# Measurement of Speed (Velocity)/ Angular Velocity



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## Speedometer Vs Odometer

- Tachometer



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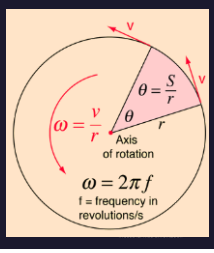
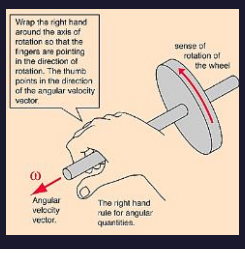
- Angular speed is the rate of change of the angle (in radians) with time, and it has units radians/s.
- Angular velocity should have a direction. The right-hand-rule: If you curl your fingers in the direction that it's rotating and stick your thumb out, the direction of your thumb is the direction of the angular velocity.

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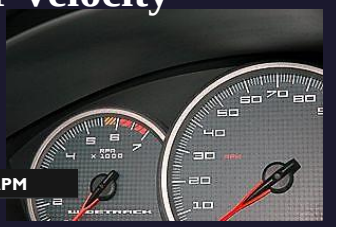
# Angular Velocity

$$\omega = 2 \times \pi \times \frac{N}{60}$$

- The angular velocity of rotating machine is usually expressed in radian per seconds, ω (rad/sec) or revolutions per minutes, N, (RPM).



**1 rad/s** **9.5493 RPM**



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# Measurement of Angular Velocity

- Tachometer is used.
- The tachometer may be defined as: An instrument which either continuously indicates the value of rotatory speed or continuously displays a reading of average speed over rapidly operated short intervals of time.



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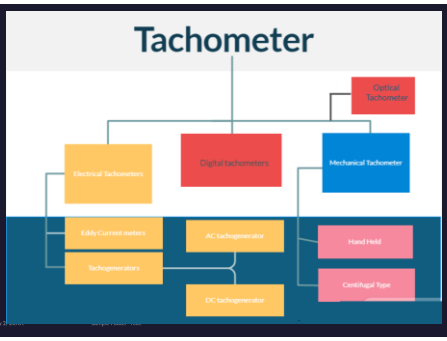


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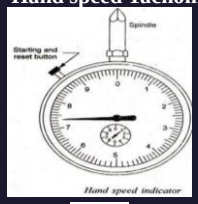
**Mechanical tachometer**

## Hand speed Tachometer




- It has a spindle attached to the object whose speed is to be measured.
- The spindle is connected to mechanical counter which displays the count.
- This indicator has an inbuilt stop watch and a mechanical counter with an automatic disconnect.
- Used up to speeds of 20,000 to 30,000 rpm with accuracy of 1%.

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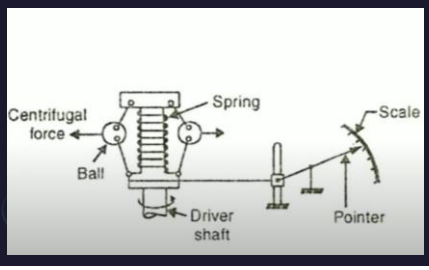
## Centrifugal Tachogenerator

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# Electrical tachometer

- DC Tachogenerator
- AC Tachogenerator
- Eddy Current Tachogenerator

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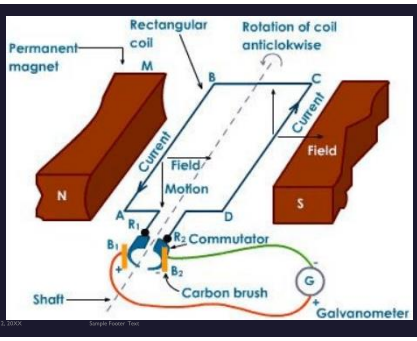


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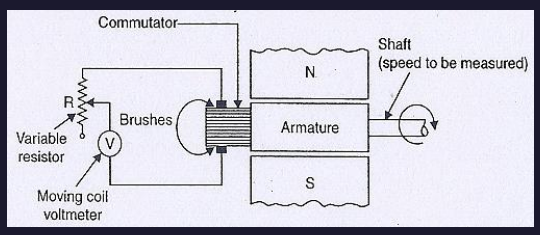


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**D.C. Tachometer generators**

- In a D.C. generator the e.m.f generated depends upon the following two factors:
  - (i) Field excitation
  - (ii) Speed
- If for the field system permanent magnet pole pieces are used, then the generated voltage depends only on the speed.
- Hence the speed can be computed by measuring the generated e.m.f.
- The shaft whose speed is to be measured is coupled to the armature.
- A moving coil voltmeter is connected across the brushes to measure the generated voltage.
- The variable resistance R is incorporated to limit the current through the voltmeter.
- Since voltage is proportional to speed, the voltmeter may be calibrated in terms of speed (r.p.m.).

