Ajay Kumar Garg Engineering College, Ghaziabad

Department of ECE

Model Solution Sessional Test-2

Course: B.Tech
Session: 2017-18
Subject: Transducer and sensors
Max Marks: 50

Semester: V
Section: EI-1
Sub. Code: NIC-502
Time: 2 hour

Note : Answer **all** the sections.

Section-A

A. Attempt **all** the parts. **(5x2 =10)**

Q1- What is Stroboscopic method ? Why it is used ?

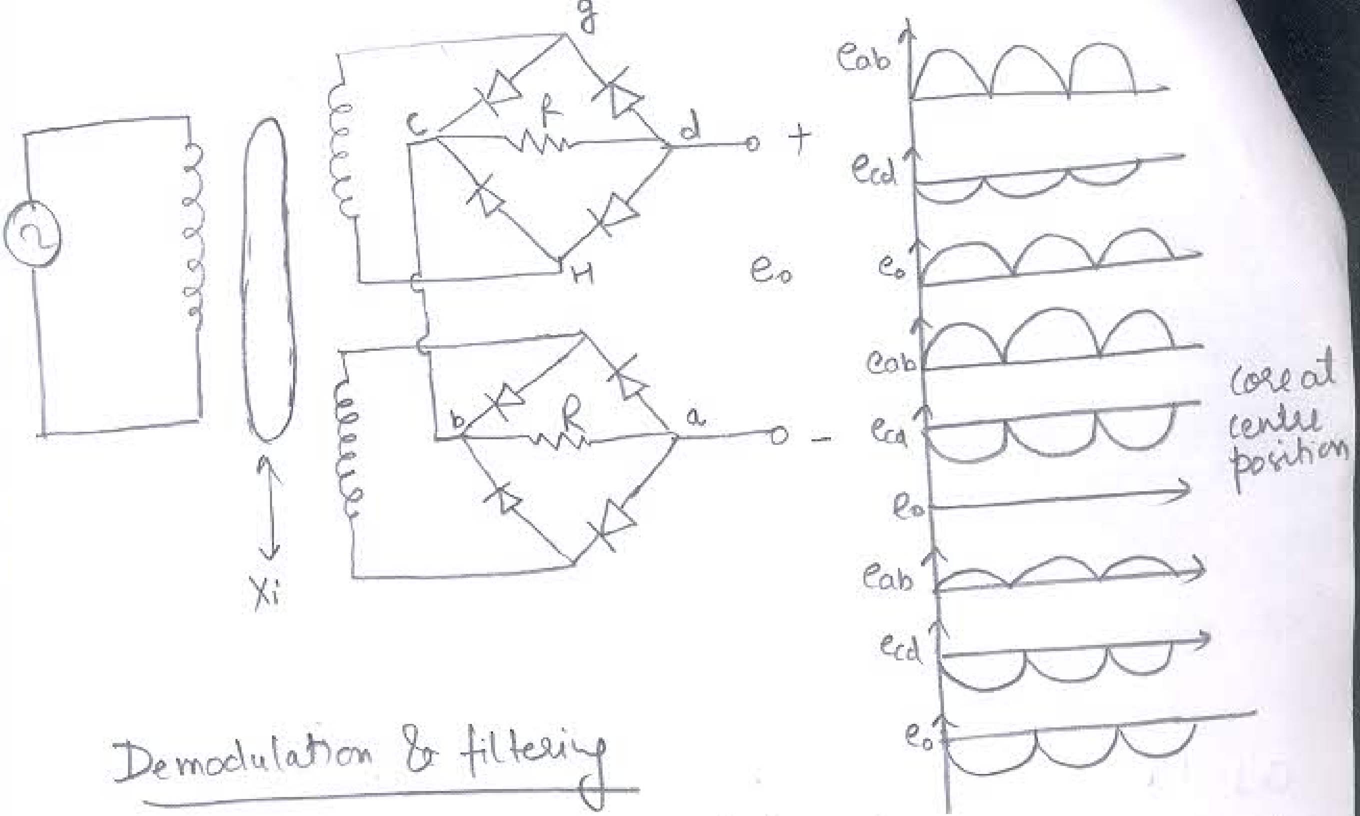
Ans- Stroboscopic method is used to measure the angular velocity. Stroboscope is a device which produces flashes of light. This flashing frequency can be adjusted. It is fixed at maximum rate first and then reduced. Angular speed is calculated by using formula.

$$n = \frac{r_1 r_N (N-1)}{r_1 - r_N}$$

where r_1 = lowest flashing frequency
r_N = highest flashing frequency
n = angular speed

Q2- Why phase sensitive demodulator circuit is used in LVDT ? Draw its diagram.

Ans- Phase sensitive demodulator circuit is used in LVDT to sense the direction of displacement, means in which direction, the core of LVDT is moving.



Demodulation & filtering

Q3- List the different methods used for force measurement.

Ans- ① Hydraulic load cell
② Pneumatic load cell
③ Proving Ring
④ Balances
⑤ Strain gauge load cell

Q4- What do you mean by Elastic force transducer? Draw idealized model for elastic force transducer.

Ans- In Elastic force transducer, force is measured due to the deflection of the device. The relationship between input force & output displacement is easily established as a simple second-order form.

