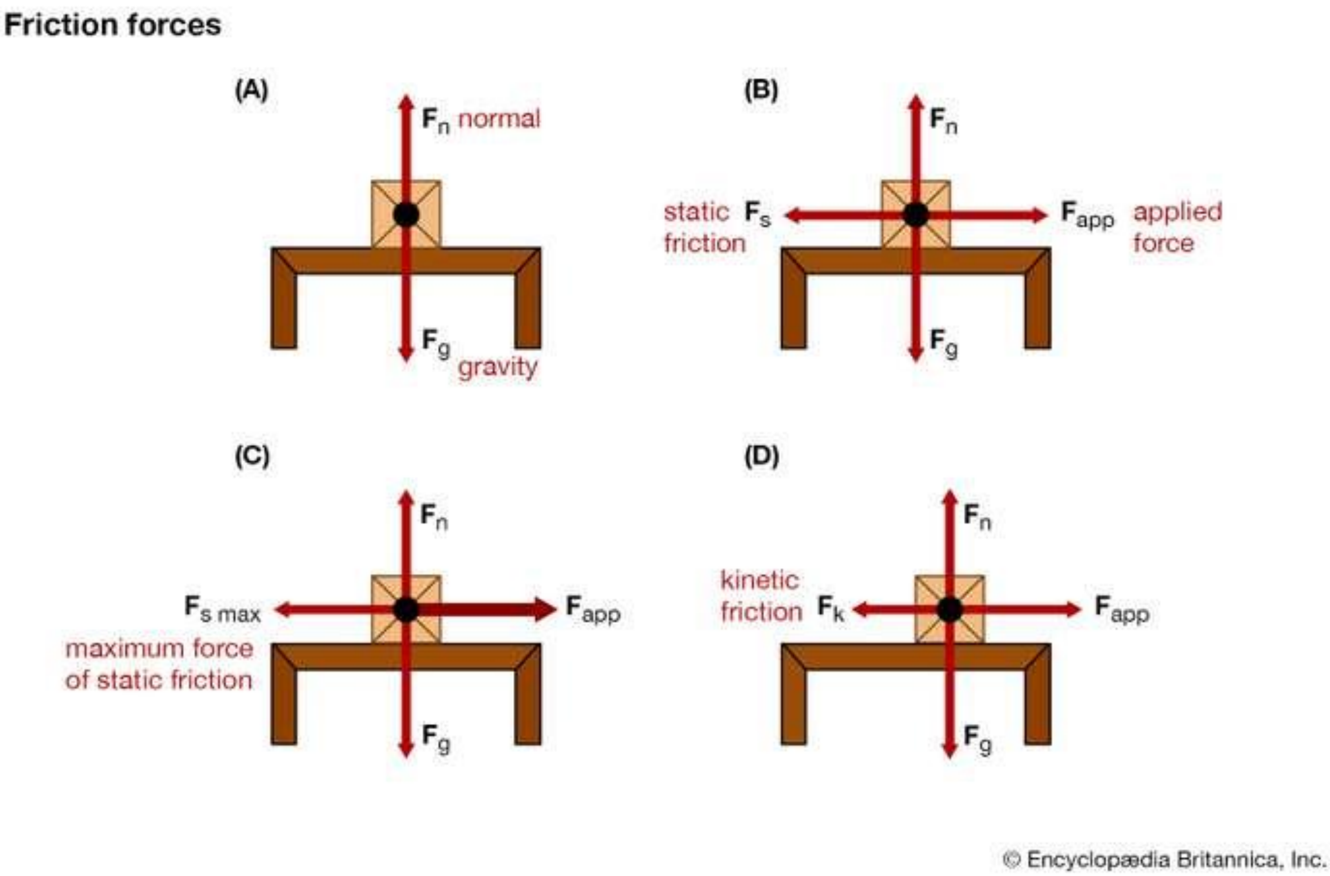
L.JOSEPHINE ANITHA M.Sc., M.Phil., B.Ed.,
Asst. Prof. Of Physics,
Annai Vailankanni Arts & Science College, Thanjavur-7

Friction:

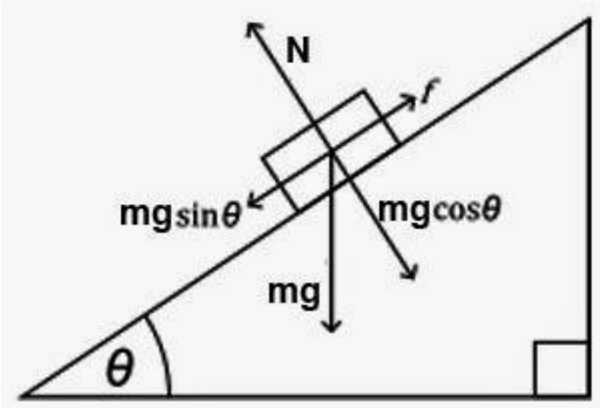
Force that resists the sliding or rolling of one solid object over another is called friction.

Frictional forces, such as the traction needed to walk without slipping, may be beneficial, but they also present a great measure of opposition to motion. About 20 percent of the engine power of automobiles is consumed in overcoming frictional forces in the moving parts.



Friction forces, Diagram illustrating how friction forces, including kineticfriction and static friction, act upon objects at rest and in motion.

Laws of Friction



The sliding of a solid body in contact with another solid body is always opposed by force of *friction*. Friction acts in the direction opposite to that of relative motion and it is tangential to the surface of two bodies at the point of contact.