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## Advantages

1. Direction of rotation is directly indicated by the polarity of the output voltage.
2. Output can be directly measured by a normal DC Voltmeter

## Disadvantages

1. Brushes produce maintenance problems as contact resistance may produce errors. Thus commutator and brushes require periodic maintenance.
2. Input resistance of meter must be high than output resistance of the generator to limit the armature currents.

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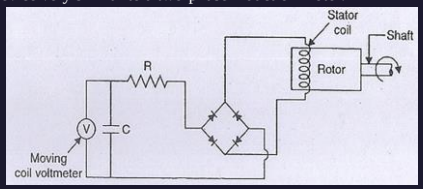
**A.C. Tachometer Generator**

- The inherent demerits associated with D.C. tachometer generator, due to the provision of commuter and brushes, are eliminated in A.C. tachometer generator.
- The AC tachometer generator is an electromechanical device very similar to a two-phase induction motor.

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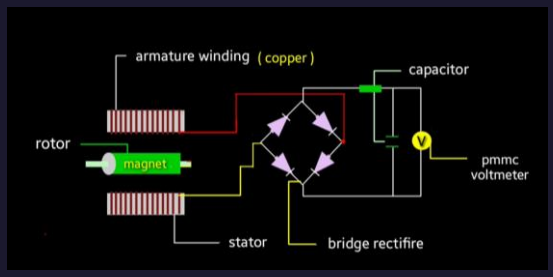


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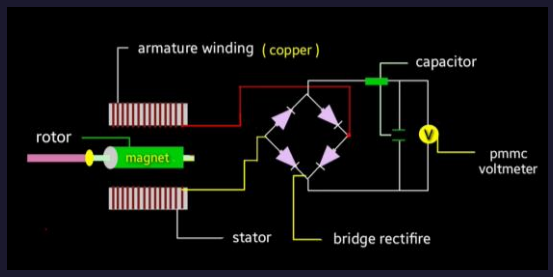


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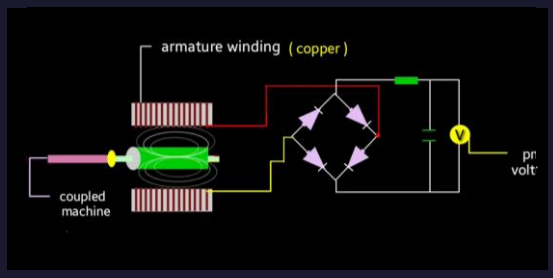


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- The rotating magnetic field induces the EMF in the stationary coil of the stator.
- The amplitude and frequency of the induced emf are equivalent to the speed of the shaft.
- Thus, either amplitude or frequency is used for measuring the angular velocity.
- The above mention circuit is used for measuring the speed of the rotor by considering the amplitude of the induced voltage.
- The induced voltages are rectified and then passed to the capacitor filter for smoothening the ripples of rectified voltages.

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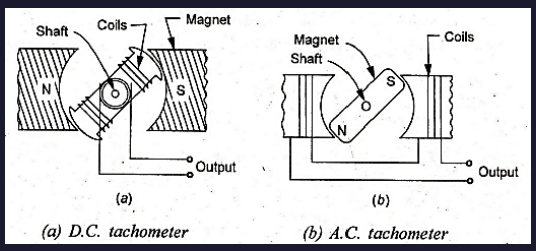


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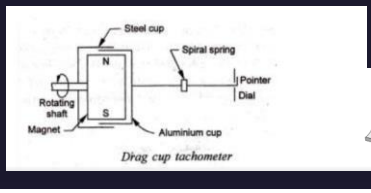
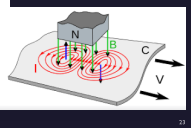
## Eddy current or Drag cup tachometer

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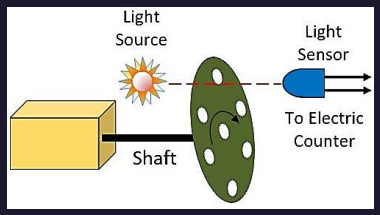
## Digital methods

**Photoelectric Tachometer**

- uses light for measuring the speed of rotation of shaft or disc of machines.

