control systems :-

→ when a number of elements or components are connected in a sequence to perform a specific function, the group thus formed is called a system.

→ When a o/p quantity is controlled by varying the i/p quantity, the s/m is said to be control s/m.

o/p quantity ⇒ controlled variable or Response.

i/p quantity ⇒ command signal or excitation.

→ For example,

(i) In a driving s/m, the speed is controlled by position of the accelerator.

Hence the i/p quantity ⇒ position of the accelerator

~~o/p~~ ctrlled o/p qty ⇒ speed

(ii) Traffic lights control s/m, a sequence of i/p signal is applied to the s/m to have o/p as one of the three lights, for particular duration of time.

→ Types of control systems:-

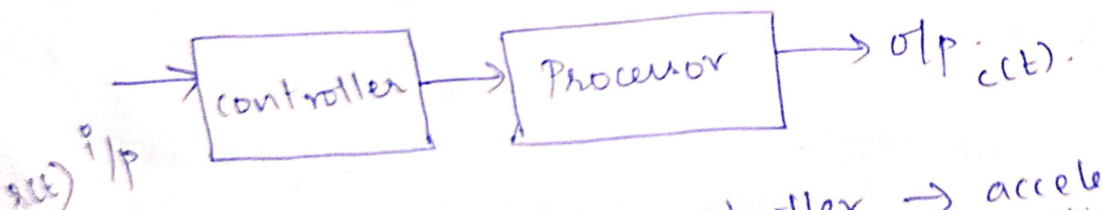
classification of control s/ms

- Based on Type of the signal
  - continuous — If the i/p signal of the s/m is continuous
  - Discrete — If the i/p signal is discrete.
- Based on no. of i/ps & o/ps
  - SISO
  - MIMO.
- Based on feedback.
  - open loop
  - closed loop

Open loop control s/ms. (OLS)

→ The s/m which does not automatically correct the variation in its o/p is called OLS.

→ The o/p quantity has no effect upon the i/p quantity. (i.e) there will be no feedback to the i/p for correction.

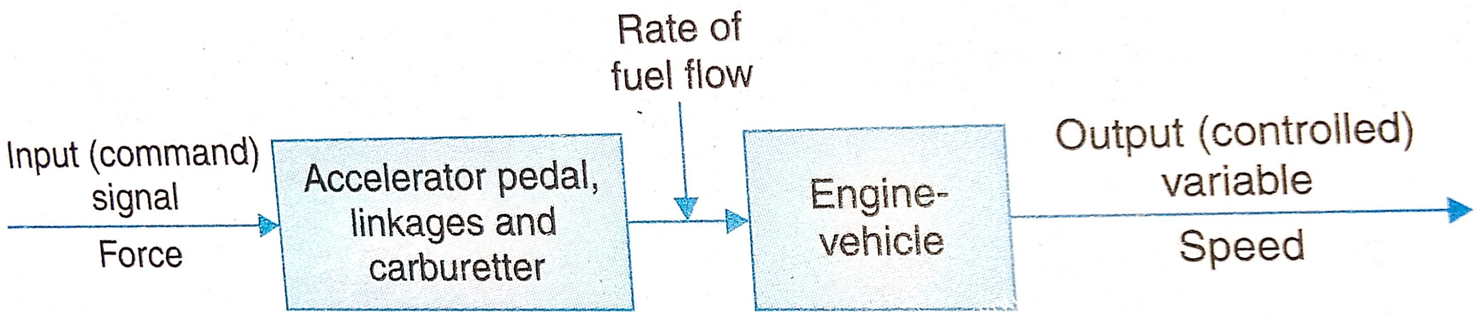


→ For a driving s/m, controller → accelerator position.

