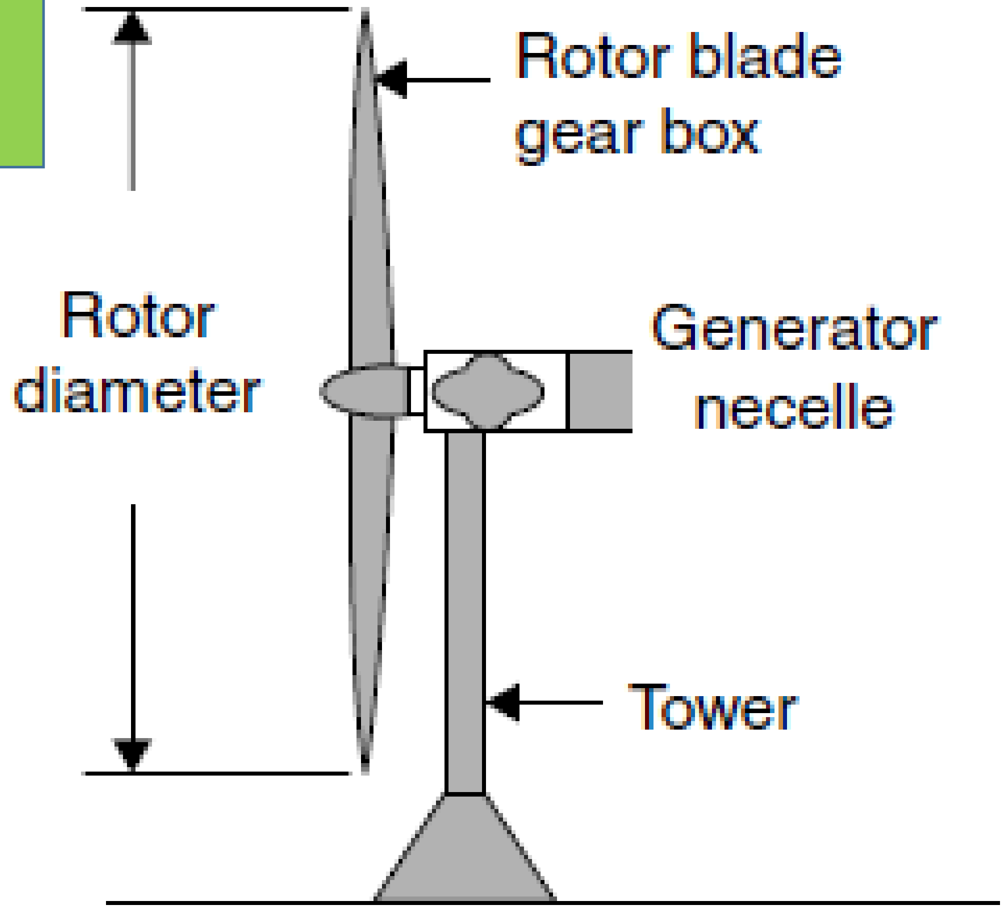


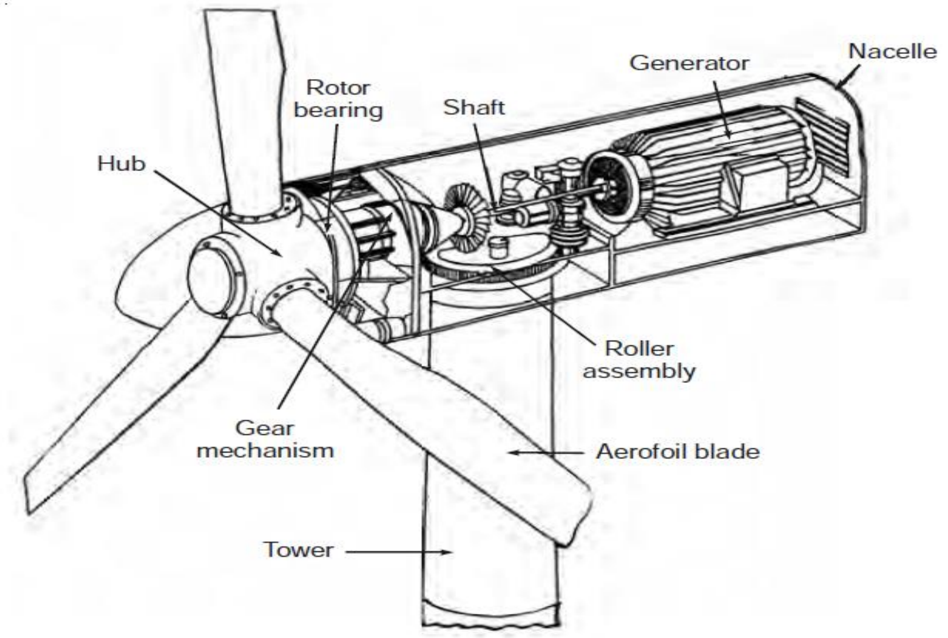
Figure: Horizontal-axis wind turbine

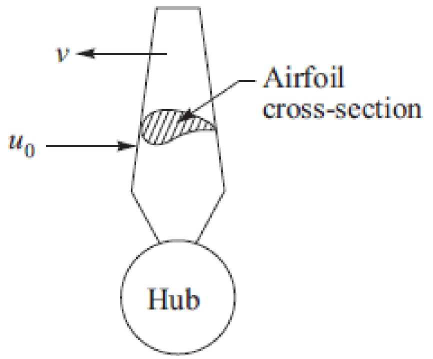
Mechanical energy of the rotating shaft

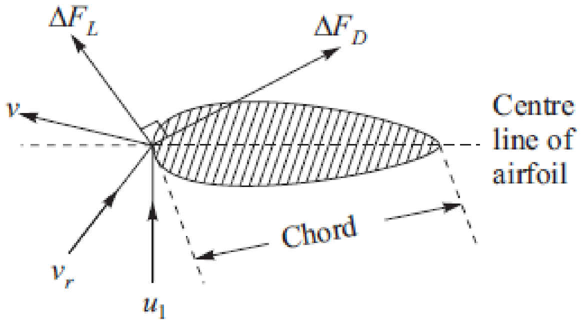
Generator

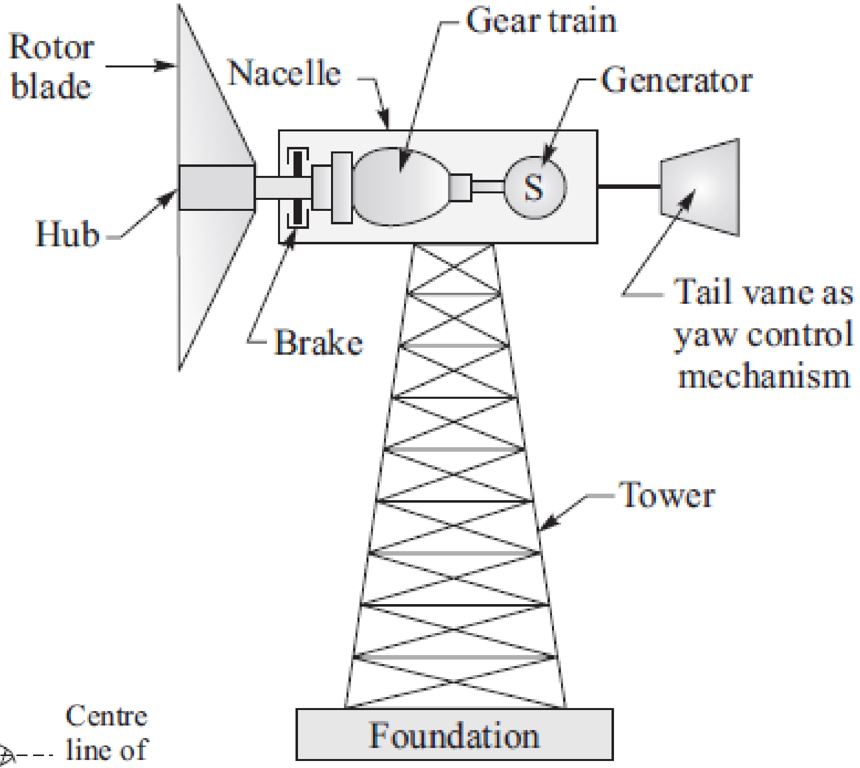
Electrical energy