Friction is a necessary on every machine because it involves wearing of the machine component and consumes energy that transfers into heat. In come cases friction is desirable in the case for the functioning of a machine, such as belt drives, friction clutches.

THE FIVE LAWS OF FRICTION

1. When an object is moving, the friction is proportional and perpendicular to the normal force (N)
2. Friction is independent of the area of contact so long as there is an area of contact.
3. The coefficient of static friction is slightly greater than the coefficient of kinetic friction.
4. Within rather large limits, kinetic friction is independent of velocity.
5. Friction depends upon the nature of the surfaces in contact.

L.JOSEPHINE ANITHA M.Sc., M.Phil., B.Ed.,
Asst. Prof. Of Physics,
Annai Vailankanni Arts & Science College, Thanjavur-7

WHAT IS CLUTCHES ?

- A **Clutch** is a mechanical device that engages and disengages the power transmission , especially from driving shaft to driven shaft.

- In the simplest application, clutches connect and disconnect two rotating shafts (drive shafts or line shafts). In these devices, one shaft is typically attached to an engine or other power unit (the driving member) while the other shaft (the driven member) provides output power for work.

TYPES OF CLUTCHES

1)Mechanical clutches
2)Pneumatic clutches
3)Hydraulic clutches
4)Electromagnetic clutches