Processor → Automobile S/m.

o/p → speed

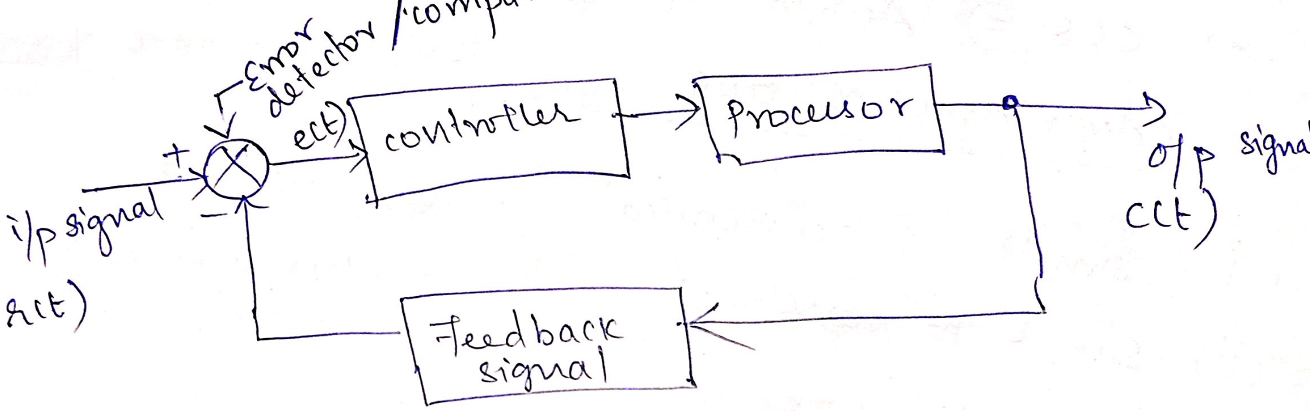
engine bringing the engine vehicle sp



→ With no restrictions in the level of speed, By adjusting the accelerator position & corresponding speed ie attained as o/p quantity.

closed loop control s/m.

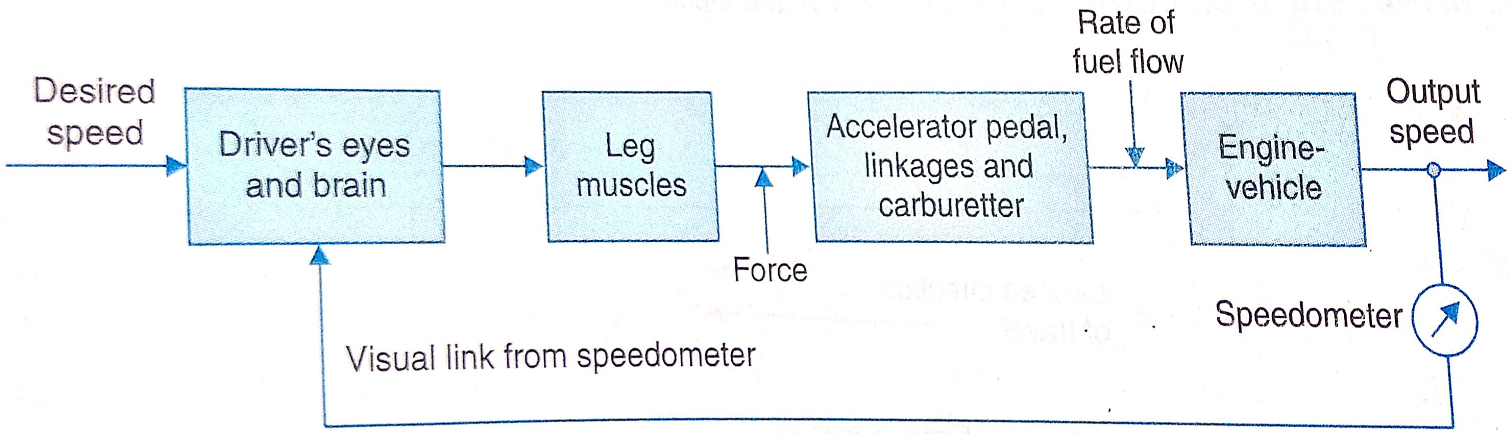
→ The control s/ms in which the o/p has an effect upon the i/p quantity in order to maintain the desired o/p is called CLS.