Parts of a Horizontal Axis Type Wind Turbine cont.

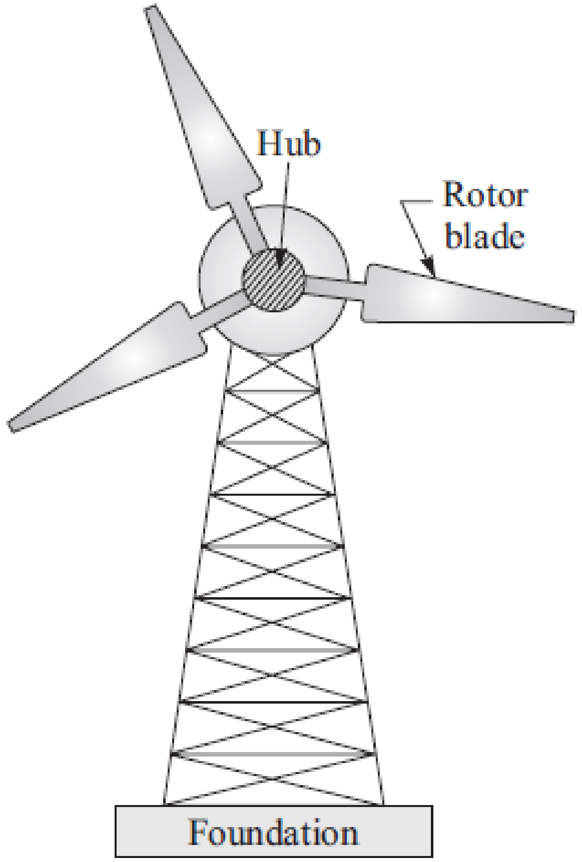








(a) Side View



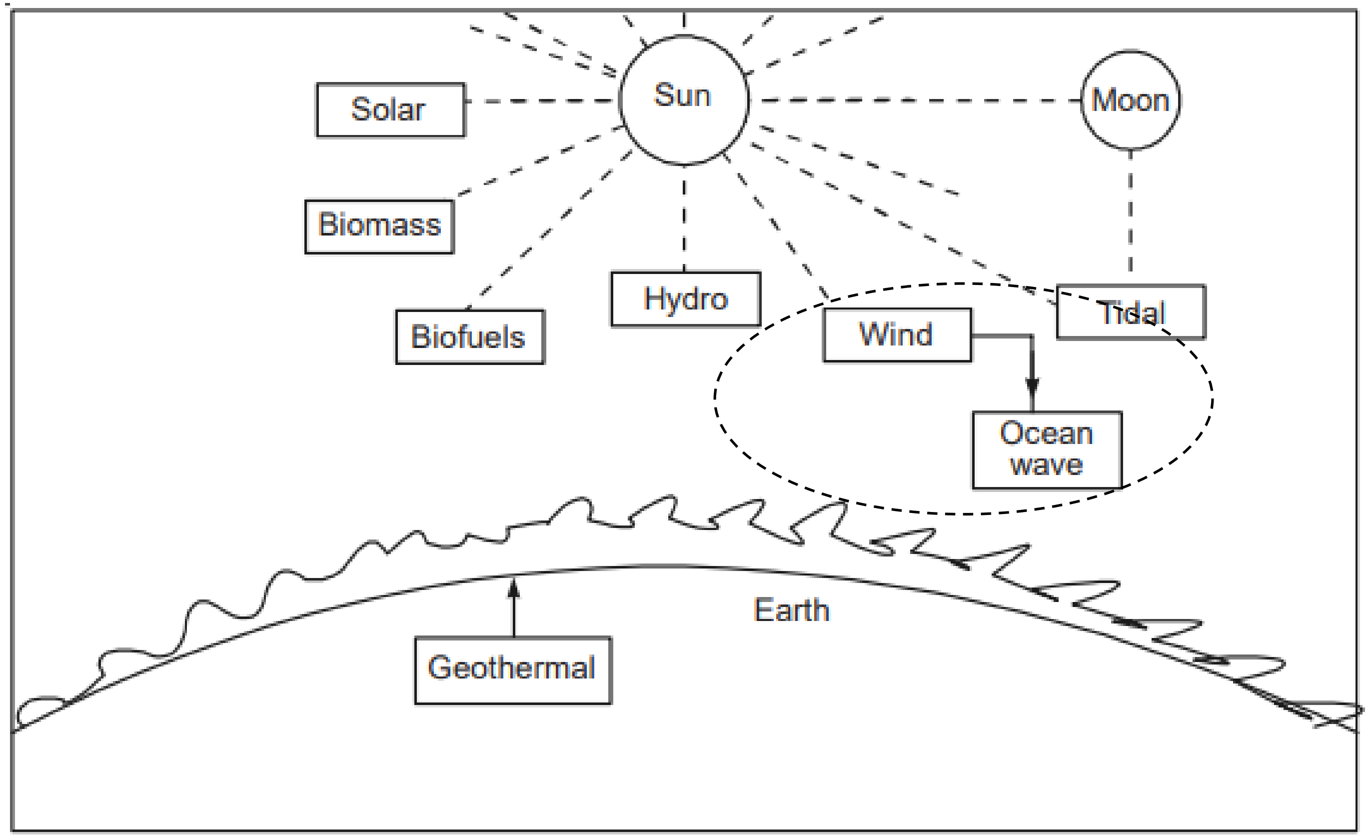
(b) Front View

- **Blades have aerofoil type cross section to extract energy from wind.**
- **Hub, helps in the attachment of all blades.**

