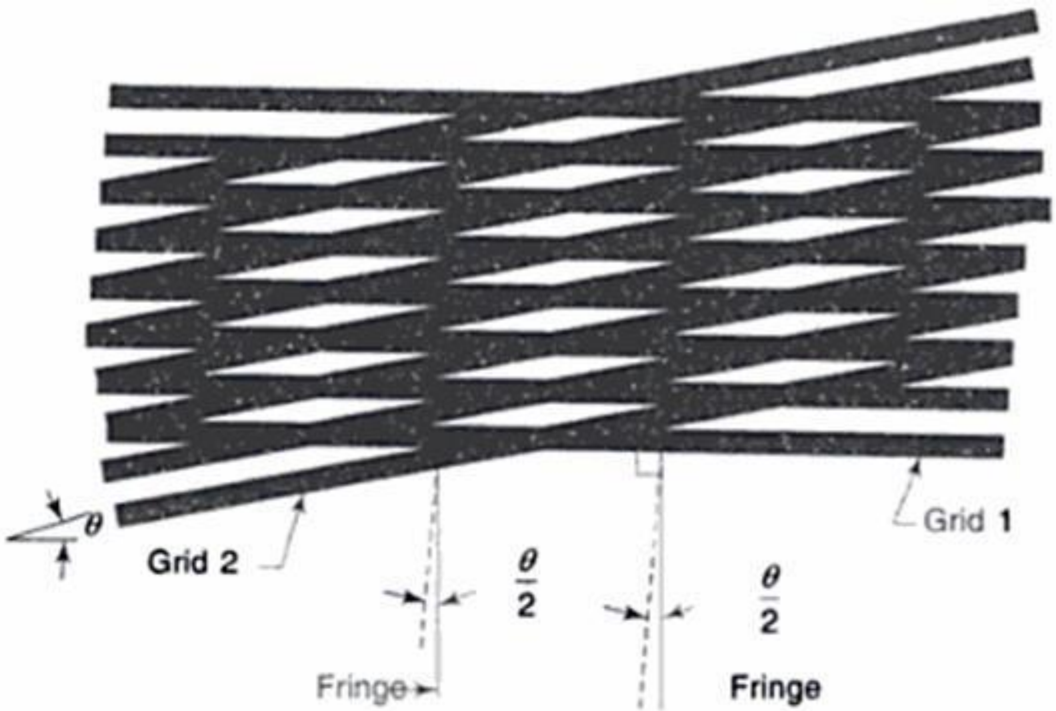
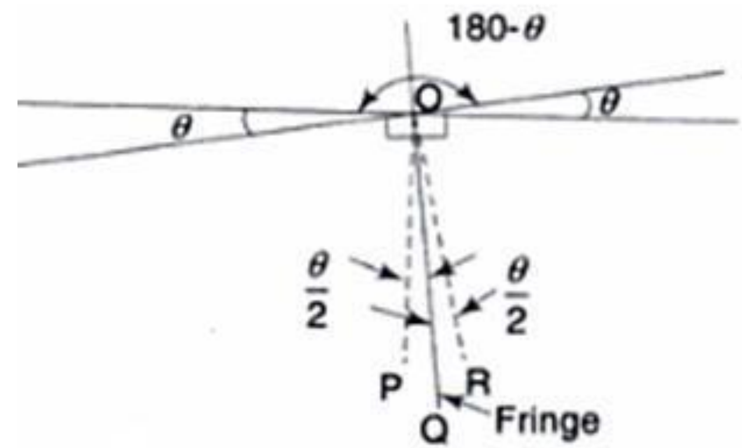
Moire-Fringe method

- This is an optical method of amplifying displacement and uses two identical gratings.
- Gratings consists of a number of transparent slits on an opaque screen.
- Pitch of gratings may be between 1/200cm & 1/2000cm.



Moire fringes

- Two gratings of same pitch, mounted face-to-face, with rulings inclined at <θ to each other.
- A set of dark bands is called Moire fringes.
- A movement of grating in a direction perpendicular to gratings would move fringes in a direction perpendicular to fringes by a larger amount.
- The number of fringes passing through a given point can be counted, using a photo-electric transducer.
- Used for measuring the movement of work in machine tools with an accuracy of ± 0.001% over a large range.
- Can be used for measuring angular displacements.
- Moire fringes are formed in a direction which bisects the obtuse angle between the line of two gratings.