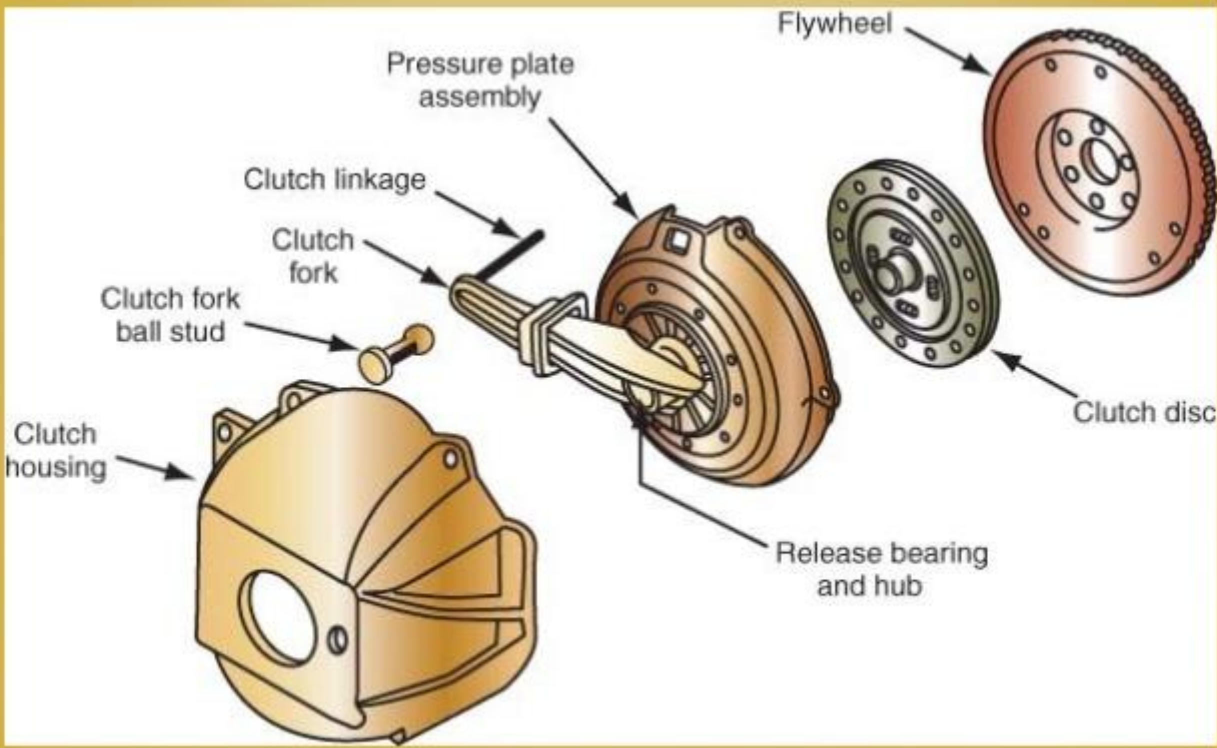
➢ **Mechanical clutches**

1)Positive contact clutches
i. jaw clutches
ii.toothed clutches

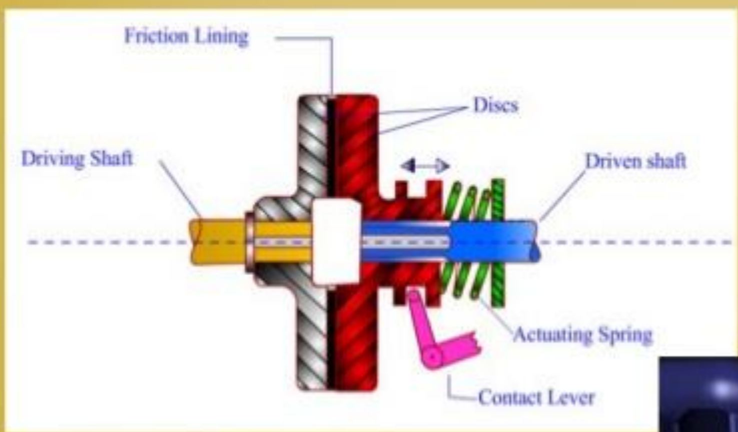
2)Friction clutches

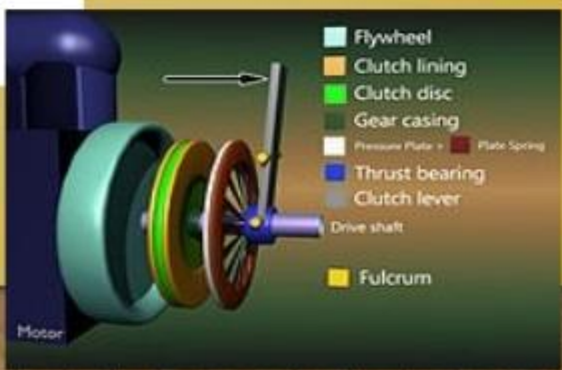
➢ Disc clutches
- Single plate clutches
- Multi plate clutches