→ consider the same driving s/m. The speed & acceleration of the vehicle are determined & controlled by the driver by observing the traffic and road conditions.

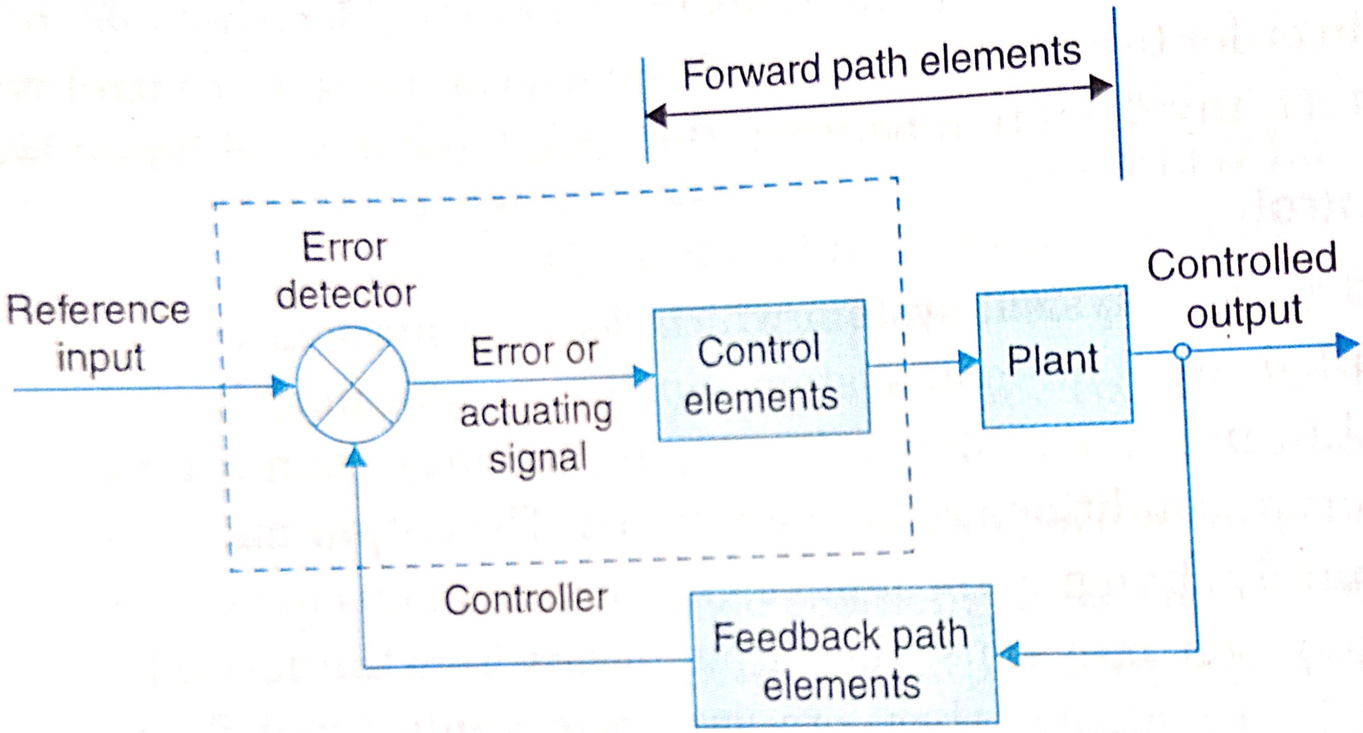
→ If the vehicle is need to be maintained at a speed of 50 km/hr, then with accelerator position, the desired speed can be attained.