Direction of fringes

- Relation between pitch of gratings & fringe spacing

OB and OD are perpendiculars to the two grating directions OC being fringe direction with <BOC = <COD = θ/2

triangles BOC and COD are equal,

$$OB = OD = p$$

fringe spacing $AC = x_1 + x_2$

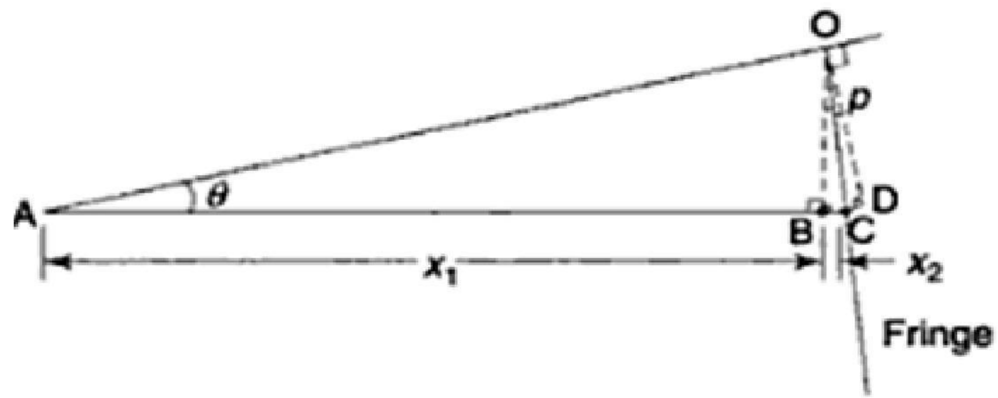
$$= \frac{OB}{\tan\theta} + OB \tan\frac{\theta}{2}$$

$$= \frac{p}{\tan\theta} + p\tan\frac{\theta}{2}$$

$$= p\left(\frac{\cos\theta}{\sin\theta} + \frac{1-\cos\theta}{\sin\theta}\right)$$

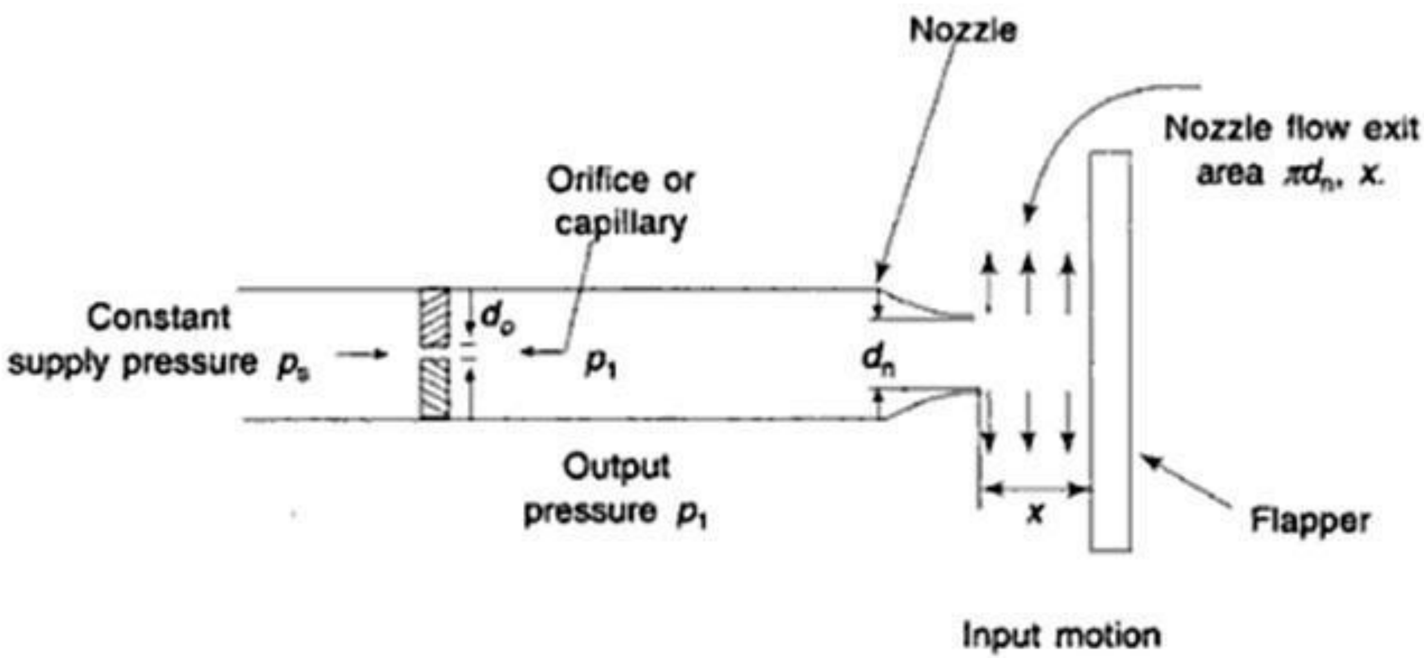
$$= \frac{p}{\sin\theta}$$

Since θ is small, fringe spacing $\gg p$.