Reference books

- **Non-Conventional Energy Resources - G.S. Sawhney**
- **Renewable Energy Resources and Emerging Technologies – D. P. Kothari, K. C. Singal, and Rakesh Ranjan**
- **Non-Conventional Energy Resources – Shobh Nath Singh**
- **Renewable Energy – M. K. Ghosh Roy**

Wave Energy



Ocean based Renewable energy source that uses the power of the waves to generate electricity

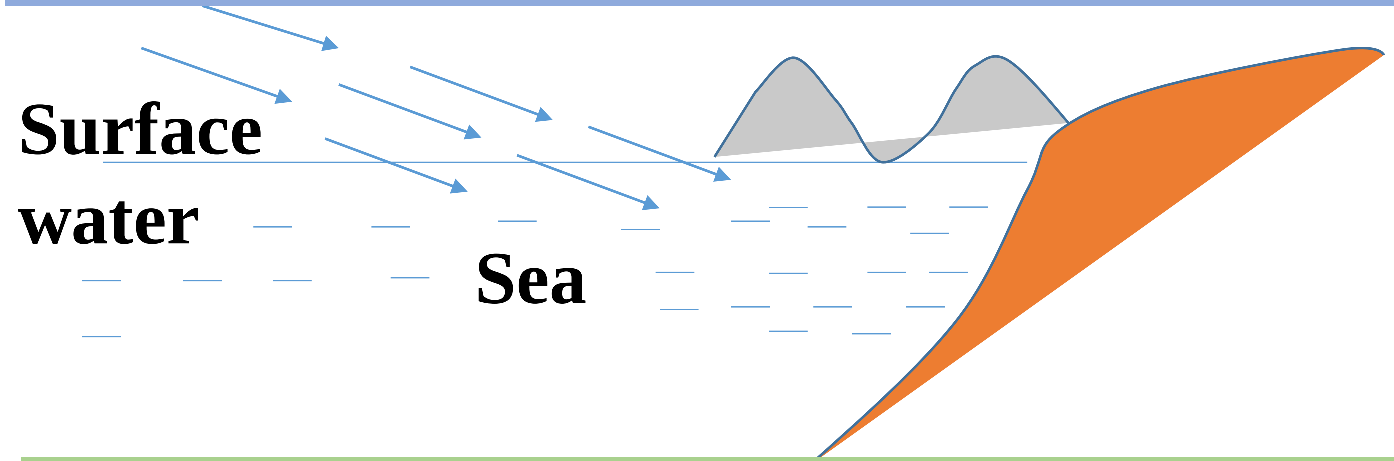
Wave Energy

It uses the vertical movement of the surface water

- **Second form of ocean energy i.e., wave energy.**
- **Wind blows over the surface of sea producing fast moving sea waves.**
- **Energy of these waves used for different kinds of work.**
- **This potential can satisfy world's 40 % need.**

Wave Energy formation

Wind Energy transfers its energy to the surface water of the ocean



Wave Energy

KE → Wave Propagation

PE → Lifting of water mass w.r.t. mean sea level

Formation of wave is a continuous phenomena and keeps on forming in the ocean and destroying on the shore.

Wave Energy

- **Differential warming of the earth causes pressure differences in the atmosphere, which generate winds.**
- **As winds move across the surface of open bodies of water, they transfer some of their energy to the water and create waves.**

✓ **Waves get their energy from the solar energy through the wind.**

✓ **Wave energy will never be depleted as long as the sun shines.**

✓ **Energy intensity may, however, have variation but it is available 24 h a day in the entire year.**

Wave Energy

- Waves are formed on the surface of water by the <u>frictional action of the winds</u> resulting in the radial depression of energy from the blowing winds in all directions.

- Wave energy is available in

✓ Coastal areas,

✓ Islands and its potential depends upon its geographic location.