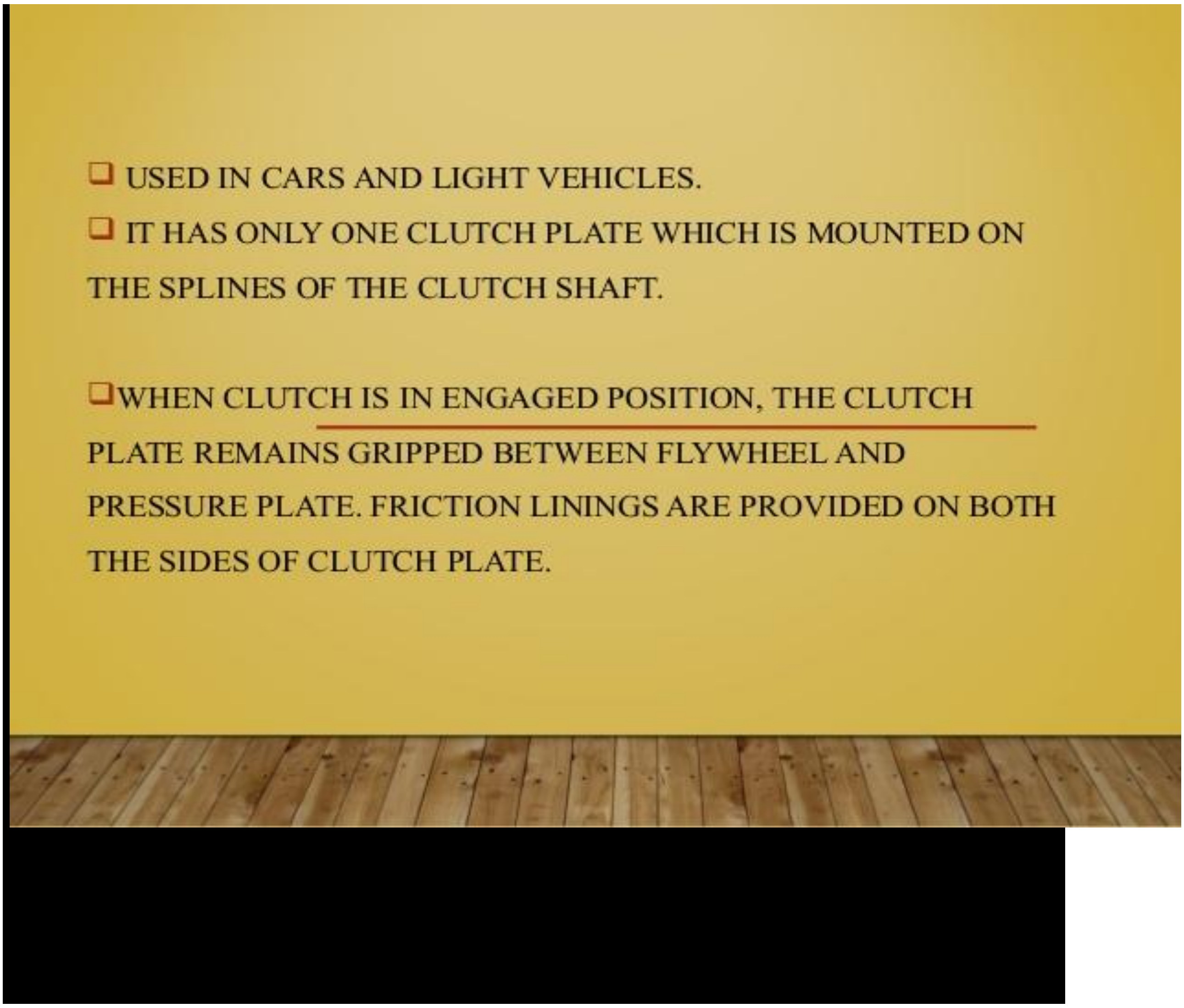
➢ Cone clutches
➢ Centrifugal clutches



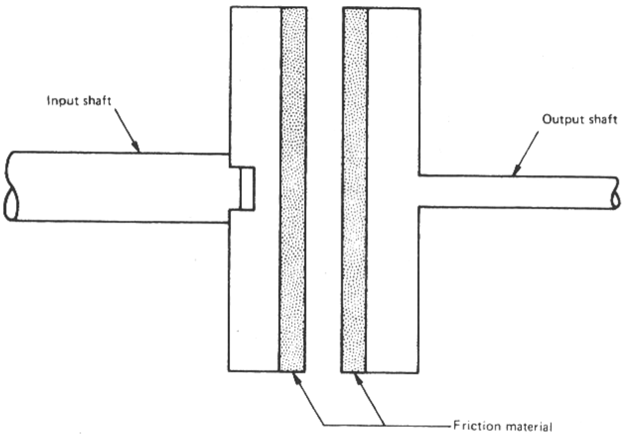
SINGLE PLATE CLUTCH







Principle and Working of Friction Clutches



Friction Disc Clutch

A friction clutch is used in the transmission of power in the form torque, of shafts and machines which must be started and stopped frequently. It is usually used when power required to be delivered to machines is partial or full. The force of friction is used to start the driven shaft from rest and gradually brings it up to the proper speed without excessive slipping of the friction surfaces.

They are extensively used in automobiles; friction clutch is used to connect the engine to the drive shaft. In operating such a clutch, care should be taken so that the friction surfaces engage easily and gradually bring the driven shaft up to proper speed. The proper alignment of the bearing must be maintained and it should be located as close to the clutch as possible. For optimum clutch operation, it is required that:

The contact surfaces should develop a frictional force that may pick up and hold the load with reasonably low pressure between the contact surfaces.

The heat of friction should be rapidly dissipated and tendency to grab should be at a minimum.

The surfaces should be backed by a material stiff enough to ensure a reasonably uniform distribution of pressure.

L.JOSEPHINE ANITHA M.Sc., M.Phil., B.Ed.,
Asst. Prof. Of Physics,
Annai Vailankanni Arts & Science College, Thanjavur-7

Acceleration due to gravity 'g' by Kater's Pendulum

Object: |To determine the value of acceleration due to gravity with Kater's pendulum.

Apparatus used: Kater's pendulum, a stop watch and a meter rod.

Formula: The following formula is used for the determination of acceleration due to gravity 'g':

$$g = \frac{8\pi^2}{\frac{T_1^2 + T_2^2}{l_1 + l_2} + \frac{T_1^2 - T_2^2}{l_1 - l_2}} \quad (1)$$

Here, T_1: time periods of the oscillating pendulum from knife-edge K1

T_2: time periods of the oscillating pendulum from knife-edge K2

l_1: distances between knife-edges K1 and CG of the pendulum

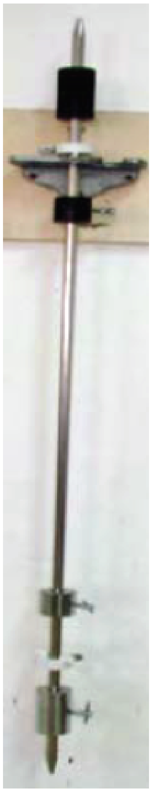
l_2: distances between knife-edges K2 and CG of the pendulum

When T_1 and T_2 are very close to each other (difference less than 1 percent), the above expression becomes as:

$$g = \frac{8\pi^2}{\frac{T_1^2 + T_2^2}{l_1 + l_2}} \quad (2)$$

Procedure:

1. Fix the weights as shown in figure. i.e.
   {one end→M→K_1→m→w→K_2→W→other end)
2. Make sure that the distances from big masses to ends and big masses to knife edges should be symmetrical.
3. Balance the pendulum on a sharp wedge such that the smaller weights are at symmetrical distant from CG. Now mark the position of its centre of gravity and measure the distance of the knife-edges K_1 and K_2 CG. This will give you value of l_1 and l_2.
4. Suspend the pendulum with the knife-edge K_1 and set it to oscillate with small amplitude. Note the times for 15, 20 and 25 oscillations respectively.
5. Now suspend the pendulum with the knife-edge K_2 and set it to oscillate with small amplitude. Note the times for 15, 20 and 25 oscillations respectively.
6. The oscillations should be seen with the help of a telescope for accuracy.



Figure

L.JOSEPHINE ANITHA M.Sc., M.Phil., B.Ed.,
Asst. Prof. Of Physics,
Annai Vailankanni Arts & Science College, Thanjavur-7

Observation:

1. Least count of stop watch=……..sec
2. Distance between K_1 and CG (l_1)=……..cm
3. Distance between K_2 and CG (l_2)=……..cm
4. *Table for time period T_1(oscillation about K_1):*

Sr. No.	Number of Oscillation n	Time of Oscillation t_1(sec)	Time Period $T_1=t_1/n$	Mean T_1 (sec)
1.	15			
2.	20			
3.	25			

5. *Table for time period T_2(oscillation about K_2):*

Sr. No.	Number of Oscillation n	Time of Oscillation T_2(sec)	Time Period $T_2=t_2/n$	Mean T_2 (sec)
1.	15			
2.	20			
3.	25			

Calculation: Using equation (1) or (2) {depending on value of T_1 and T_2} calculate the value of g.

Result: Acceleration due to gravity 'g'=……….m/s^2

Standard value of 'g' = ……….m/s^2

Percentage error: $\frac{\Delta g}{g} \times 100 = \frac{g_{s\tan dard} - g_{measured}}{g} \times 100. = ...\%$

Precautions:

1. The two knife-edges should be parallel to each other.
2. The amplitude of vibration should be small so that the motion of the pendulum satisfies the condition of simple harmonic motion.
3. To avoid any irregularity of motion the time period should be noted after the pendulum has made a few oscillation.
4. To avoid friction there should be glass surface on rigid support.