Pneumatic Devices

- A displacement signal is converted to a pressure signal.
- Air at constant supply pressure P_s supplied through an orifice & passes to outside through a nozzle.
- Motion x of flapper controls the pressure P_1 at output.
- Device is linear over a certain range of impact & is quite sensitive.
- Widely used in control systems & precision gauging equipment.



Mass flow rate of air through the supply

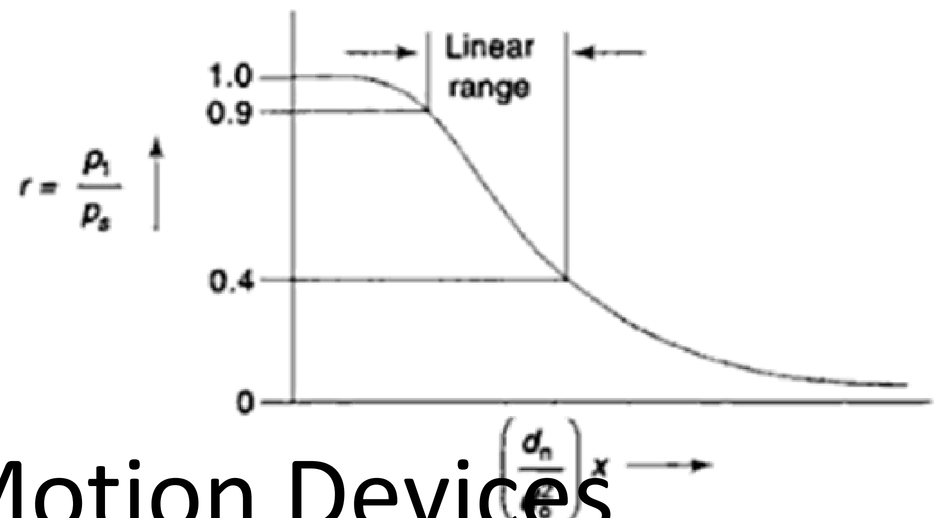
Orifice $= \dfrac{\pi}{4} k_1 d_0^2 \sqrt{2\rho(p_s - p_1)}$ where k_1 = constant of the orific meter,
ρ is mass density of the fluid viz-air
d_0 is diameter of supply orifice.

mass flow rate through the nozzle $= \pi d_n x k_2 \sqrt{2 p_1 \rho}$

where k_2 = constant of the nozzle
d_n as the nozzle diameter.

Taking k1 and k2 as equal and equating mass flow rate at steady state, from above equations, we get