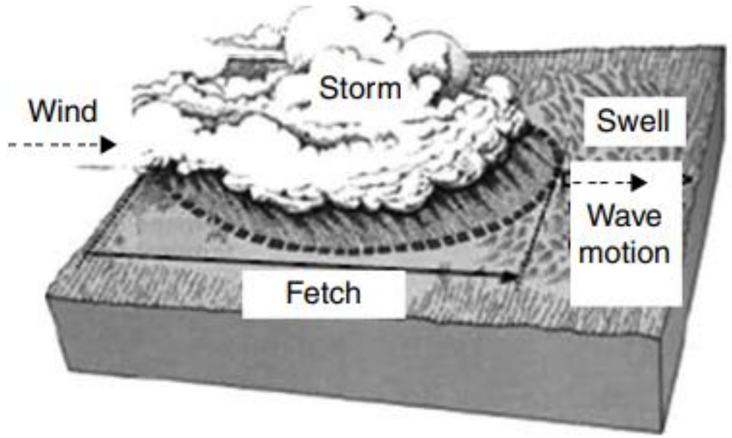


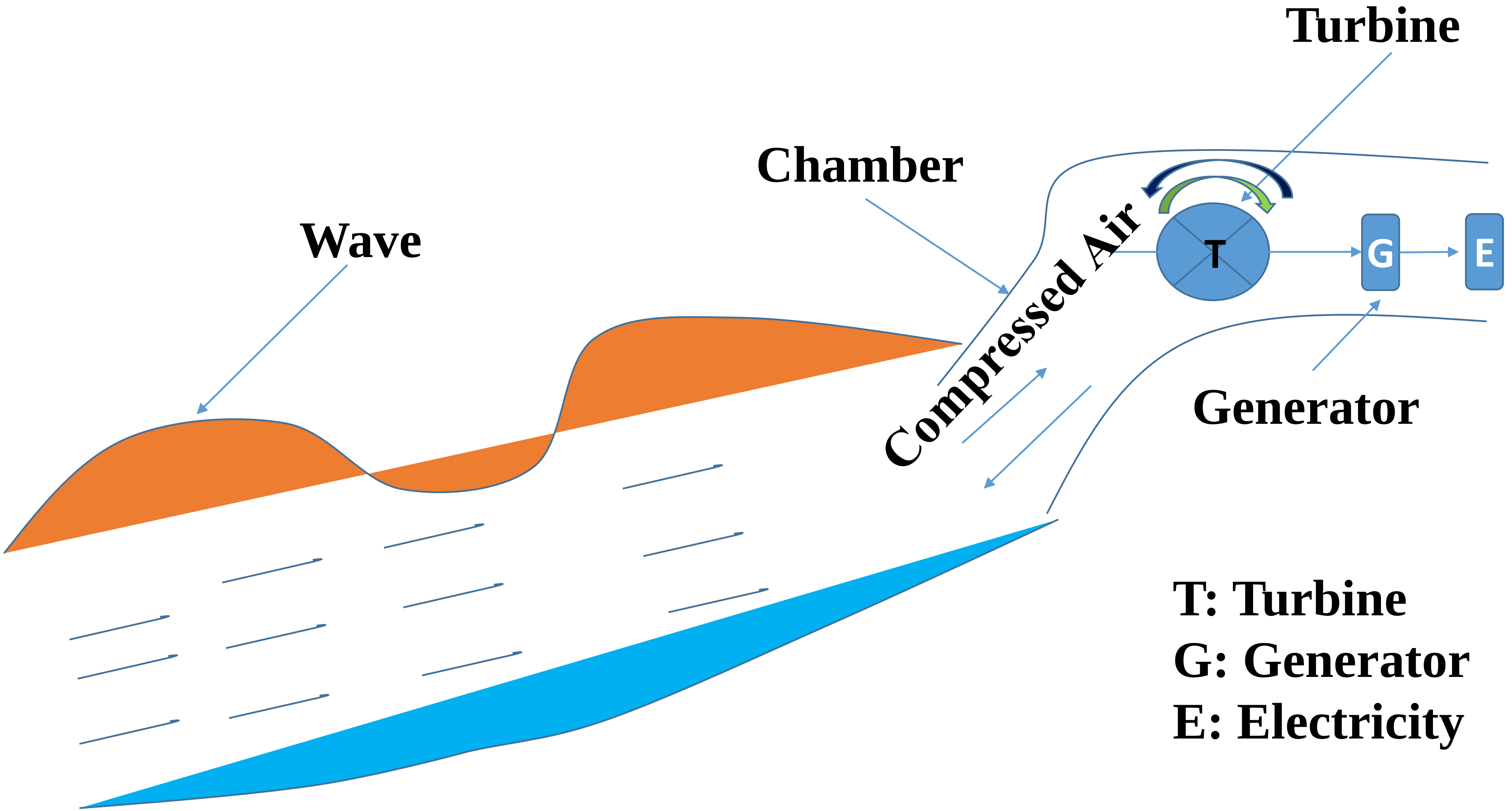
Figure : Sea wave formation by storm

Three major factors which govern the quantum of wave energy

- Wind speed
- Effective fetch value
- Depth of the sea water

Fetch: Ocean waves are generated by wind passing over long stretches of water

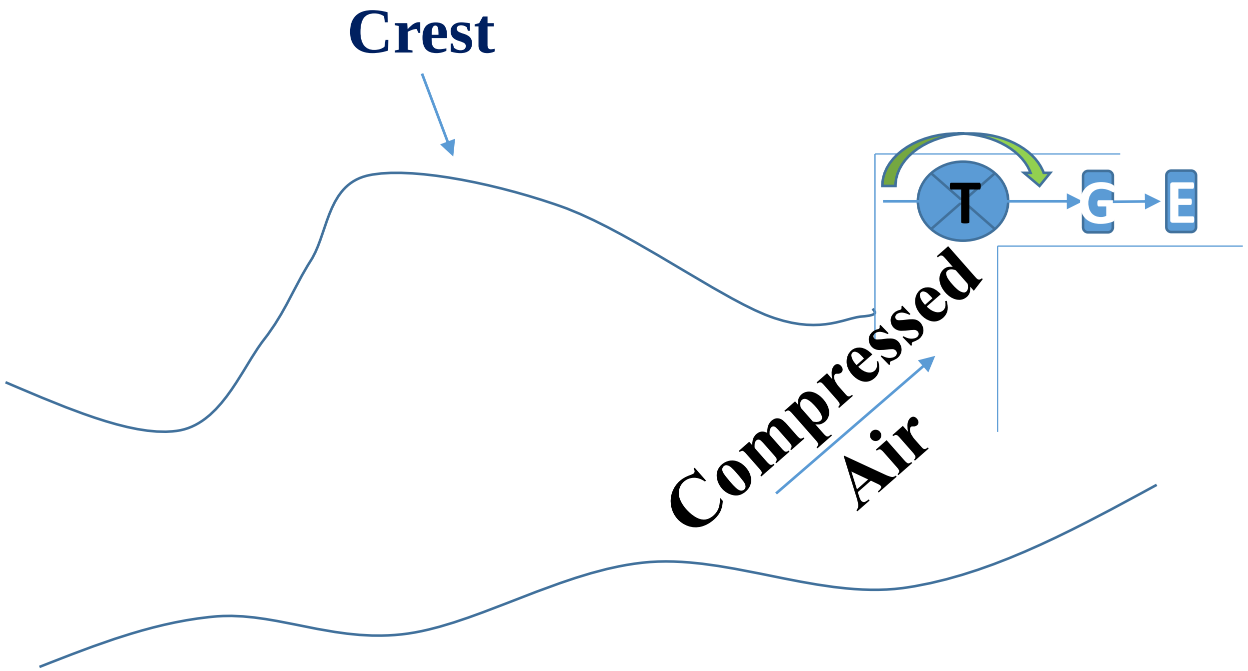
Wave Energy



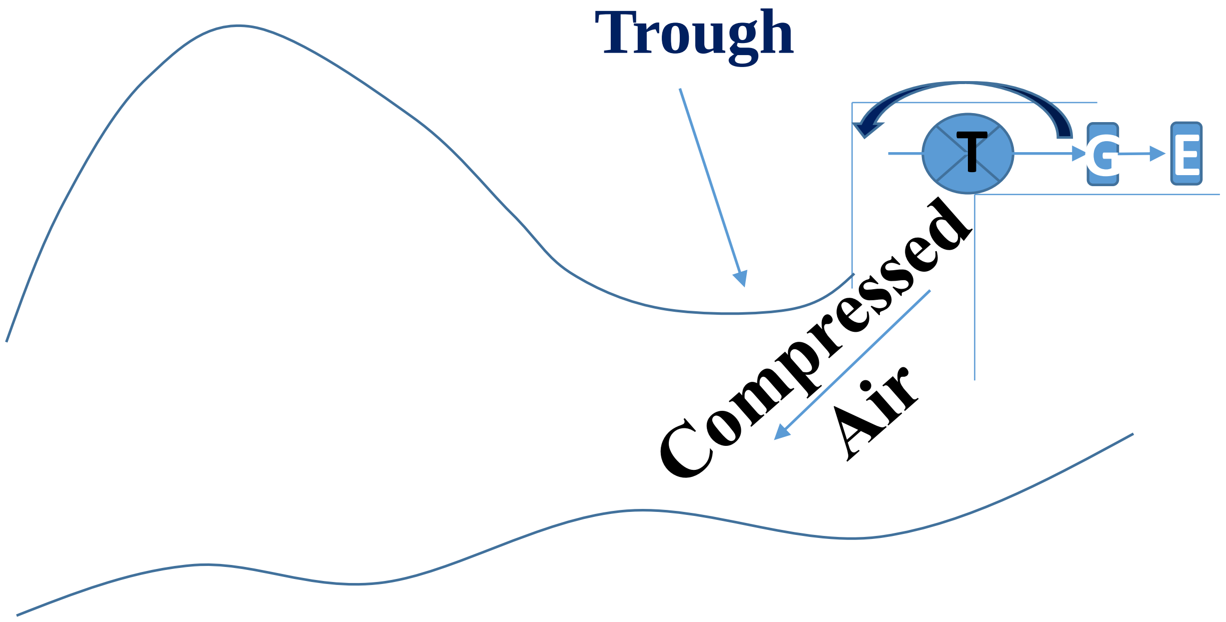
Turbine
Chamber
Wave
Compressed Air
T
G
E
Generator
T: Turbine
G: Generator
E: Electricity

Wave Energy

The maximum height of the wave



The lowest height of the wave



T: Turbine
G: Generator
E: Electricity

Waves are characterized by the following parameters cont.

1. Crest: The peak point (the maximum height) on the wave is called the crest.
2. Trough: The valley point (the lowest point) on the wave is called the trough.