L.JOSEPHINE ANITHA M.Sc., M.Phil., B.Ed.,
Asst. Prof. Of Physics,
Annai Vailankanni Arts & Science College, Thanjavur-7

COMPOUND (PHYSICAL) PENDULUM

OBJECTIVE:

Use the compound pendulum to find:

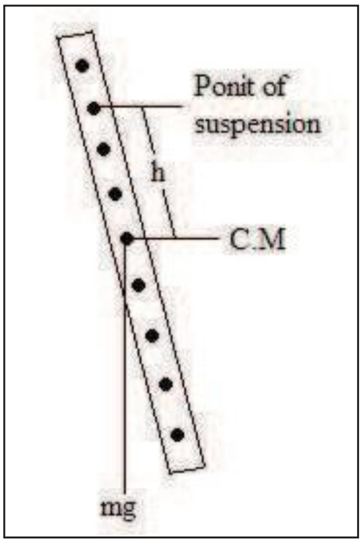
1) The acceleration due to gravity *g*.

2) The moment of inertia of the rod.

THEORY:

Any object mounted on a horizontal axis so as to oscillate under the force of gravity is a compound pendulum. The one used in this experiment is a uniform rod suspended at different locations along its length. The period T of a compound pendulum is given by

$$T = 2\nu\sqrt{\frac{I}{Mgh}} \qquad (1)$$



Where:

I is the rotational inertia of the pendulum about the axis of suspension

M is the pendulum mass

And h is the distance between the suspension point and the center of mass.

Using the parallel axis theorem

$$I = I_G + Mh^2 \qquad (2)$$

I_G is the rotational inertia of the body about its center of mass and it is given by

$$I_G = MK^2 \qquad (3)$$

Substituting equation 3 in equation 2

$$I = M(h^2 + K^2) \qquad (4)$$

Where K is the radius of gyration .substituting equation 4 in equation 1

$$T = 2\nu\sqrt{\frac{h^2 + K^2}{\quad}} \qquad (5)$$

The period of the simple pendulum is given by

$$T = 2\nu\sqrt{\frac{L}{\quad}} \qquad (6)$$

L.JOSEPHINE ANITHA M.Sc., M.Phil., B.Ed.,
Asst. Prof. Of Physics,
Annai Vailankanni Arts & Science College, Thanjavur-7

The period of a compound pendulum equals the period of a simple pendulum of a length

$$L = \frac{h^2 + K^2}{h} \qquad (7)$$

This equation can be solved to find L and K:

$$L = h_1 + h_2 \qquad (8)$$

$$K = \sqrt{h_1 h_2} \qquad (9)$$

PROCEDURE:

1- First hang the pendulum horizontally and move it until it reaches equilibrium so you can find the center of mass and mark it.

2- Secondly hang it vertically inserting the tip of the knife in the first hole from the center of mass. Then set it oscillating through a small angle.

3- Measure the time needed for 20 oscillations and the corresponding h. 4-

Repeat steps 2 and 3 for the other holes.

5- Record your measurements in a table.

Centre of Gravity:

The **center of gravity** is the point through which the force of **gravity** acts on an object or system. In most **mechanics** problems the gravitational field is assumed to be uniform. The **center of gravity** is then in exactly the same position as the **center** of mass.

What are the conditions of equilibrium for a floating body ?

Ans. → The following are the conditions for equilibrium for a floating body :

↪The weight of the liquid displaced by the immersed part must be equal to the weight of the body .

↪The centre of gravity and the centre of buoyancy of the body should be along the same vertical line .

↪The centre of gravity lies vertically below the centre of buoyancy (stable equilibrium) and if centre of gravity lies Above the centre of buoyancy (unstable equilibrium).

Equilibrium of Floating Body

1. Stable equilibrium
2. Unstable equilibrium
3. Neutral equilibrium

Stable equilibrium

When a body is given a small angular displacement, i.e. it is tilted slightly by some external force and then it returns back to original position due to internal forces. Such equilibrium is called stable equilibrium.

Unstable equilibrium

If a body does not return to its original position from the slightly displaced angular position and moves father away when give a small angular displacement such equilibrium is called an unstable equilibrium.

Neutral equilibrium

The body remains at rest in any position to which it may be displaced, no net force tends to return the body to its original state or to drive it further away from the original position, is called neutral equilibrium.

Metacentre

When a small angular displacement is given to a body floating in a liquid, it starts oscillation about some point M. This point about which the body starts oscillating is called the metacentre .

Metacentre (M) may be defined as the point of intersection of the axis of body passing through centre of gravity (G) and original centre of buoyancy (B) and a vertical line passing through the new centre of buoyancy (B�) of the titled position of the body.

10.4 Metacentric height

Metacentric height: The distance between the centre of gravity of a floating body and the metacentre, i.e. distance GM is called meta-centric height . Relation between centre of gravity and metacentre in different three types of equilibrium:

(a) ***Stable equilibrium***

In this, position of metacentre (M) remains higher than centre of gravity of body.