→ But if suddenly the situation changes, & there should be a change in the speed level [(ie) 50 km/hr to 20 km/hr] the state of o/p is feedback to the i/p & it is used to modify the controlling s/m to get the desired o/p.



Desired speed
Driver's eyes and brain
Leg muscles
Force
Accelerator pedal, linkages and carburetter
Rate of fuel flow
Engine-vehicle
Output speed
Speedometer
Visual link from speedometer

such a manner as to reduce



→ The reference signal or i/p signal corresponds to the desired o/p. The error signal generated by the error detector & the difference between the reference signal and feedback signal.

→ Then the controller modifies & amplifies the error signal to get a better control action on the o/p.

→ CLS ⇒ Automatic control s/m.

→ Advantages of OLS

(i) simple & economical

(ii) Easier to construct.

(iii) stable.

→ Advantages of CLS

(i) accurate

(ii) less affected by noise.

→ Disadvantages of OLS

(i) Inaccurate & unreliable.

(ii) No automatic correction with respect to ~~changes in~~ external conditions.

→ Disadvantages of CLS

(i) complex & costly.

(ii) The feedback may lead to oscillations.

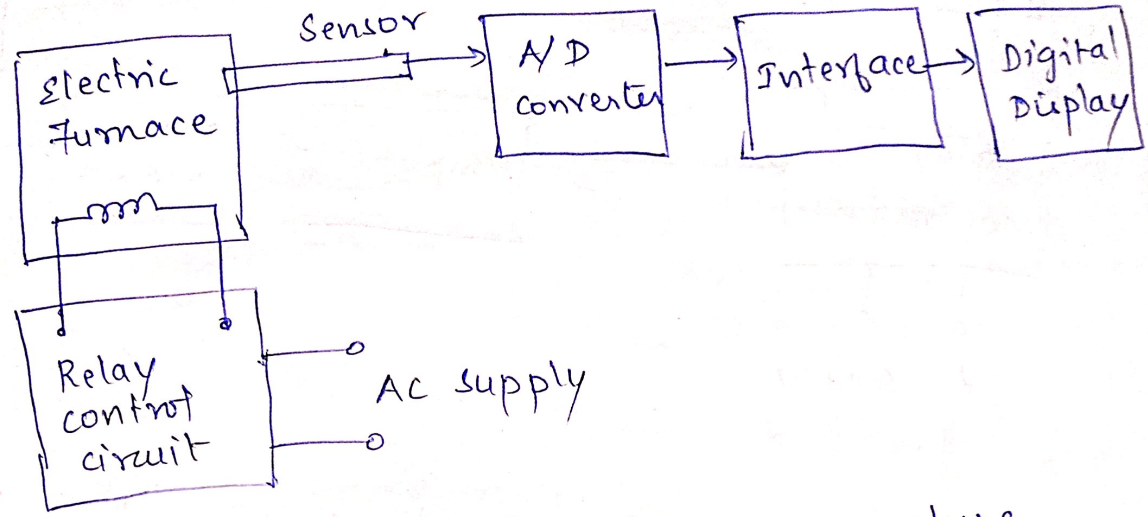
(iii) Reduces the overall gain.

(iv) less stable.

Examples of control s/ms.

→ Temperature control s/m.

(i) open loop s/m.