3. Wave height (H): Wave height is a vertical distance between the wave crest and the next trough (m).
4. Amplitude (a): It is defined as H/2 (m).
5. Wave length (λ): It is the horizontal distance either between the two successive crests or troughs of the ocean waves (m).

The shape of the typical wave is described as sinusoidal (that is, it has the form of mathematical sine function)

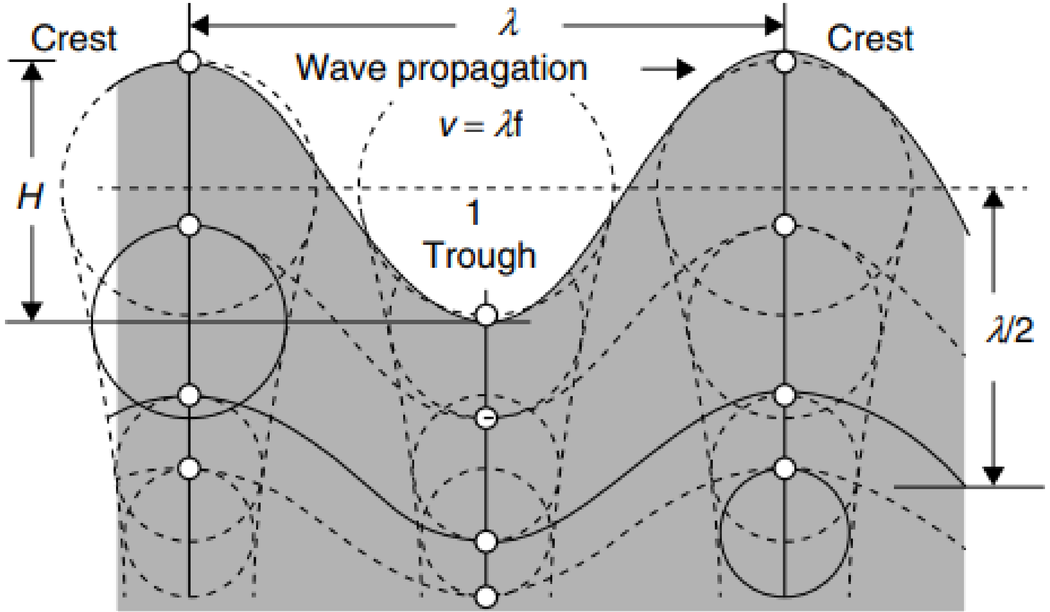


Figure: Sea wave propagation

Waves are characterized by the following parameters

6. Wave propagation velocity (v): The motion of seawater in a direction (m/s).

7. Wave period (T): It measures the size of the wave in time(s). It is the time required for two successive crests or two successive troughs to pass a point in space.

8. Frequency (f): The number of peaks (or troughs) that pass a fixed point per second is defined as the frequency of wave and is given by f = 1/T (cycle/s).