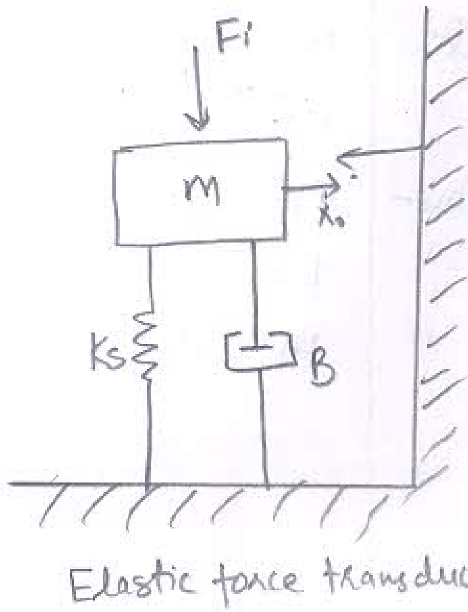
$F_i - K_s x_o - B\dot{x}_o = M\ddot{x}_o$

$$\frac{x_o}{F_i}(D) = \frac{K}{D^2/\omega_n^2 + 2\xi_q D/\omega_n + 1}$$

where $\omega_n = \sqrt{K_s/M}$

$$\xi_q = \frac{B}{2\sqrt{K_s M}}$$

$$K = \frac{1}{K_s}$$



Elastic force transducer

Q5- A barium titanate pickup has the dimensions of 5mm X 5mm X 1.25 mm. The force acting on it is 5N. Its charge sensitivity is 150 pC/N & its permitivity is 12.5×10^{-9} F/m. If the modulus of elasticity of barium titanate is 12×10^{6} N/m², Calculate the strain. Also calculate the charge & capacitance.

Sol

Area of plates $A = 5 \times 5 \times 10^{-6} = 25 \times 10^{-6} m^2$

Pressure $P = F/A = \frac{5}{25 \times 10^{-6}} = 0.2\ MN/m^2$

voltage Sensitivity $g = \frac{d}{\varepsilon_0 \varepsilon_r} = \frac{150 \times 10^{-12}}{12.5 \times 10^{-9}}$

$= 12 \times 10^{-3}\ Vm/N$

voltage generated $E_0 = gtp = 12 \times 10^{-3} \times 1.25 \times 10^{-3} \times 0.2 \times 10^{6}$

$= 3V$

$\text{Strain} = \frac{\text{Stress}}{\text{Young's Modulus}} = \frac{0.2 \times 10^{6}}{12 \times 10^{6}} = 0.0167$

Charge $Q = dF = 150 \times 10^{-12} \times 5 = 750\ pC$

Capacitance $C_p = \frac{Q}{E_0} = \frac{750 \times 10^{-12}}{3} = 250\ pF$ Ans

Section B

B- Attempt all the parts: (5X5=25)

6- Define Gauge factor. Derive the expression for gauge factor in case of strain gauge used for displacement measurement.

As- Gauge factor indicates the sensitivity of strain gauge. It is $\frac{\Delta R/R}{\Delta L/L}$

Now if we apply stress on the wire

$$\frac{\partial R}{\partial s} = \frac{\rho}{A}\frac{\partial L}{\partial s} - \frac{\rho L}{A^2}\frac{\delta A}{\delta s} + \frac{L}{A}\frac{\delta \rho}{\delta s}$$

Dividing by $R = \frac{\rho L}{A}$

$$\frac{1}{R}\frac{\partial R}{\partial S} = \frac{1}{L}\frac{\partial L}{\partial S} - \frac{1}{A}\frac{\partial A}{\partial S} + \frac{1}{\rho}\frac{\partial \rho}{\partial S}$$

$$\frac{1}{A}\frac{\partial A}{\partial S} = \frac{2}{D}\frac{\partial D}{\partial S}$$

$$\frac{1}{R}\frac{\partial R}{\partial S} = \frac{1}{L}\frac{\partial L}{\partial S} - \frac{2}{D}\frac{\partial D}{\partial S} + \frac{1}{\rho}\frac{\partial \rho}{\partial S}$$

Now Poissons Ratio

$$\nu = \frac{\text{lateral strain}}{\text{axial strain}} = \frac{-\partial D/D}{\partial L/L}$$

$$\frac{1}{R}\frac{\partial R}{\partial S} = \frac{1}{L}\frac{\partial L}{\partial S} + \nu\frac{2}{L}\frac{\partial L}{\partial S} + \frac{1}{\rho}\frac{\partial \rho}{\partial S}$$

$$\frac{\Delta R}{R} = \frac{\Delta L}{L} + 2\nu\frac{\Delta L}{L} + \frac{\Delta \rho}{\rho}$$

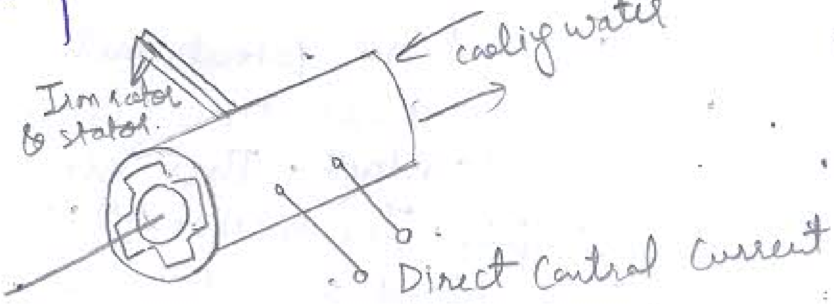
Gauge factor $G = \frac{\Delta R/R}{\Delta L/L}$

$$\boxed{G = 1 + 2\nu + \frac{\Delta\rho/\rho}{\varepsilon}}$$

Q7- Explain Eddy Current brake drum dynamometer & Prony Brake type dynamometer.