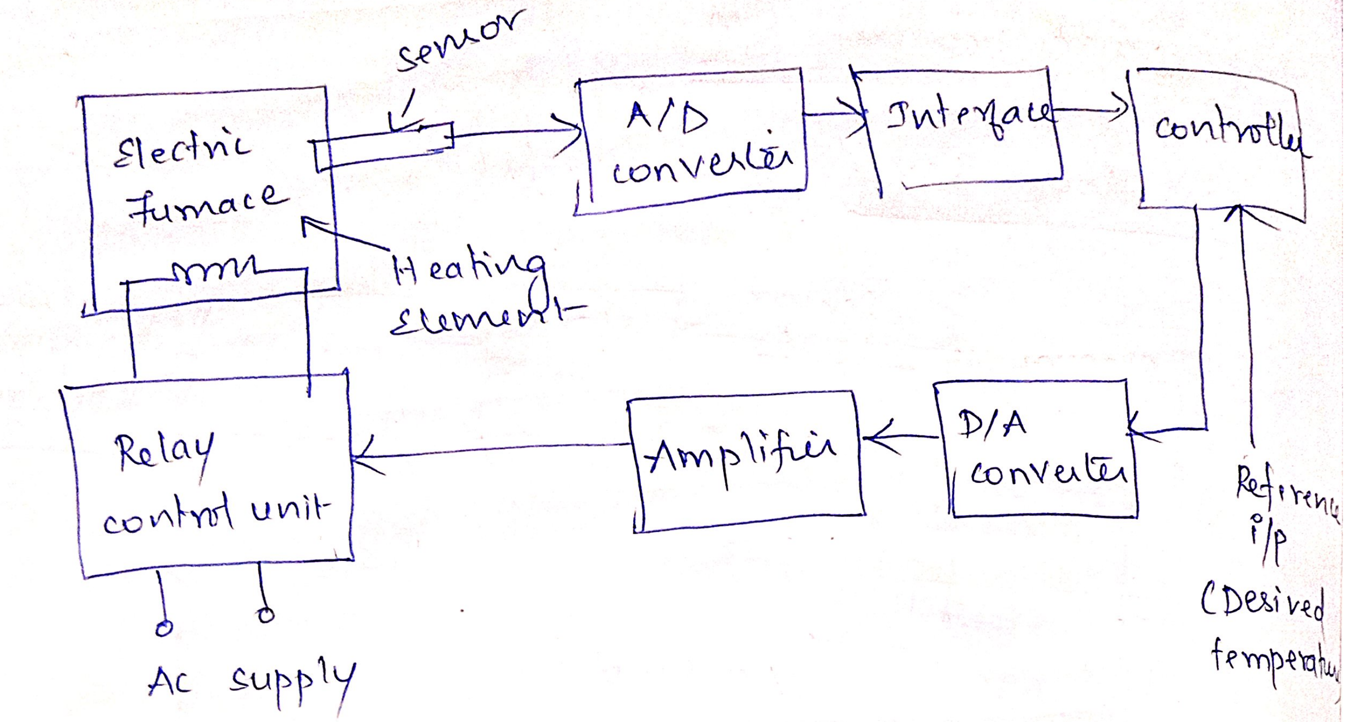
→ The o/p in the s/m is the temperature which depends on the time during which the supply to heater remains ON.

→ The temperature is measured by the sensor which gives the analog value corresponding to the temperature of the furnace.

→ The analog signal is converted to a digital signal by A/D converter and the display is used to display the value of the temperature.

→ So, in this s/m, if there is any change in the o/p temperature, the ON time of the relay is not automatically altered.

(ii) closed loop s/m :-



→ Here, the ON & OFF time of relay is controlled by a controller.

→ The actual temperature is sensed by the sensor and converted to digital by A/D.

→ The computer (ie) controller unit reads the actual temperature and compares with desired temperature.

→ ~~there~~ If there is any difference in the temperature, then it sends signal to switch ON or OFF the relay thro' D/A converter and Amplifier.

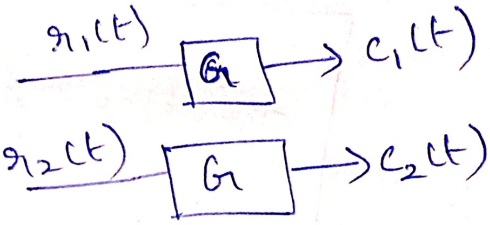
→ Thus the s/m. automatically corrects any changes in the o/p.