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- The pulses are measured through the electric counter.
- When the opaque portion comes in the line of light source and sensor, then the disc blocked the light source, and the output becomes zero.
- The production of pulses depends on the following factor:
  1. The number of holes on the disc.
  2. The speed of rotation of the disc.
- The holes are fixed, and hence the pulse generation depends on the speed of the rotation of the disc.
- The electronic counter is used for measuring the pulse rate.

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**Advantages**

1. The output format is digital so for a digital system A to D conversion is not required.
2. The pulse amplitudes are constant.

**Disadvantage:**

1. The light source must be replaced from time to time.
2. The accuracy of this method depends on the error represented by one pulse. The gating period, the time period in which the number of pulses are counted, should be sufficiently large.

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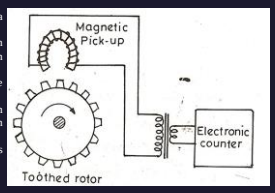
**Toothed rotor variable reluctance tachometer/ Pick-up tachometer**

- This tachometer generator consists of a metallic toothed rotor mounted on the shaft whose speed is to be measured.
- A magnetic pick-up is placed near the toothed rotor.
- The magnetic pick-up consists of a housing containing a small permanent magnet with a coil wound around it.
- When the rotor rotates, the reluctance of the air-gap between the pick-up and the toothed rotor changes, giving rise to an induced emf in the pick-up coil.
- This output is in the form of pulses, with a variety of wave shapes.
- Since the number of teeth is known, the speed of rotation can be determined by measuring the frequency of pulses with an electronic counter.
- Suppose a rotor has T teeth, the speed of rotation is n rps (rotations per second) and number of pulses per second is P.
- Hence, speed n = pulses per second/ number of teeth

  **n = P/T rps = (P/T) x 60 rpm**
- If a typical rotor has 60 teeth, the number of pulses per second will give the speed in rpm.

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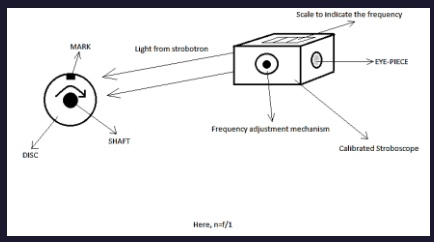
**Stroboscopic Tachometers**




Here, n=f/1



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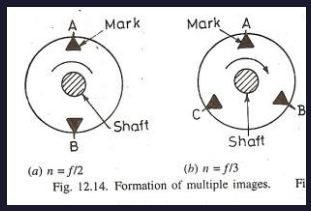
**Formation of multiple images (If n<f)**




(a) $n = f/2$ (b) $n = f/3$

Fig. 12.14. Formation of multiple images.

Where
n=speed of shaft
f=Flashing frequency



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**Stroboscopic Tachometers**

- A stroboscope, also known as a strobe, is an instrument used to make a cyclically moving object appear to be slow-moving, or stationary.
- When a rotating or vibrating object is observed with the stroboscope at its vibration frequency (or a submultiple of it), it appears stationary.
- Thus, stroboscopes are also used to measure frequency.
- Simple & portable manually-operated type of tachometer.
- Basically, the instrument is a source of variable frequency flashing brilliant light, the flashing frequency set by the operator.
- A variable frequency oscillator which controls the flashing frequency is used.
- The speed is measured by adjusting the frequency so that the moving objects are visible only at specific intervals of time.
- If a strong light is caused to flash on a moving object, at the time of each flash occurs, in a given position, the object will appear to be stationary.

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**Shaft Speed Measurement**

- A distinctive timing mark is made on the shaft or on a disc attached on the shaft.
- As the disc rotates with the shaft, the stroboscope is made to flash light directly on the mark.
- Flashing frequency is manually adjusted by the operator until the mark appears to be stationary.
- Under these conditions, the speed is equal to the flashing frequency provided that the approximate speed of the shaft is known and the flashing frequency is not allowed to depart too much away from this value.
- The scale is calibrated in terms of speed.



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