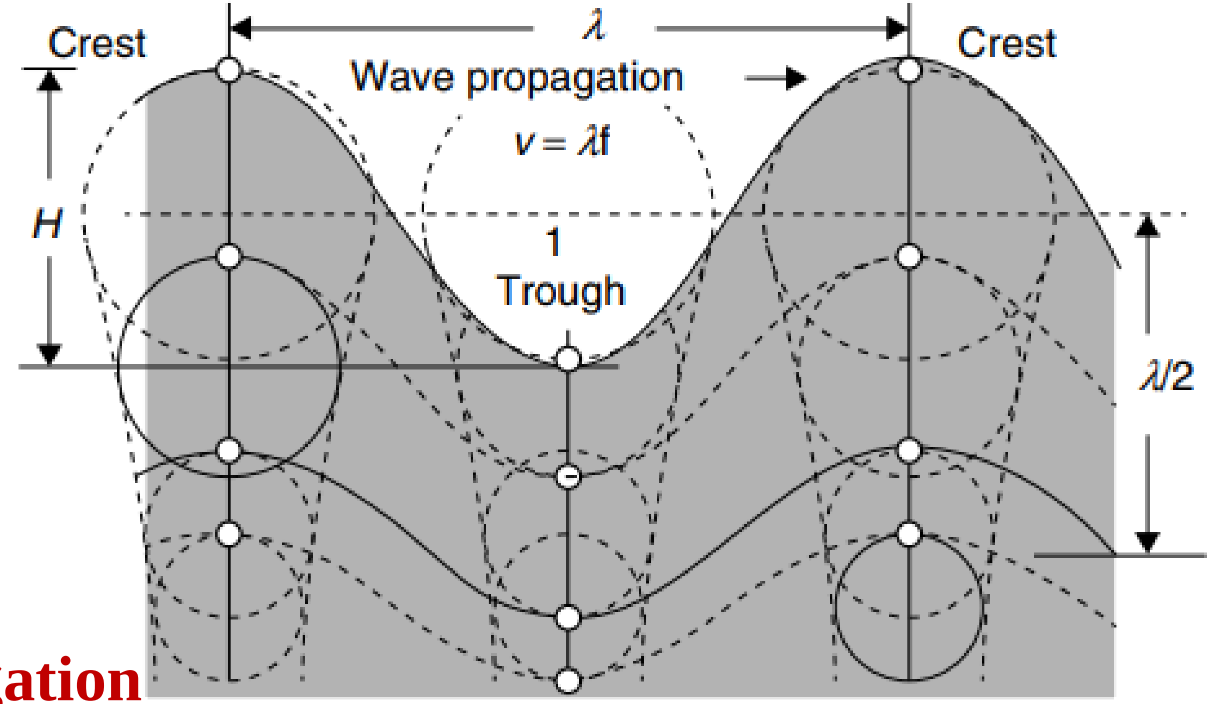
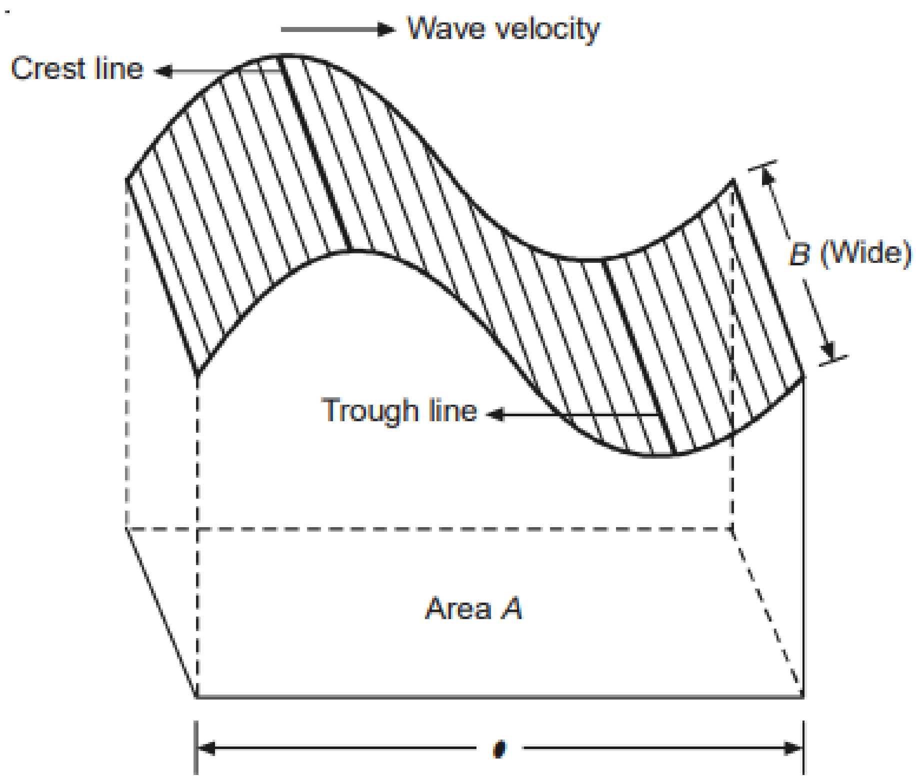


Figure: Sea wave propagation

Numerical Problems

Q.1 A progressive sea wave has a wave width of 100 m with a period of 5 seconds. Calculate the wavelength, the wave velocity and the wave area.

Solution:



$$\text{Wave Length, } \lambda = 1.56T^2 = 1.56 \times 5^2 = 39 \text{ m}$$

$$\text{Wave velocity, } C = \frac{\lambda}{T} = \frac{39}{5} = 7.8 \text{ m/s}$$

$$\begin{aligned}\text{Wave area, } A &= \text{wave length} \times \text{wave breadth} \\ &= \lambda \times B \\ &= 39 \times 100 \\ &= 3900 \text{ m}^2\end{aligned}$$

Figure: Water wave width B and length λ (B > λ)

Numerical Problems

Q.2 Ocean waves on an Indian coast had an amplitude of 1 m with a period of 5 s measured at the surface water 100 m deep. Calculate the wavelength, the wave velocity, the energy density and the power density of the wave. Take water density as 1000 kg/m^3.

Solution:

$$\text{Wavelength, } \lambda = 1.56T^2 = 1.56 \times 5^2 = 39 \text{ m}$$

$$\text{Wave velocity, } C = \frac{\text{Wavelength } \lambda}{\text{Period } T} = \frac{39}{5} = 7.8 \text{ m/s}$$

$$\text{Wave frequency, } f = \frac{1}{5} \text{ s}^{-1}$$

$$\text{Energy density, } \frac{E}{A} = \frac{1}{2} \times 1000 \times 1^2 \times 9.81 = 4905 \text{ J/m}^2$$

$$\text{Power density, } \frac{P}{A} = \left(\frac{E}{A}\right) f = 4905 \times \frac{1}{5} = 981 \text{ W/m}^2$$

Wave Energy Devices

Wave Energy $\xrightarrow{\text{Wave Energy Devices}}$ Mechanical Energy

- **On the basis of location in sea.**
- **On the basis of actuating motion used in capturing wave energy.**

Wave Energy

Wave Energy Device (WED)