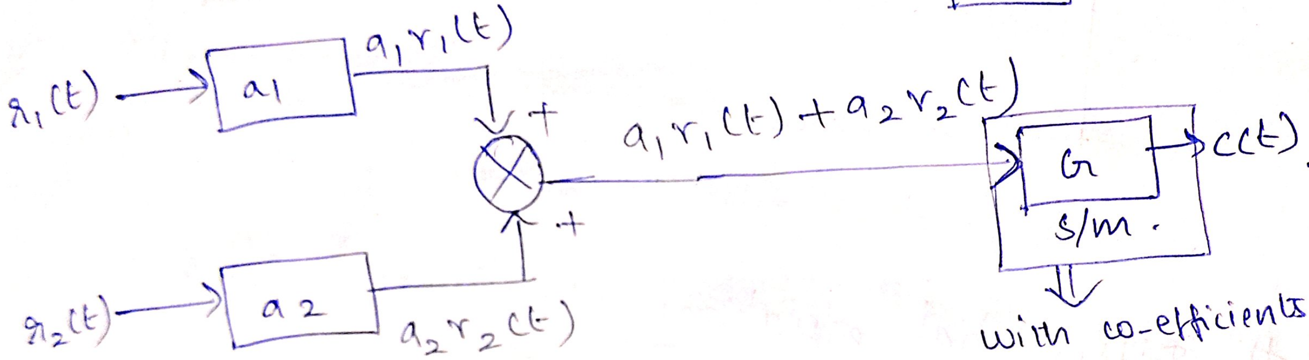
Mathematical Models of control s/ms.

→ The i/p - o/p relations of various physical components of a s/ms are governed by the set of differential equations.

→ These differential equations are solved by using transforms (Laplace transforms).

→ Linear ~~time~~ ~~Invariant~~ s/ms.





with co-efficients

→ Linear Time Invariant s/ms :-

→ The s/m is said to be linear time Invariant if the co-efficients of the differential equation describing the s/m are constants.

→ Linear - time varying s/ms.

→ The s/m is said to be Linear time varying if the co-efficients of the differential equations are functions of time.

→ Transfer function :-

→ The transfer function of a s/m is defined as the ratio of laplace transform of o/p to the laplace transform of i/p with zero initial conditions.

$$\boxed{\text{Transfer func.} = \left.\frac{LT(o/p)}{LT(i/p)}\right|_{\substack{\text{zero initial}\\ \text{conditions.}}}}$$

Differential equations of physical s/ms :-

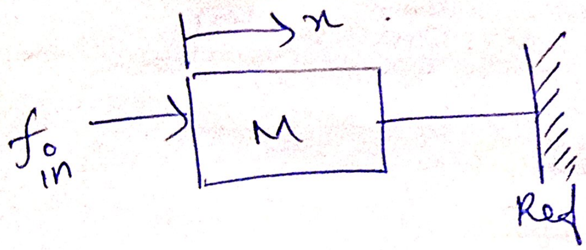
(1) Mechanical-translational s/ms.

→ The model of mechanical translational s/ms can be obtained by using three basic elements

(i) Mass ⇒ weight of Mechanical s/m
(ii) Spring ⇒ elastic deformation
(iii) dash-pot ⇒ Friction.

→ When a force is applied to the translational mechanical s/m, it is opposed by opposing forces due to mass, friction & elasticity of the s/m.

(i) Mass element



f – force

M – Mass

x – displacement.

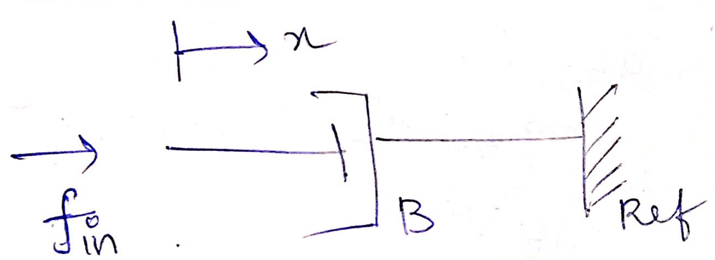
→ When a force is applied on a body of Mass M, the mass will offer a opposing force which is ~~d~~ proportional to acceleration of the body.