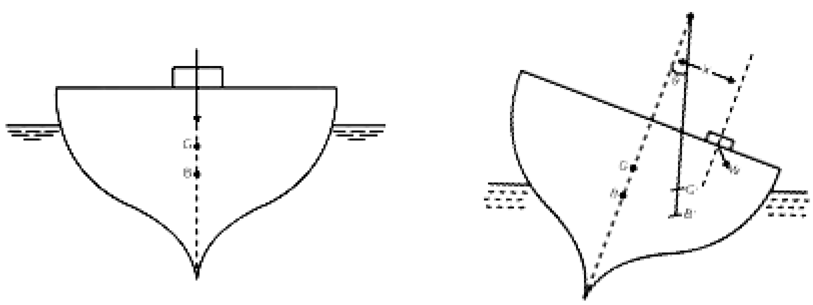
(b) ***Unstable equilibrium***

In this position of metacentre (M) remains lower than centre of gravity of body.

(c) ***Neutral equilibrium***

The position of metacentre (M) coincides with centre of gravity of body.

Stability of ship



L.JOSEPHINE ANITHA M.Sc., M.Phil., B.Ed.,
Asst. Prof. Of Physics,
Annai Vailankanni Arts & Science College, Thanjavur-7

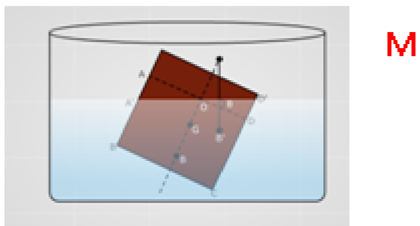
Condition of stability of ship

The above cases were of submerged body. For floating body particularly ship the construction of ship body plays an important role in its stability. It is such so as to withstand high wave and tide .

Calculation of Metacentric Height

In the below Fig.

G = Centre of gravity
O = The point at which line BM and top liquid surface intersect
M = Metacentre
B = Centre of buoyancy
BM = Distance between centre of buoyancy and metacentre



Metacentric height

$$BM = \frac{I}{V}$$

Where I = area moment of inertia of the cross sectional area at the surface of fluid .

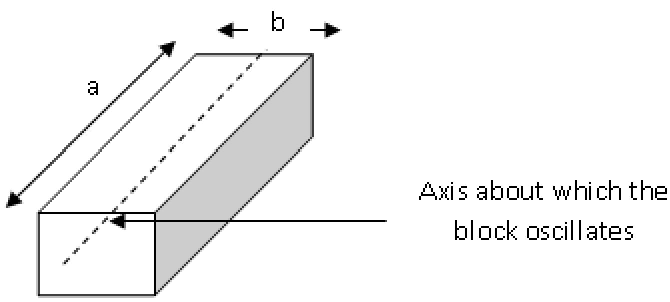


Fig. a&b is the cross sectional area at the surface of liquid

Area moment of Inertia $I = \frac{ab^3}{12}$

V= volume of the displaced fluid.

Metacentric Height GM = BM - BG

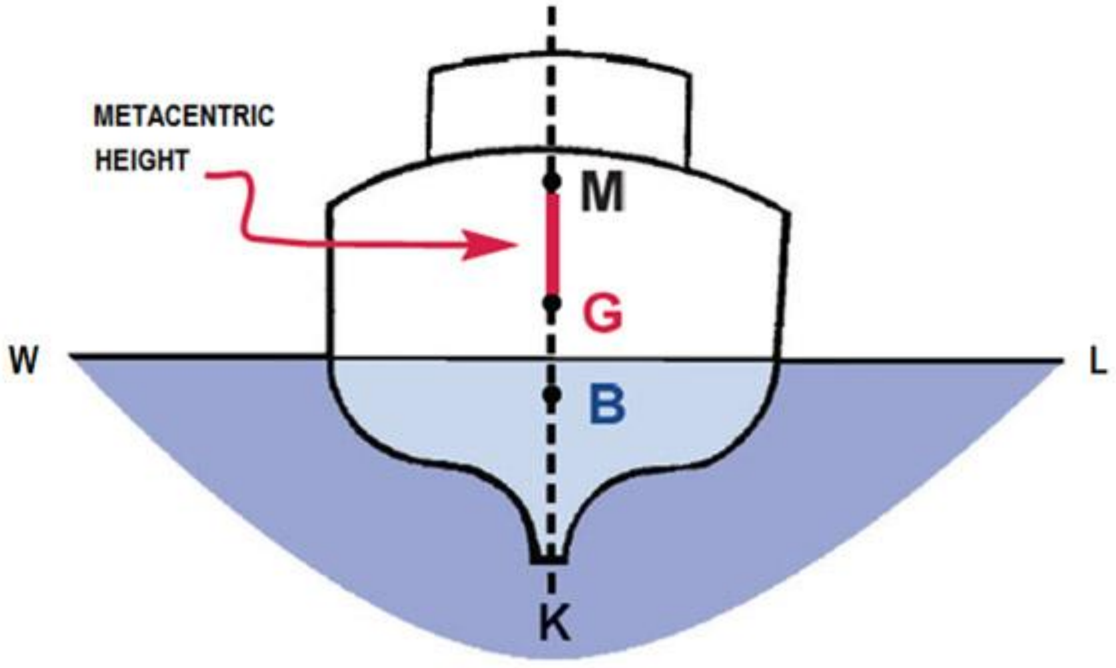
If GM is +ve then G is above point B.

If GM is - ve then G is below point B.

Determination of Metacentric Height

When a ship heels, the centre of buoyancy of the ship moves laterally. It might also move up or down with respect to the water line. The point at which a vertical line through the heeled centre of buoyancy crosses the line through the original, vertical centre of buoyancy is the metacentre. The metacentre remains directly above the centre of buoyancy by definition.