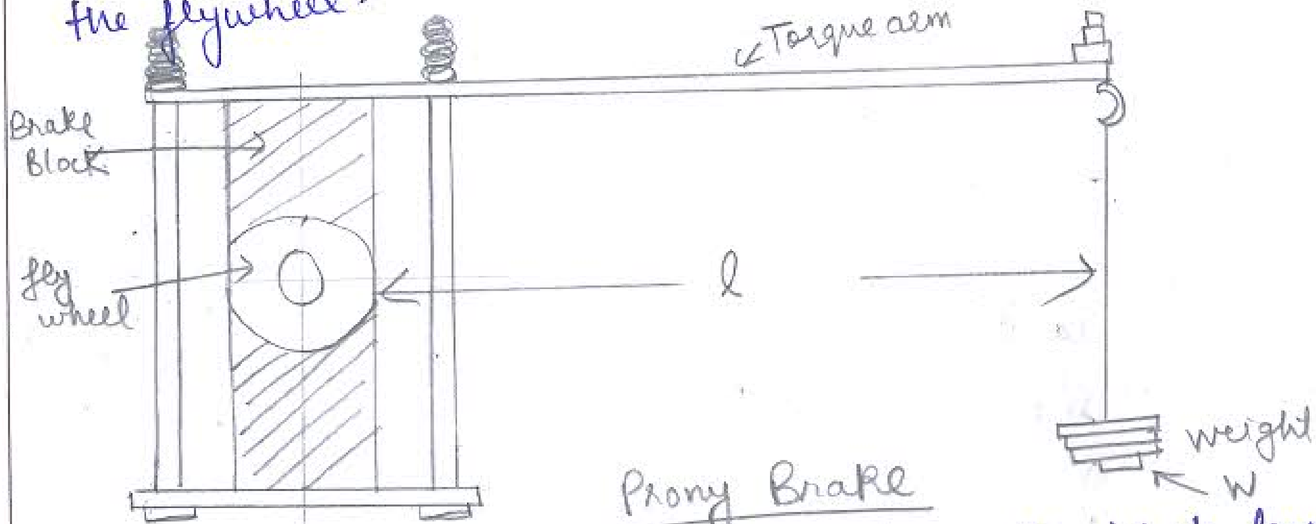
Ans- Dynamometer is used for shaft's power measurement.

Eddy Current dynamometer → It consists of a stator on which no of electromagnets are fitted & a rotor disc, made of copper or steel and coupled to the output shaft of the engine. When the rotor rotates eddy currents are produced in the stator due to magnetic flux set up by the passage of field current in the electromagnets. These eddy currents are dissipated in producing heat so that this type of dynamometer requires some cooling arrangement. The torque is measured exactly as in other types of absorption dynamometers. i.e. with the help of a moment arm. The load in internal combustion engine testing is controlled by regulating the currents in the electromagnets.



Eddy-Current brake

Prony Brake Dynamometer → It is to attempt to stop the engine by means of a brake on the flywheel & measure the weight which an arm attached to the brake will support, as it tries to rotate with the flywheel.



Prony Brake

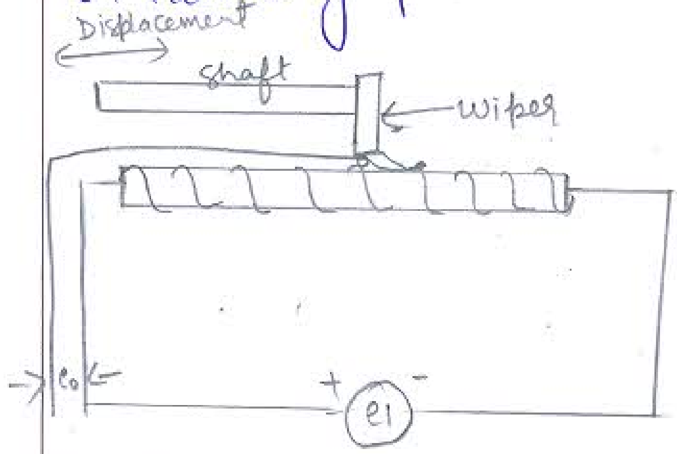
Prony Brake shown above consists of wooden-block, frame, rope, brake shoes & flywheel. It works on the principle of converting power into heat by dry friction. The whole of the power absorbed is converted into heat & hence this type of dynamometer must be cooled.

$$\text{Brake power} \Rightarrow \frac{2\pi NT}{60}$$

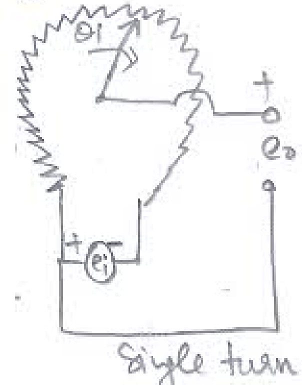
T = weight applied (w) × distance 'l'

Q8- Explain the principle, construction & working of resistive potentiometers. How resistive potentiometers are used to measure the displacement of a body?