→ The opposing force is denoted by (f_m)

$\therefore f_m \propto \frac{d^2x}{dt^2}$. [Due to mass]

$$\boxed{f_{in} = f_m = M\frac{d^2x}{dt^2}.}$$

(ii) Dash-pot / Damper.



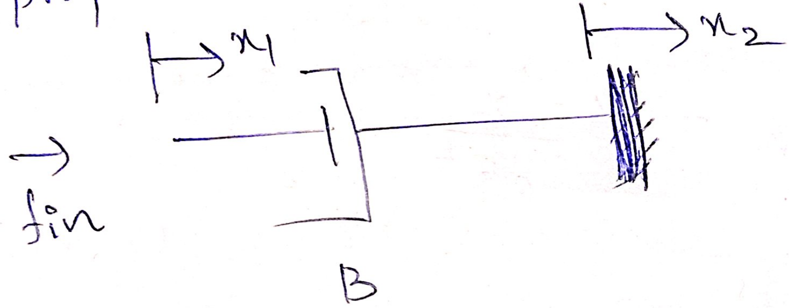
→ ~~With~~ To a frictional element of negligible mass and elasticity, the force is applied, then that dash-pot (frictional element) will offer a opposing force proportional to the velocity of the body.

→ The opposing force due to friction, denoted by f_b is given by

$$f_b \propto \frac{dx}{dt}$$

$$\boxed{f_{in} = f_b = B\frac{dx}{dt}}.$$

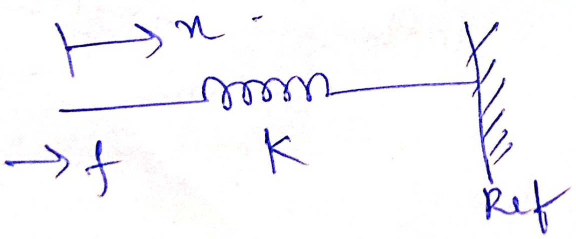
→ If the dashpot has the displacement at both ends, then the opposing force is proportional to differential velocity.



$$f_b \propto \frac{d(x_1 - x_2)}{dt}$$

$$\boxed{f_{in} = f_b = B\frac{d(x_1 - x_2)}{dt}}.$$

(iii) Spring

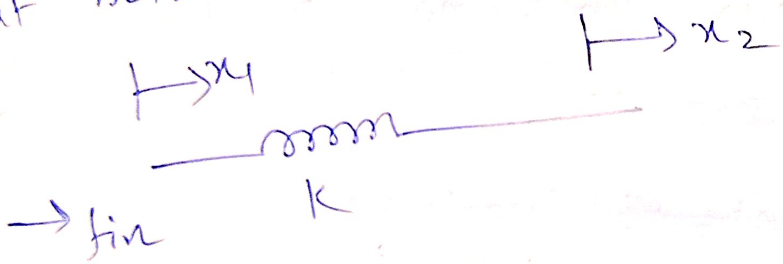


→ When a force applied on the spring, it will offer an ~~force~~ opposing forcing which is proportional to the displacement of the body.

$$f_K \propto x$$

$$\boxed{f_{in} = f_K = Kx.}$$

→ With the spring that has displacemente at both ends



$$f_K \propto (x_1 - x_2)$$

$$\boxed{f_K = K(x_1 - x_2)} = f_{in}$$

(2) Mechanical - Rotational s/ms.

→ The Model of rotational-mechanical s/ms can be obtained by using three basic elements.