$$p_1 = \frac{p_s}{1 + 16\left(\dfrac{d_n^2 x^2}{d_0^4}\right)}$$

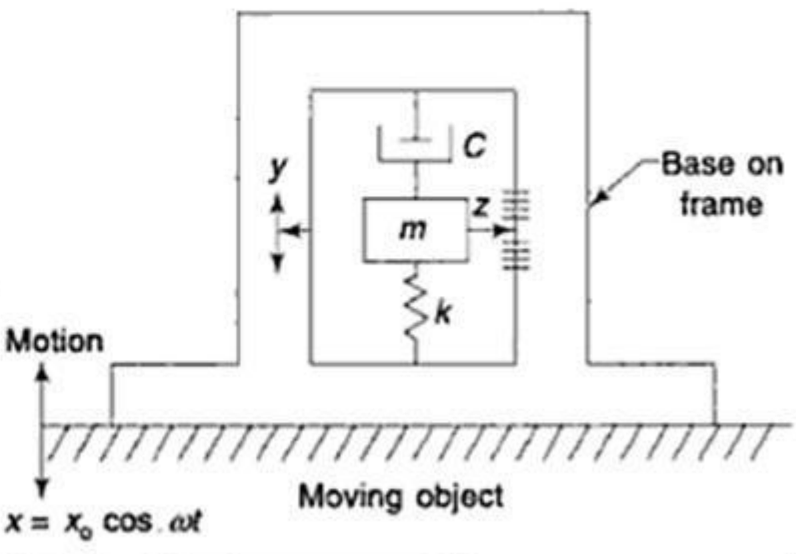


Absolute Motion Devices

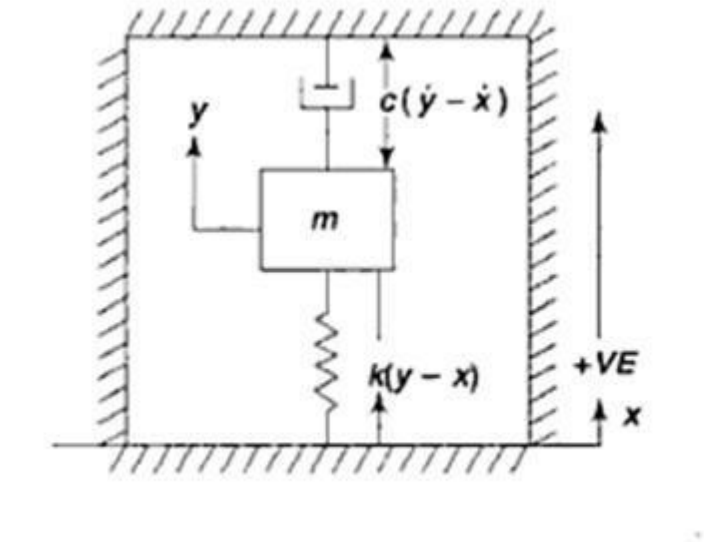
Variation of pressure ratio 'r'

Seismic Devices (Spring-Mass Type)

- The base of device or transducer is attached to object whose motion is to be measured.
- Inside the transducer, mass m is supported on a spring of stiffness k and viscous damper with damping coefficient c.
- The motion of mass relative to the frame or base, gives an indication of motion of the object and is the output of instrument.



Seismic instrument



Seismic instrument showing forces acting on the mass

Let $x = x_0 \cos \omega t$ be the harmonic motion of the object, which is to be measured. If y is the absolute motion of the mass at any instant, when the object motion is x, as shown in Fig. equation of motion of the mass m is:

$$m\ddot{y} = -c(\dot{y} - \dot{x}) - k(y - x)$$

where $\cdot$ denotes differentiation with respect to time. Writing $y - x = z$, where z is the motion of the mass relative to the frame, equation may be written as:

$$m\ddot{z} + c\dot{z} + kz = -m\ddot{x} = m\omega^2 x_0 \cos \omega t$$

(substituting $x = x_0 \cos \omega t$.)

Steady state solution of equation is $\quad z = z_0 \cos(\omega t - \varphi)$

where amplitude

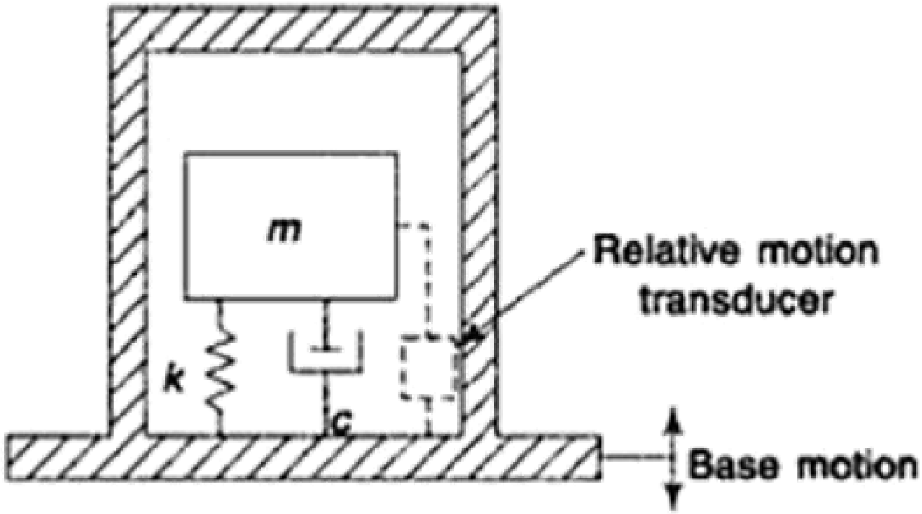
$$z_0 = \frac{m\omega^2 x_0}{\sqrt{(k - m\omega^2)^2 + (c\omega)^2}}$$