Ans - Basically a resistance potentiometer, or simply a POT consists of a resistive elements provided with a sliding contact. This sliding contact is called a wiper. The motion of the sliding contact may be translatory or rotational. A linear pot or rotatory pot are shown in fig.

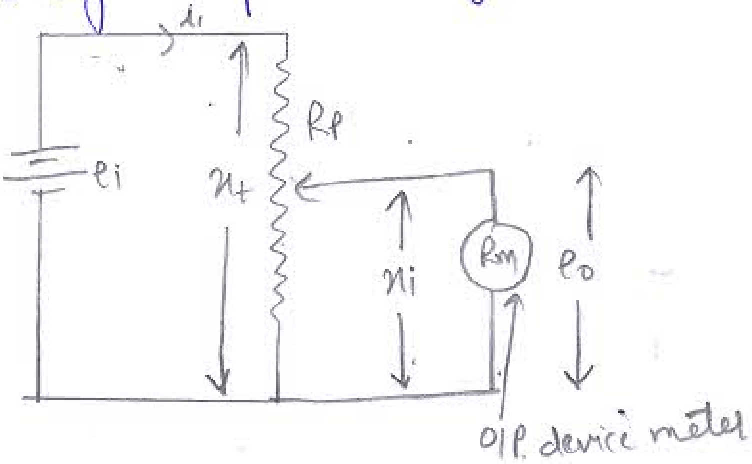


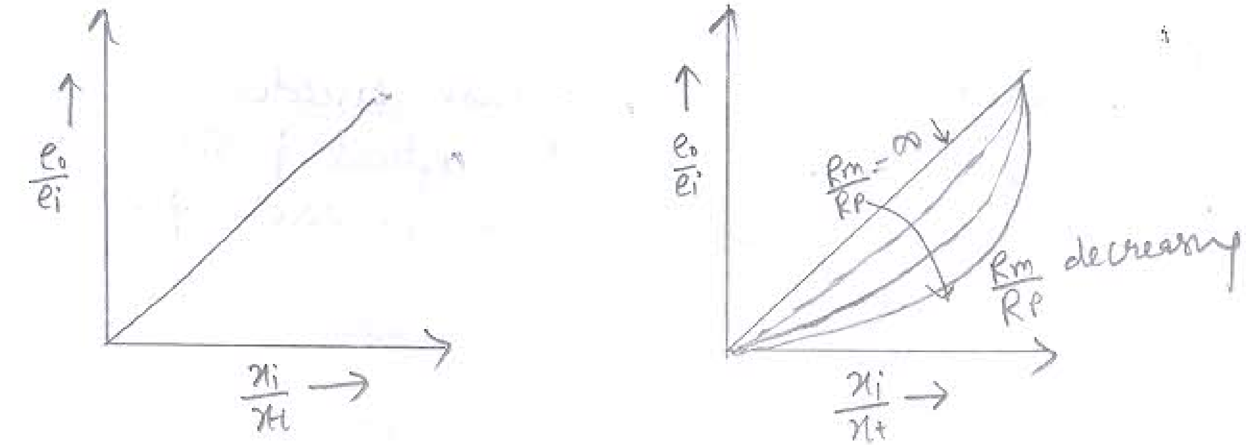
(a) Linear POT



(b) Rotational

The ckt shown in fig is potentiometer divider since they produce an output voltage which is a fraction of the input voltage. Thus the input voltage is "divided". The potential divider is a device for dividing the potential in a ratio determined by the position of the sliding contact.





Characteristics of potentiometer

<u>Sensitivity</u> → $S = \frac{\text{Output}}{\text{Input}}$

$$= \frac{e_o}{x_i} = \frac{e_i}{x_t}$$

so $\boxed{x_i = \frac{e_o}{e_i} x_t}$

Q9- Explain all the three class of Digital displacement transducer & shaft encoder in detail.

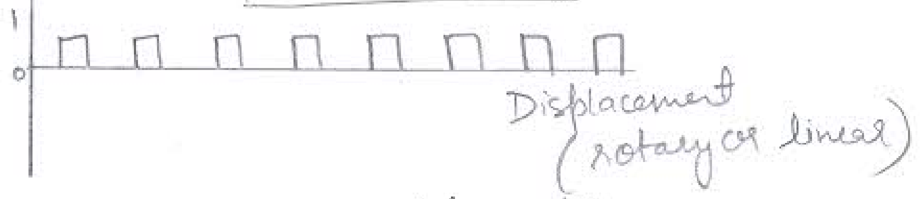
Ans- <u>Classification of Encoders</u> :

(1) <u>Tachometer</u> → A tachometer encoder has only a single output signal which consists of a pulse for each increment of displacement. Reverse motion cannot be detected in this. It is used for measurement of angular speed only.