Classified based on the site they are mounted

There are three areas for which wave energy converters are represented

Offshore System

Deals with swell energy not breaking waves

Near shore System

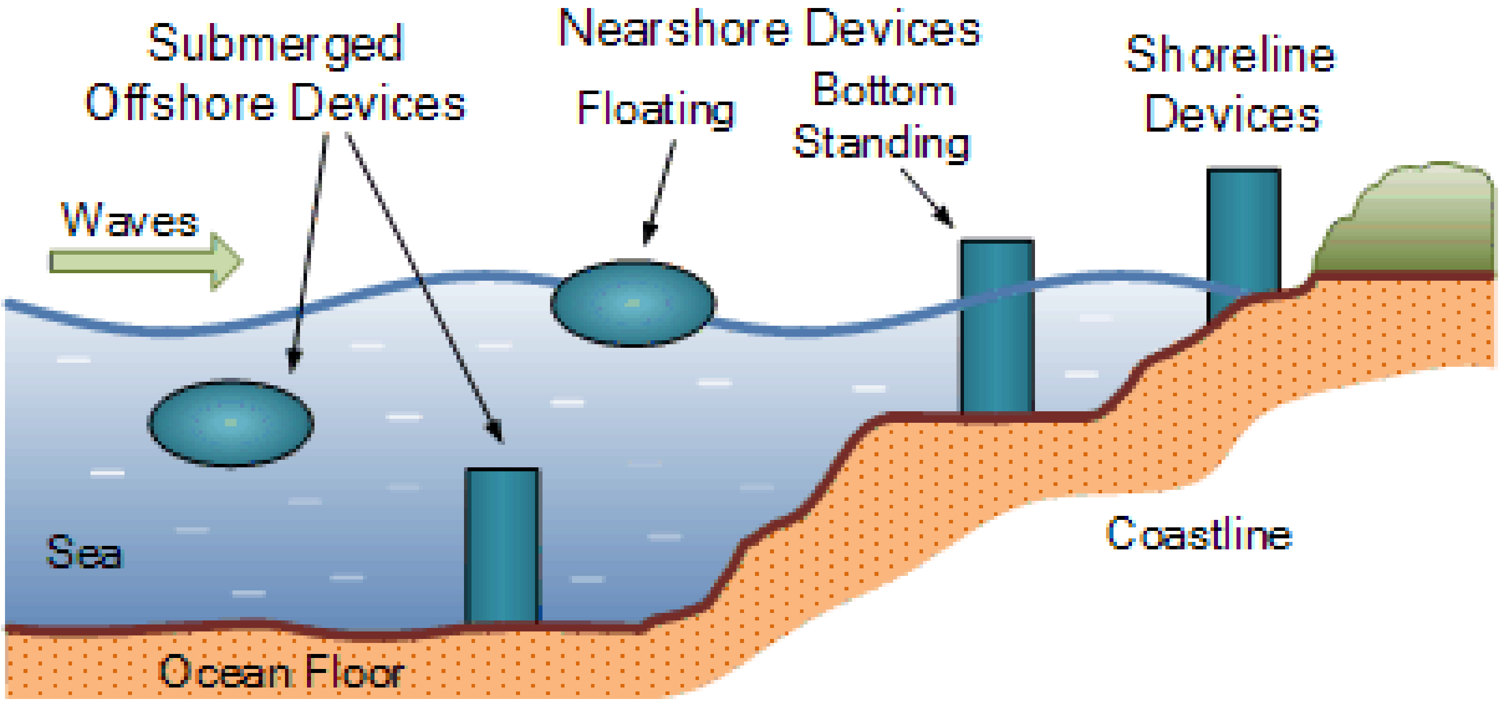
Maximum wave amplitude

Embedded System

Built into shoreline to receive breaking wave-but energy loss is occurring while the wave is breaking

Wave Energy Uses the Power of the Waves

- Ocean wave energy has many advantages over ocean wind energy in that it is more predictable, less variable and offers higher available energy densities.
- Depending on the distance between the energy conversion device and the shoreline, wave energy systems can be **classified** as being either ***Shoreline devices***, ***Nearshore devices or Offshore devices***.



Wave Power Devices

- ✓ ***Shoreline devices*** are wave energy devices which are fixed to or embedded in the shoreline, that is they are both in and out of the water.
- ✓ ***Nearshore devices*** are characterized by being used to extract the wave power directly from the breaker zone and the waters immediately beyond the breaker zone, (i.e. at 20m water depth).
- ✓ ***Offshore devices or deep water devices*** are the farthest out to sea and extend beyond the breaker lines ***utilizing the high-energy densities*** and ***higher power wave profiles*** available in the deep water waves and surges. **Offshore devices are situated in much deeper water, with typical depths of more than 30 meters**.

S. No.	Wave Energy Device	Water Depth	Maximum Wave Height
1	Onshore	10–15 m	reach up to 7.8 m
2	Nearshore	15–25 m	
3	Offshore	Higher than 50 m	reach up to 30 m or even more