Expression for amplitude ratio z_0/x_0 may be written

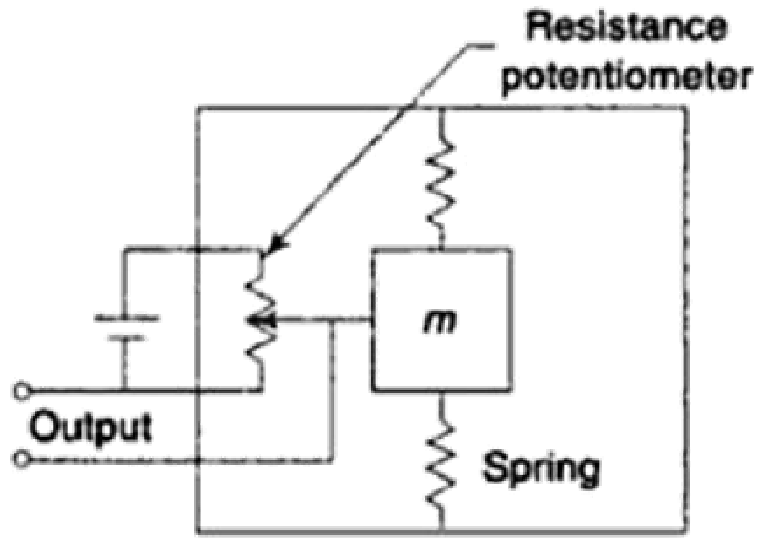
$$\frac{z_0}{x_0} = \frac{r^2}{\sqrt{(1 - r^2)^2 + (2\xi r)^2}}$$

where $r = \omega/\omega_n$, called frequency ratio

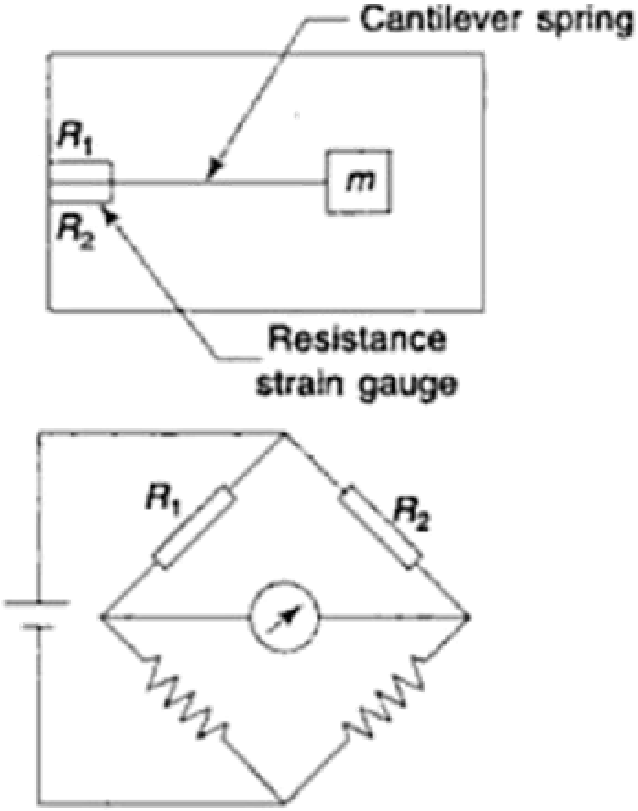
$\omega_n = \sqrt{\dfrac{k}{m}}$, called undamped natural frequency