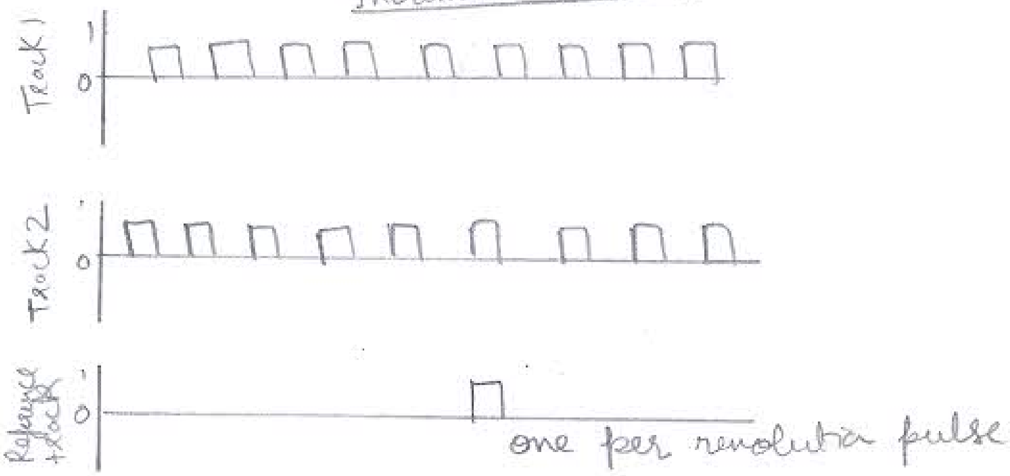
(2) <u>Incremental Encoder</u> → It has two disc, one is for the detection of forward motion & other one is for the detection of reverse motion only. Hence Reverse motion can be detected in this case. It is used for position measurement.

Absolute Encoder → Absolute encoder has multiple tracks. It indicates the actual position of the shaft. It generates a code for each position of the shaft.