The metacentric height (GM) is a measurement of the initial static stability of a floating body. It is calculated as the distance between the centre of gravity of a ship and its metacentre. A larger metacentric height implies greater initial stability against overturning.



Chapter 5 Measurement of Atmospheric Pressure

5.1 Definition and Units

5.1.1 Definition

The atmospheric pressure is the force exerted by the weight of the Earth's atmosphere, expressed per unit area in a given horizontal cross-section. Thus, the atmospheric pressure is equal to the weight of a vertical column of air above the Earth's surface, extending to the outer limits of the atmosphere.

5.1.2 Units

In meteorology, atmospheric pressure is reported in hectopascals (hPa). 1 hPa is equal to 100 Pa, the pascal being the basic SI (System of International Unit) . 1 Pa is equal to 1 Newton per square meter (N/m^2). And 1 hPa is equal to 1mb that was used formerly.

The scales of all barometers used for meteorological purposes should be graduated in hPa. Some barometers are graduated in the unit inHg or mmHg. Under standard conditions, the pressure exerted by a pure mercury column which is 760 mm high is 1013.250 hPa, so the conversion factors are represented as follows:

1 hPa = 0.750062 mmHg;

1 mmHg = 1.333224 hPa.

And because of the relation between inch and mm (1 inch = 25.4 mm), the following conversion coefficients are provided:

1 hPa = 0.029530 inHg;

1 inHg = 33.8639 hPa;

1 mmHg = 0.03937008 inHg.

Pressure data measured with the barometer should preferably be expressed in hectopascals (hPa).

5.2 Principle of Atmospheric Pressure Measurement

5.2.1 Mercury Barometer

(1) Principle of mercury barometer

When a one-meter long, open ended glass tube is filled with mercury and is then turned upside down into a container filled with mercury, part of the mercury flows out of the glass tube into the container. "Torricellian vacuum" is then produced at the top of the glass tube and the mercury level stabilizes at approximately 76 cm from the mercury level in the container (See Figure 5.1). Torricelli's experiment revealed that such a height indicates the ambient atmospheric pressure.

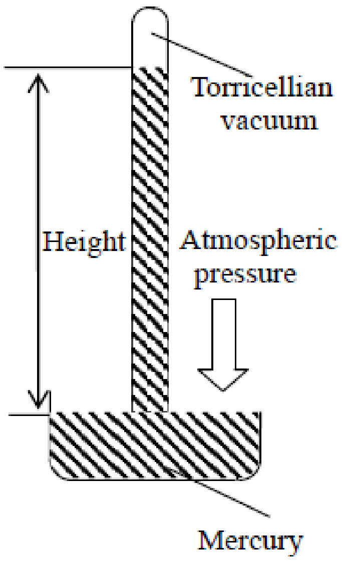


Figure 5.1 Torricelli's experiment

The principle of mercury barometer is to measure atmospheric pressure from precise measurement of this height.

(2) Structure of the Fortin barometer

As shown in Figure 5.2, a mercury barometer consists of three main parts: the mercury cistern (right), the glass barometer tube (center) and the scale (left). The bottom of the mercury cistern is made of a wash-leather bag (sheepskin). The mercury level can be changed by rotating an adjusting screw. The barometer tube is secured with the wash-leather bag in the upper part of the mercury cistern in order to lead atmospheric pressure from the point at the bounded leather. An ivory pointer is put on the top of the mercury cistern, whose tip indicates