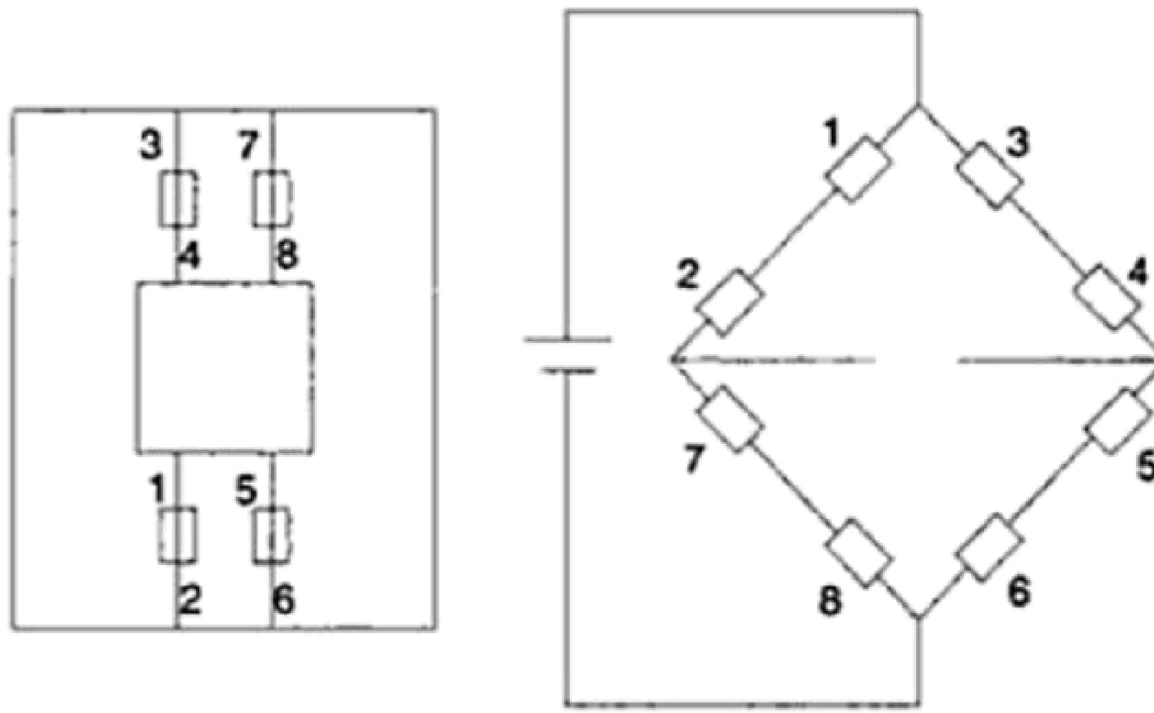
Use of a relative motion transducer in an absolute motion type transducer