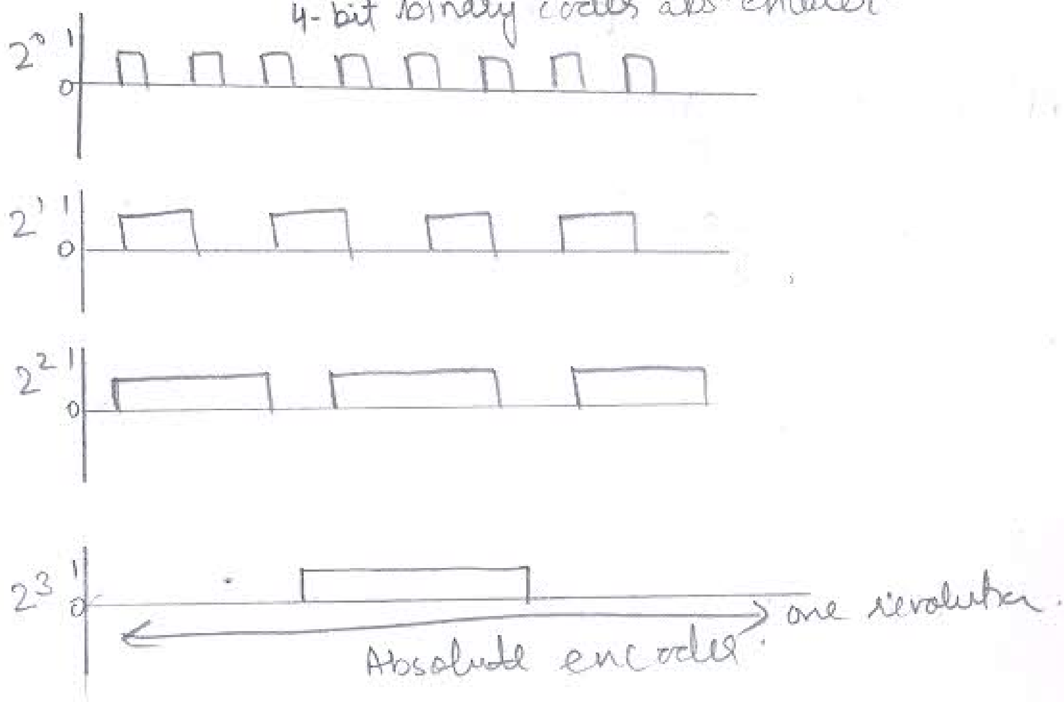
Tachometer encoder



Incremental encoder

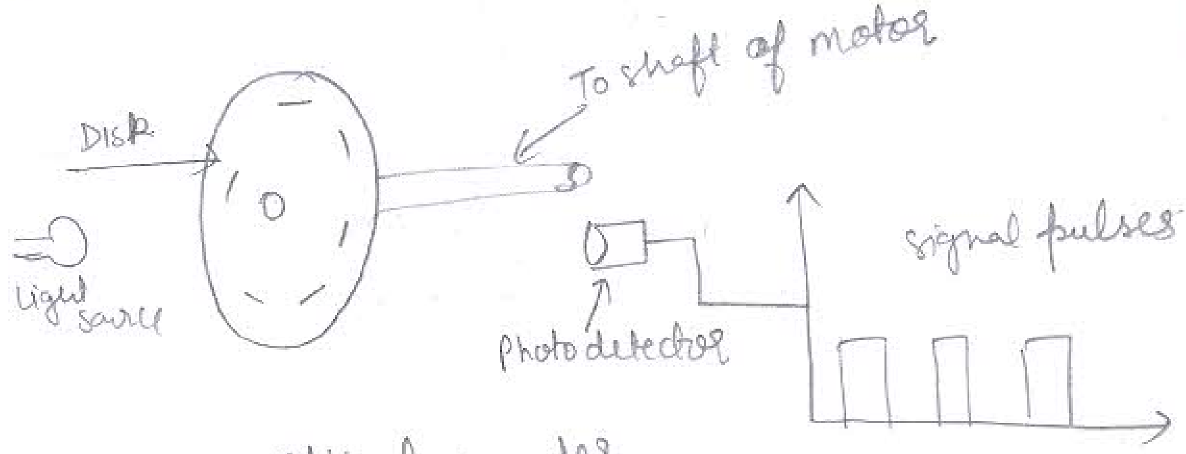


4-bit binary codes abs. encoder.



Classification of Encoders

Shaft encoder → A shaft encoder is a digital device used for measurement of angular position. They are also contacting type (Brush type) & non contacting type.



Optical encoder

In this, disc is attached to the shaft of motor whose speed is to be measured. Disc have a coded slot through which light passes from LED to photo detector & a pulse is generated. No of signal pulse in a particular period of time gives the angular speed of shaft. This is used for rotational speed that's why it is an example of shaft encoder for non-contacting type.

Q10- What is piezoelectric effect? List the materials used for piezoelectric transducers. Describe the different mode of operation of piezoelectric transducers.

As— A piezoelectric material is one in which an electric potential appears across certain surfaces of a crystal if the dimension of crystal are changed by the application of a mechanical force or vice versa. This effect in the crystal is called piezoelectric effect.

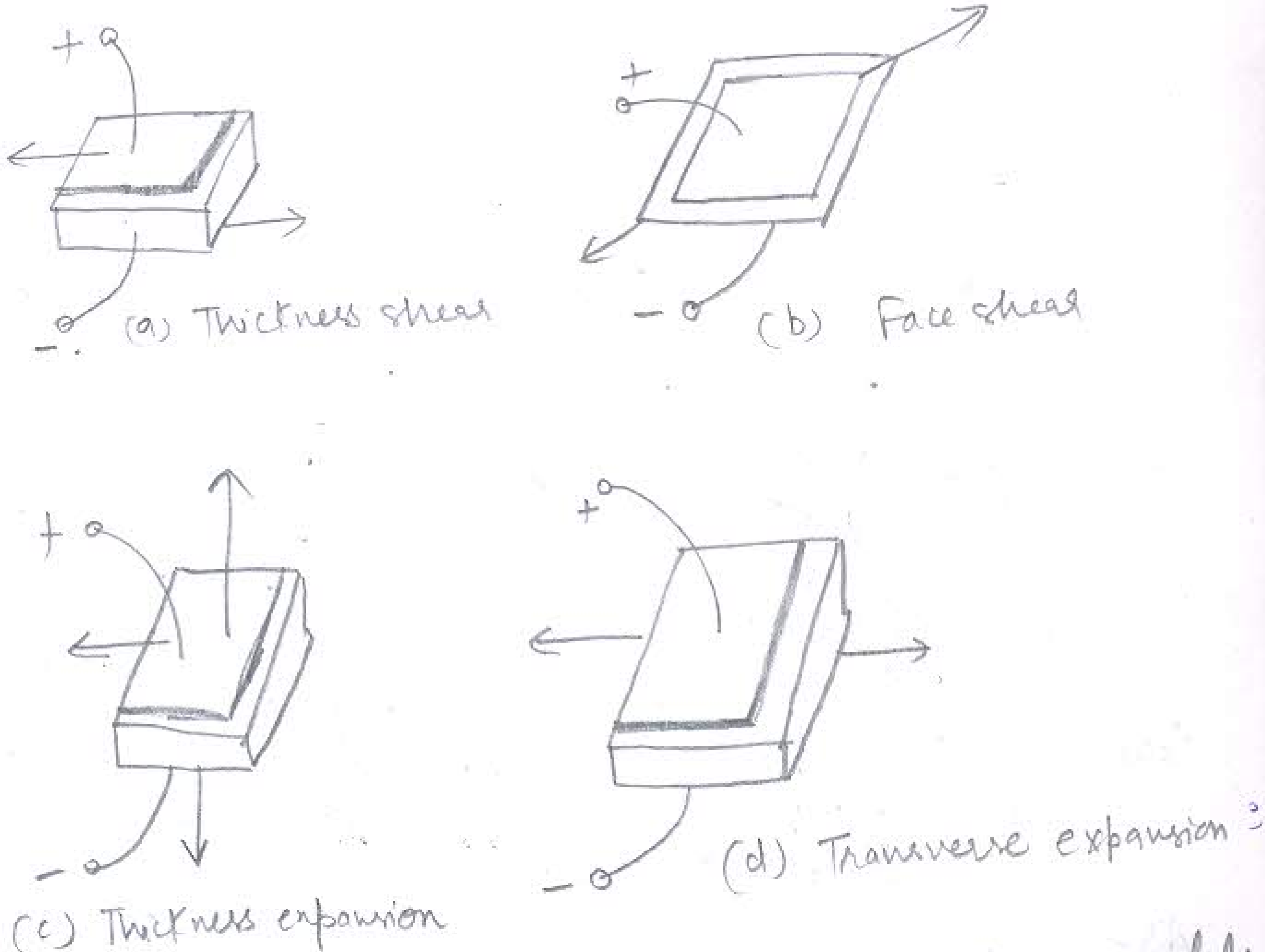
Common piezo-electric materials include Rochelle salts, ammonium dihydrogen phosphate, lithium sulphate, dipotassium tartrate, potassium dihydrogen phosphate, quartz, ceremics A & B.