(i) moment of Inertia (J) of mass

(ii) dash-pot with rotational frictional co-efficient (B)

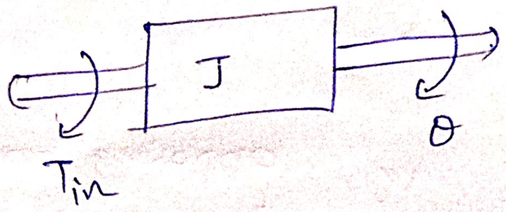
(iii) torsional spring with stiffness (K)

→ ~~(i) Moment of Inertia.~~

→ when a torque is applied to a rotational mechanical s/m, it is opposed by opposing torques due to moment of inertia, friction and elasticity of the system.

(i) Moment of Inertia (J)

consider a mass element, when a torque is applied, ~~to~~ it will produce an opposing torque ~~which~~ which is proportional to the angular acceleration.



opposing torque $\rightarrow T_j$

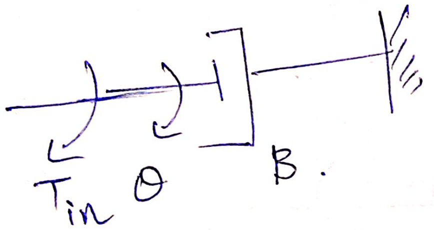
$\theta \rightarrow$ angular displacement

$T_{in} \rightarrow$ i/p Torque.

$$T_j \propto \frac{d^2\theta}{dt^2}.$$

$$\boxed{T_{in} = T_j = J\frac{d^2\theta}{dt^2}}$$

(ii) dash-pot $\quad T_b \propto$ angular velocity.

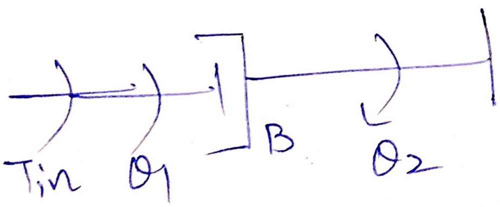


opposing Torque $\rightarrow T_b$.

$$T_b \propto \frac{d\theta}{dt}$$

$$\boxed{T_{in} = T_b = B\frac{d\theta}{dt}}$$

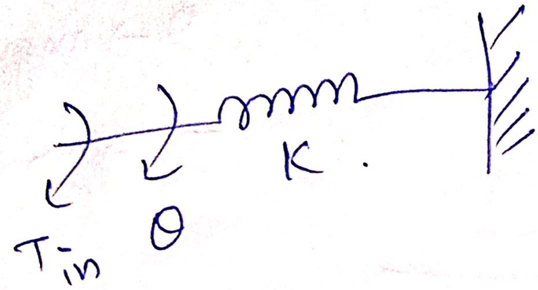
If the dash-pot has angular displacement at both ends, then



$$T_b \propto \frac{d(\theta_1-\theta_2)}{dt}$$

$$\boxed{T_{in} = T_b = B\frac{d}{dt}(\theta_1-\theta_2)}$$

(iii) Elastic-element spring.

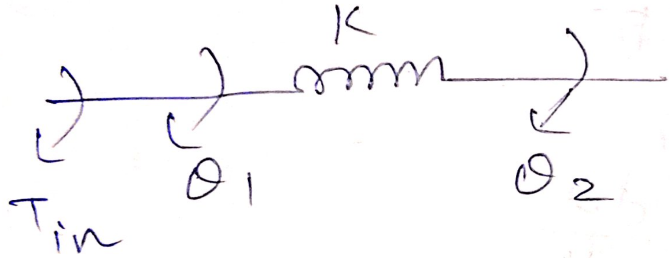


Opposing torque T_K is proportional to angular displacement

$$T_K \propto \theta$$

$$T_{in} = \boxed{T_K = K\theta}.$$

If the element has angular displacement at both the ends, then



$$T_K \propto (\theta_1 - \theta_2)$$

$$T_{in} = \boxed{T_K = K(\theta_1 - \theta_2)}$$