Seismic transducer using resistance potentiometer

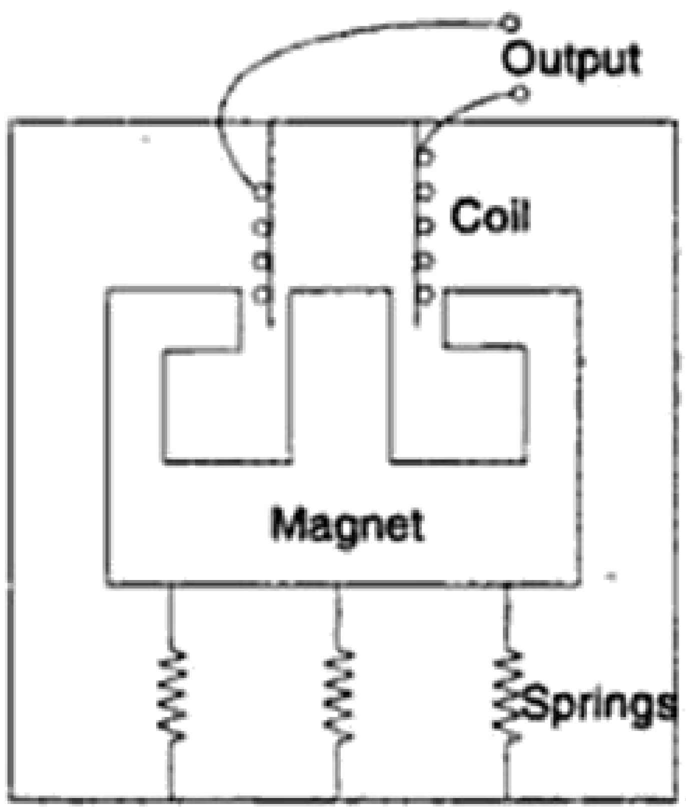


Seismic transducer using resistance strain gauges



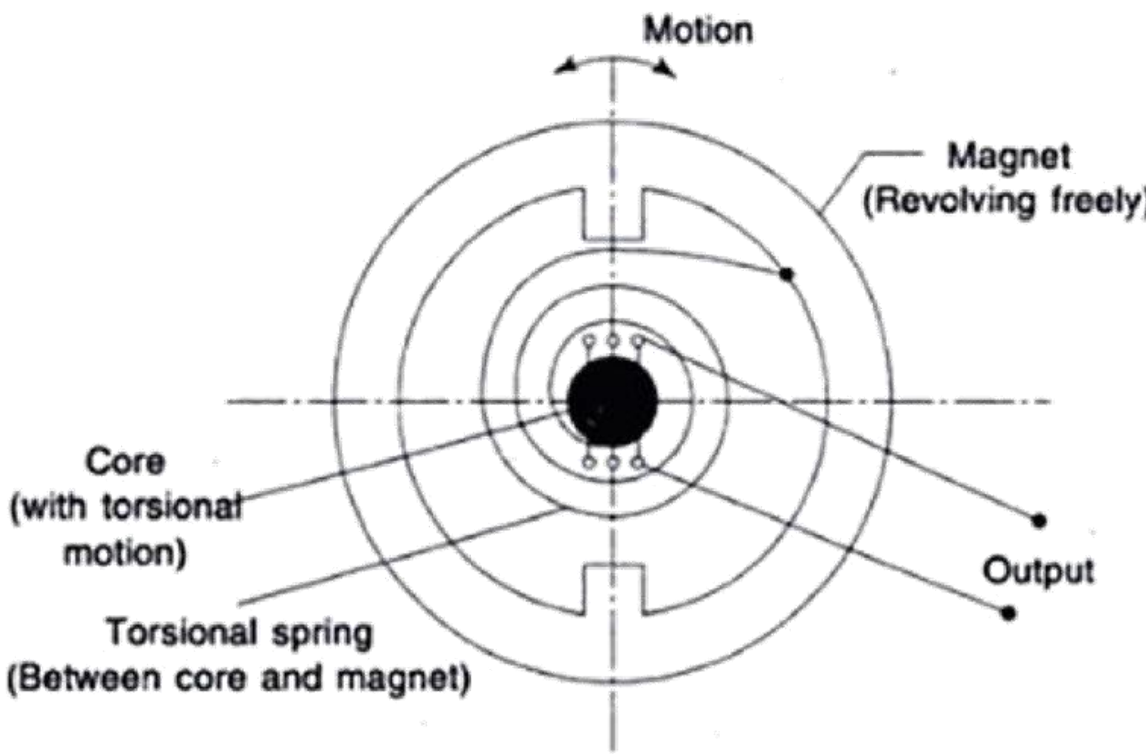
Accelerometer using resistance strain gauges

Figure shows the constructional features of another seismic motion transducer or device in which a magnet forms the seismic mass m. The relative motion of m with respect to the coil on the casing results in a voltage output from the coil, which is proportional to the rate of change of magnet motion relative to that of the coil or the base. Thus, for soft springs, the output is proportional to the velocity of the base, hence a velocity transducer.



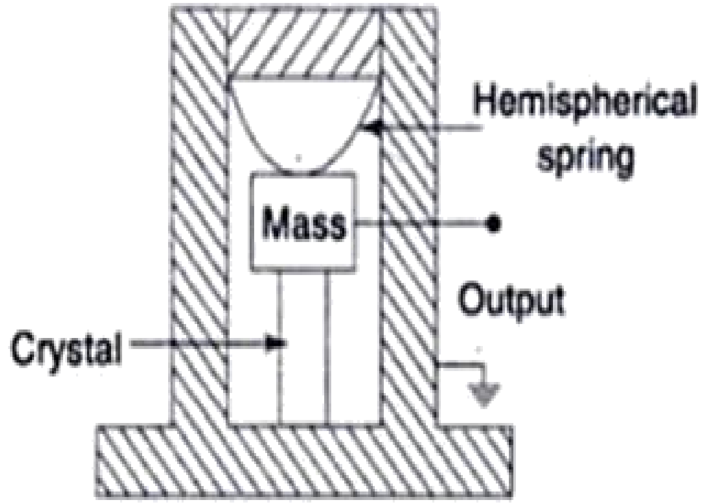
Velocity transducer

Figure shows a torsional angular motion sensor, based on the above principle. The magnet, which provides the seismic inertia, is free to revolve in angular motion while the core is attached to the shaft whose torsional motion is to be measured. A torsional spring is used between the core and the magnet. Due to torsional motion or vibrations of the shaft, there is a relative angular motion between the magnet and the cores which gives a voltage output in the coil attached to the core. The voltage output is proportional to torsional angular velocity.