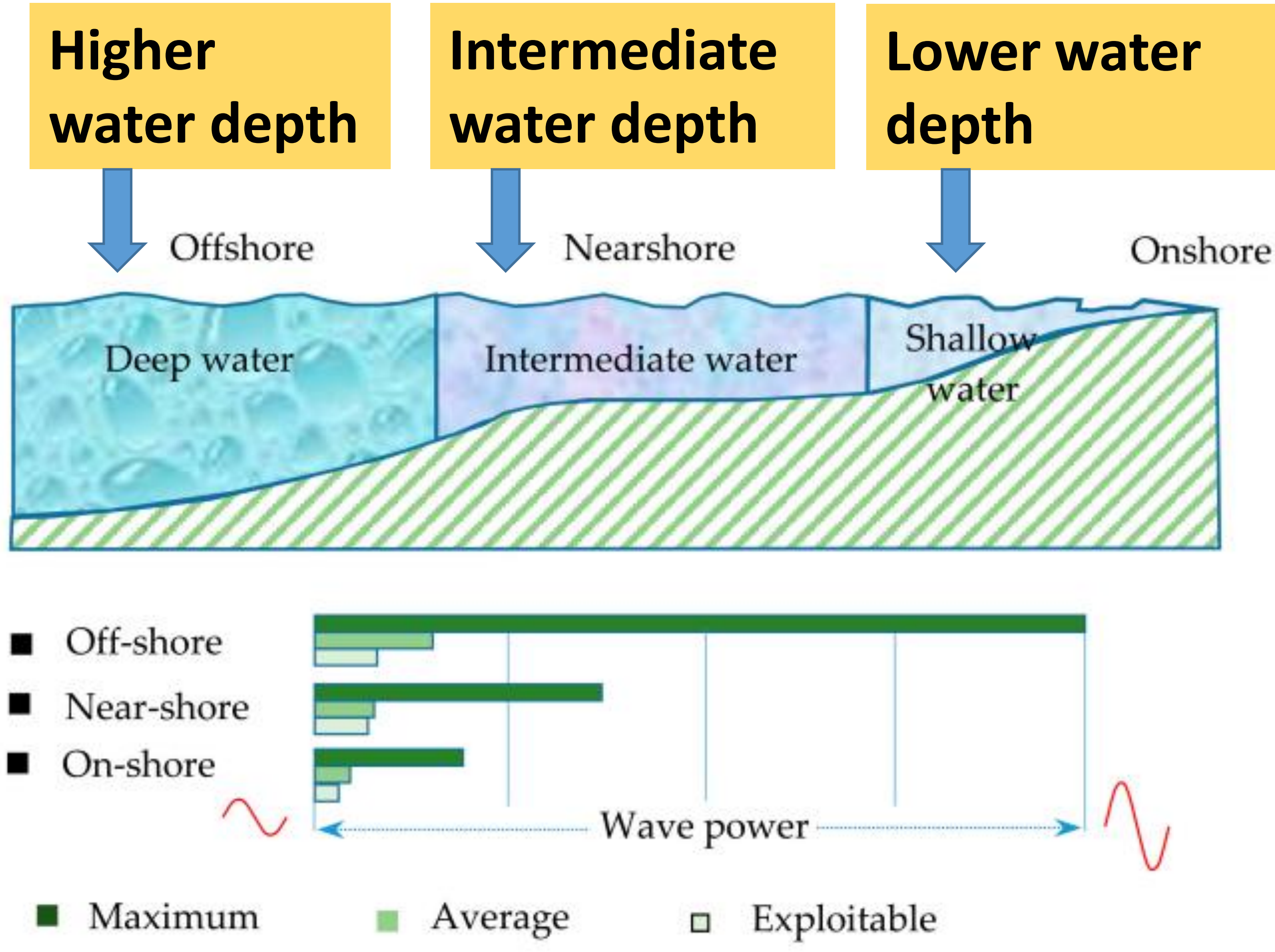


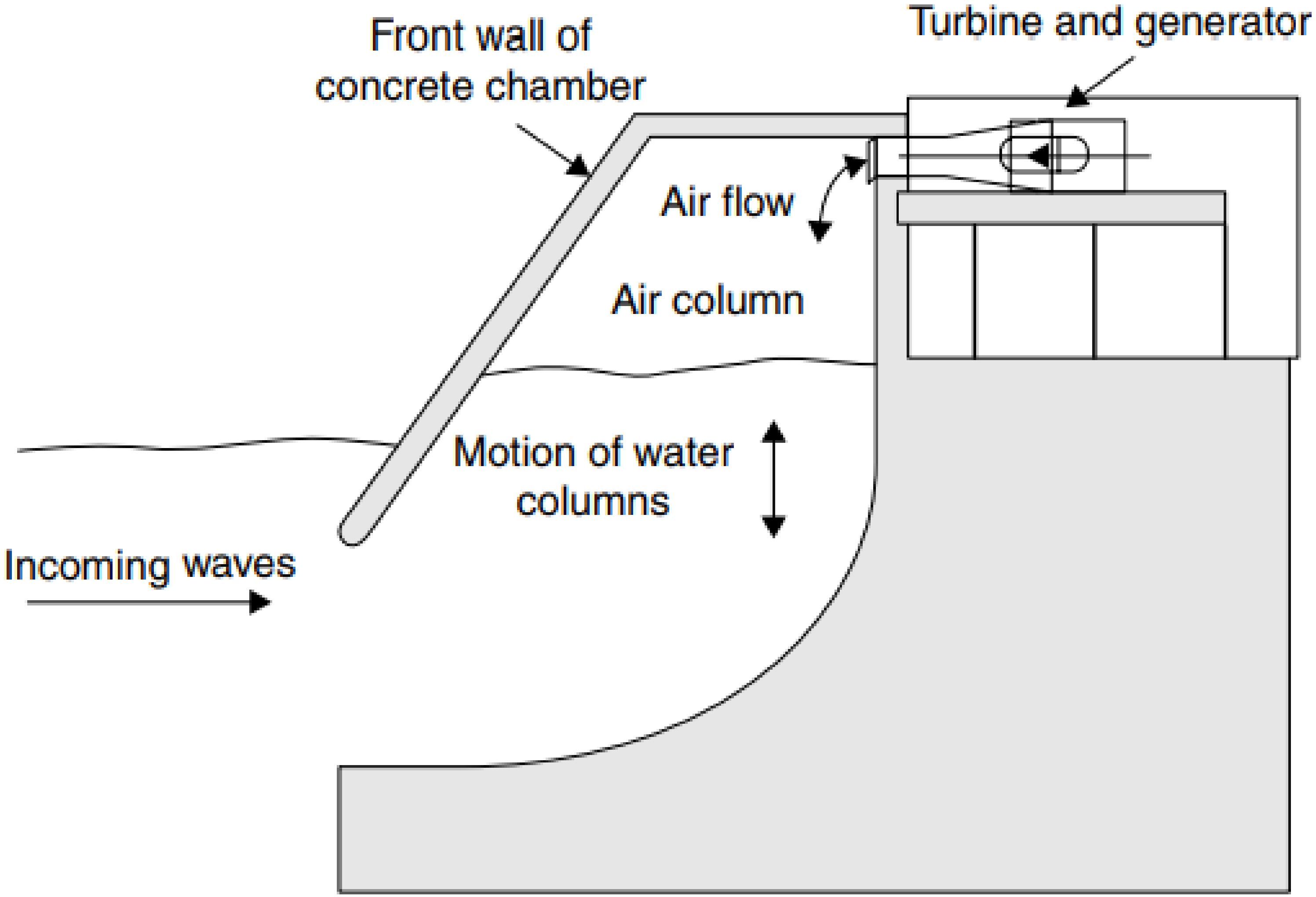
Figure. Position of the wave energy converter system in the sea.

Comments

- ***Onshore device:-*** **The waves lose energy as they approach shore due to interaction with the sea floor.**
- ***Offshore device:-*** **For a wind turbine; to extract all of the kinetic energy from a wave, the wave has to be stopped.**

✓ **It needs an appropriate mechanism for transporting the generated electricity back to shore.**

Oscillating Water Column Devices (OWC) cont.



- **An oscillating water column (OWC) converter is an example of terminator device.**
- **It is a wave energy device oriented perpendicular to the direction of the wave and has one stationary and one moving part.**

- **The moving part moves up and down like a car piston in response to ocean waves and pressurizes air to drive a turbine.**

Oscillating Water Column Devices (OWC)

- **These devices generally have power ratings of 500 kW to 2 MW, depending on the wave parameters and the device dimensions.**
- **It is a shoreline-based oscillating water column.**
- **Wells' turbines are used to extract energy from the reversing air flow.**
- **It has the property of rotating in the same direction regardless of the direction to the airflow.**

Advantages of Waves

- ✓ **Non-polluting and continuous source of energy.**
- ✓ **It will remain for a very long period of time.**
- ✓ **It is free and renewable energy source.**
- ✓ **Highly suitable to develop power in remote islands, on drilling platforms and on ship where other alternatives are impossible.**
- ✓ **No storage of power is required.**

Disadvantages of Waves

- ✓ **Current technology cannot utilize wave energy efficiently.**
- ✓ **The equipment for utilizing wave energy would be expensive as they have to withstand severe weather conditions.**

Disadvantages of Waves

- ✓ **It may cause disturbance of marine life.**
- ✓ **Sea water is corrosive and life of equipment used in conversion devices is limited.**
- ✓ **Wave energy conversion devices obstruct shipping traffic.**
- ✓ **Strong waves during storms can damage the wave energy conversion devices.**
- ✓ **Marine growth such as algae adversely affects the working of wave energy conversion devices.**

References

- https://www.alternative-energy-tutorials.com/wave-energy/wave-energy.html

Reference books

- **Non-Conventional Energy Resources - G.S. Sawhney**
- **Renewable Energy Resources and Emerging Technologies – D. P. Kothari, K. C. Singal, and Rakesh Ranjan**
- **Non-Conventional Energy Resources – Shobh Nath Singh**
- **Renewable Energy – M. K. Ghosh Roy**