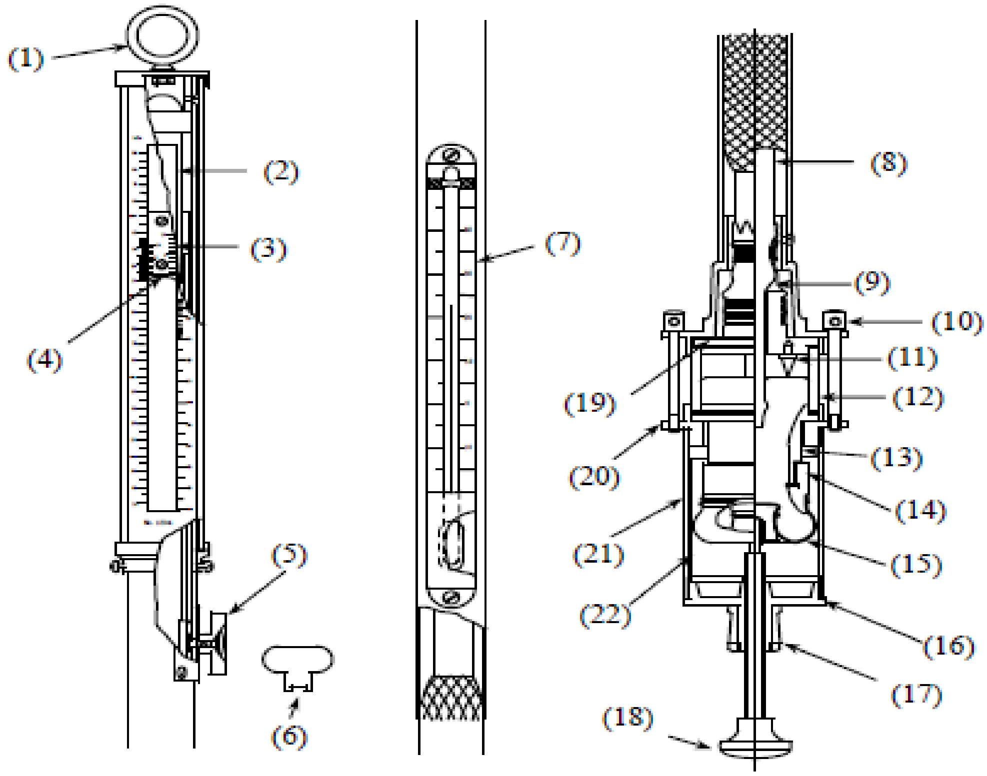


Figure 5.2 Structure of the Fortin barometer

(1) Hanger ring (2) Slot (3) Vernier (4) Top of the mercury column (5) Knob (6) Pin face wrench (7) Attached thermometer (8) Barometer tube (9) Vent wash-leather (10) Three screws (11) Ivory pointer (12) Glass cylinder (13) External thread wooden frame (14) Internal thread wooden frame (15) Wash-leather bag (16) Under cover (17) Screw bridge (18) Adjusting screw (19) Wooden base for leather washer (20) Metal frame (21) Brass cover (22) Mica plate.

the zero of the scale. When the level of the mercury touches the tip, the atmospheric pressure is read at the top of the mercury column. The precise height of the mercury column is measured with the vernier.

The main body has a hanger hook at its top and is used to hang the barometer from a latch on a hanger plate. The bottom is secured to the screw bridge through a vertical axis pivoting link with three screws. Both the hanger hook and the screw bridge can be rotated while the barometer is set on the hanger plate. This allows verticality checks at any time.

A mica plate is wound inside the brass cylinder to prevent the direct contact between brass and the wash-leather bag. The plate serves as a heat insulator as well as prevents contamination, discoloration, and wear.

(3) Handling precautions for mercury

High-purity distilled and refined mercury is used in mercury barometers. When the mercury surface oxidizes, the interface between the surface and the ivory pointer becomes unclear. Heavily contaminated mercury surface requires cleaning. Since mercury is a toxic substance, it is necessary to pay attention to the following when handling mercury.

1) A container of mercury must be sealed tightly to prevent leakage and breakage. Do not put mercury into any metal containers as mercury reacts and amalgamates almost all metals except for iron.
2) The floor of the room where mercury is stored or used in large amounts should be shielded and laid with an impervious covering. It must not be stored together with other chemicals, especially with ammonia or acetylene.
3) Mercury has a relatively low boiling point of 357 °C, and produces dangerous poisonous gas if on fire. It must not be stored close to a heat source.
4) Check the mercury handling room and personnel periodically to make sure that the amount of mercury does not exceed the dangerous limit. (The environmental regulation on water contamination affecting personal health limits the total amount of mercury to 0.0005 mg/l.)

(4) Correction of barometer readings

The mercury barometer's reading should be corrected to the one and the standard condition. Standard condition is defined as a temperature of 0 °C, where the density of mercury is 13.5951 g/cm^3 and a gravity acceleration of 980.665 cm/s^2.

During actual observation, the reading should be corrected for the index error, temperature correction, and gravity acceleration as follows:

(a) Corrections on index error

Individual mercury barometers include index errors (difference between the value indicated by an individual instrument and that of the standard). The index error is found by comparison with the standard, and the value is stated on a "comparison certificate".

(b) Corrections for temperature

The temperature correction means to correct a barometric reading, obtained at a certain temperature, to a value when mercury and graduation temperatures are 0 °C. The temperature of the attached thermometer is used for this purpose.

The height of the mercury column varies with temperature, even the atmospheric pressure is unchanged. The graduation of the barometer is engraved so that the correct pressure is indicated when temperature is 0 °C. In a case that when temperature is above 0 °C, the graduation expands and the measured value will be smaller than the true value. This effect of temperature must be corrected from these two aspects collectively.

Correction for the expansion and contraction of mercury is much larger than that for the expansion and contraction of the graduation.

The correction value for temperature *Ct* is expressed as follows:

$$Ct = -H\frac{(\mu - \lambda)t}{1 + \mu t}$$

where:

H hPa is the barometric reading after the correction for index error.

t °C is the temperature indicated by the attached thermometer.

μ is the volume expansion coefficient of mercury.

λ is the linear expansion coefficient of the tube.

There is a small difference in absolute values for correction between temperatures below and above 0 °C. The values for correction at temperatures above 0 °C are negative and those below 0 °C are positive.

(c) Corrections for gravity

Gravity affects the height of the mercury column. After the corrections for index error and temperature, the reading under the local acceleration of gravity has to be reduced to the one under the standard gravity acceleration. This is called corrections for gravity.

The gravity value for correction C_g is derived by:

$$C_g = H_0 - H = H\frac{g - g_0}{g_0}$$

where:

g_0 is the standard gravity acceleration.

g is the gravity acceleration at an observing point.

H is the barometric reading after the index error and temperature corrections

H_0 is the value already corrected for gravitation.

The gravity acceleration used in corrections for gravity value is calculated to the fifth decimal place, in m/s^2. When the gravity acceleration at the observing point is larger than the standard gravity acceleration, the gravity value for correction is positive. Otherwise, the value for correction is negative.

To use a barometer for regular observations at a particular location, a synthesis correction table that summarizes values for correction for index error, temperature and gravity should be used.