Torsional angular motion transducer

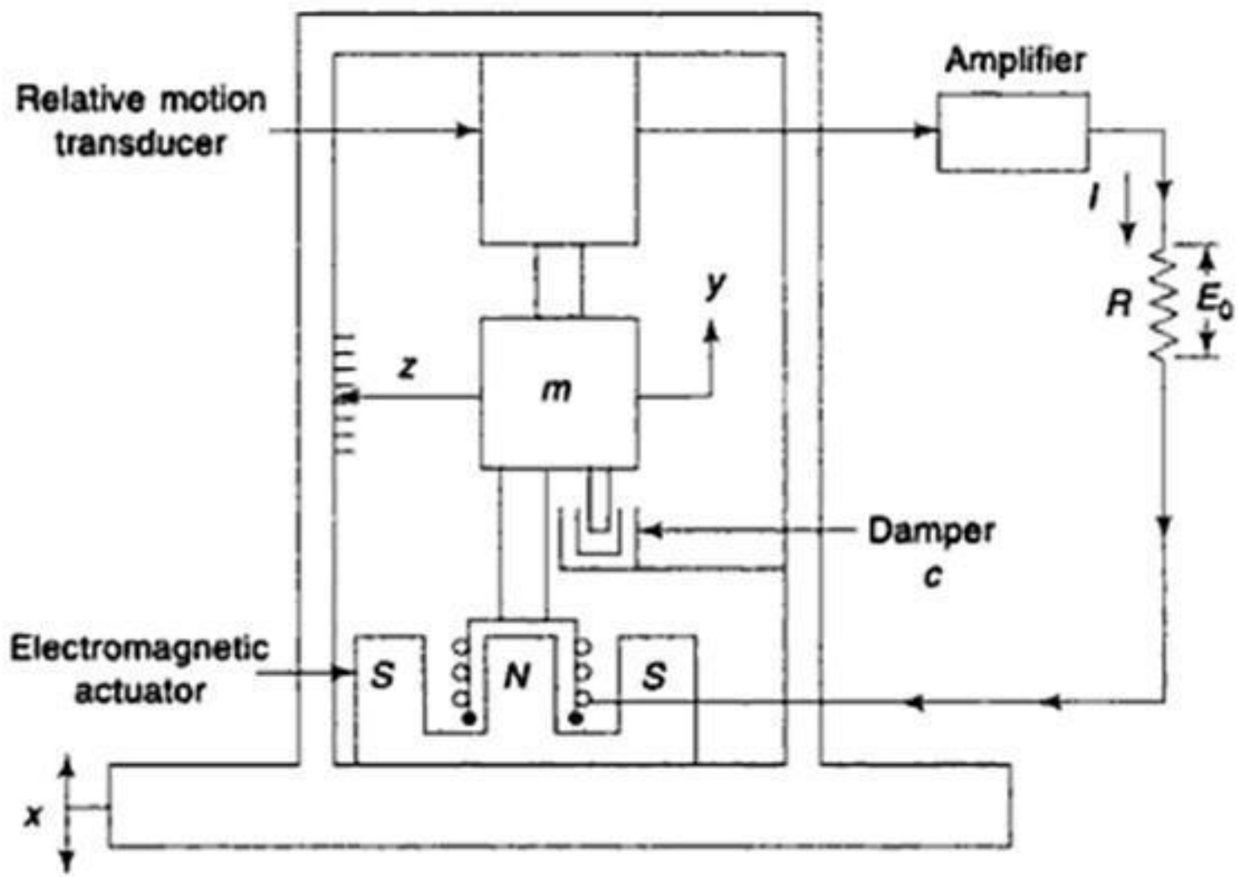
Figure shows a seismic transducer using a piezo-electric crystal. This is commonly used for shock and vibration measurements. The crystal is fairly stiff and held in compression by a spring. Because of the motion of the frame due to the moving object to which it is attached, an output voltage proportional to the acceleration of the moving object is obtained. Hence, the device is known as piezo-electric accelerometer. Such devices are very sensitive and light-weight and can be used over a wide frequency range.



piezo-electric accelerometer.

Force-Balance Type Seismic Devices

- These are similar to seismic devices except that there is no mechanical spring used here and the restoring force is provided by a feedback arrangement.



Force balance type motion transducer

A feedback loop is used to produce a force due to the electrical output of the relative motion transducer, using an electromagnetic actuator and the force is applied to the mass m. A state of balance or equilibrium is reached, with the output current I or voltage E, across a resistor R being the output and thus a measure of input motion x.

A relation between the input motion x and E_0, is now derived:

$$z = y - x$$

y being the absolute motion of mass.

$$k_1 I + m\ddot{y} + c\dot{z} = 0$$

k being force constant of actuator

$$\text{Current } I = k_2 z$$

k_2 being constant of the relative motion transducer.

Replacing time derivative by D, we get

$$I = \frac{-mD^2(z+x) - cDz}{k_1}$$

$$\text{Output } E_0 = IR$$

$$(mD^2 + cD + k_1 k_2)\, E_0 = -m k_2 R D^2 x$$

- Used in inertial navigation systems.
- Possible to get higher accuracy and increased stability as effects like hysteresis, non-linearity, temperature effects, etc.