The piezoelectric crystals are used in many modes. These modes are

(i) Thickness shear (ii) Face shear

(iii) thickness expansion

(iv) Transverse expansion



Modes of operation of piezo-electric crystals

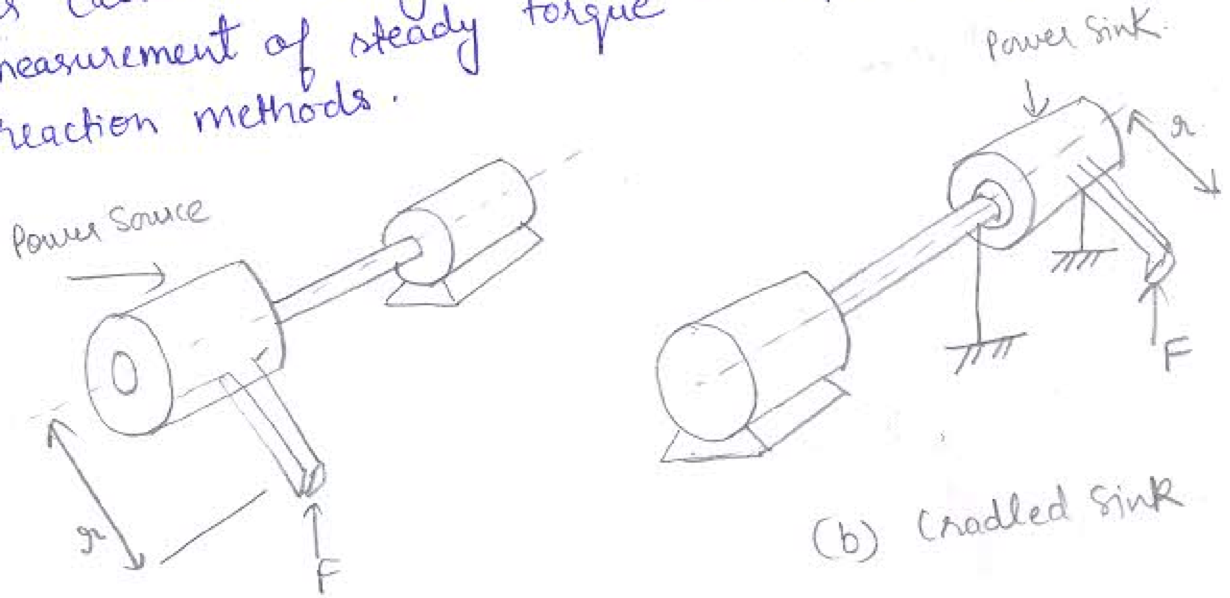
Section-C

C. Attempt all the parts (2×7.5=15)

Q11- Explain various methods for torque measurement of rotating shaft.

Ans- There are two methods for torque measurement-
(i) Torque reaction methods
(ii) Torque measuring methods using sensors

(i) Torque Reaction Methods → Torque measurements are done by mounting either the source or the sink in trunnion bearings as shown in fig. This concept of mounting sources or sinks in trunnion bearings is called cradling and forms the basis of measurement of steady torque and power by torque reaction methods.

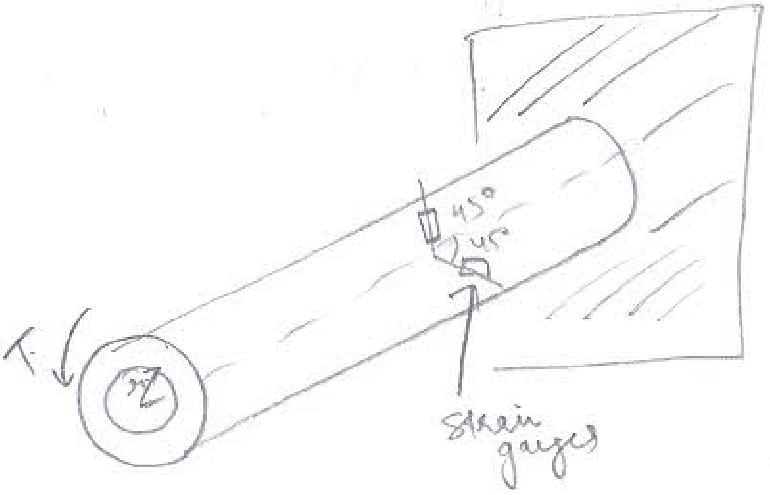


(a) Cradled Source (b) Cradled Sink

(ii) Torque Measuring methods using Sensors

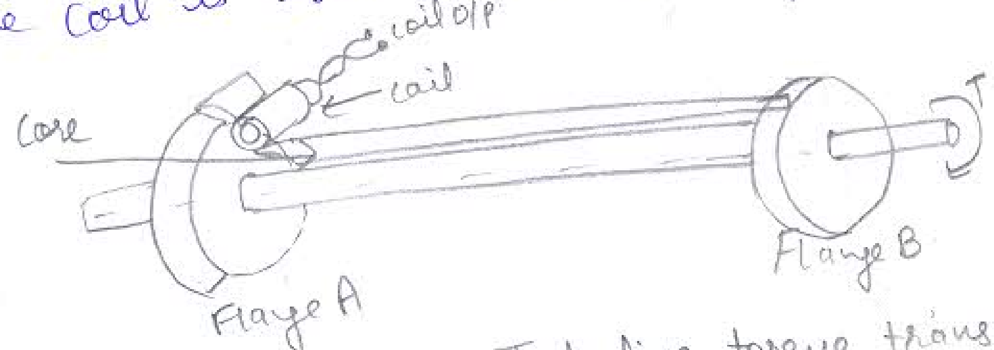
(a) Using Strain Gauges → The principle of this method is explained by Fig given below. Two strain gauges are mounted on a shaft at an angle of 45° to each other. The torque is given by

$$T = \frac{\pi G (R^4 - r^4)\theta}{2L}$$



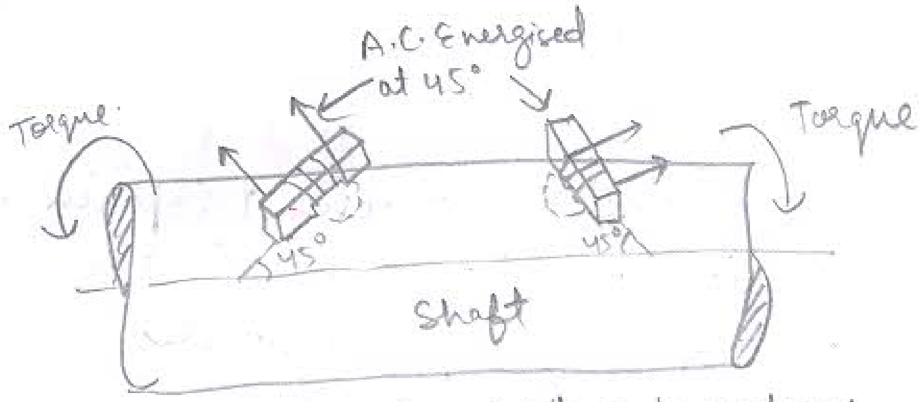
measurement of torque in hollow shaft

(2) Inductive Torque Transducer → In this Flange A carries a coil & flange B, an iron core. This core moves in and out of the coil according to relative displacement of the two flanges. Therefore inductance of the coil is altered on account of relative displacement. The coil is used as an arm of an a.c. bridge.



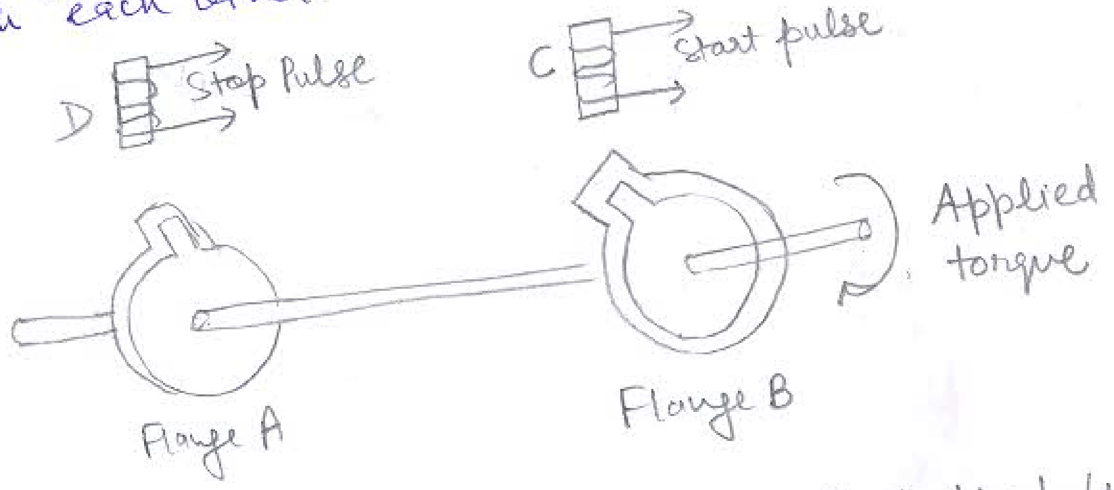
Inductive torque transducer

(3) Magnetostrictive Transducer → The action of Magnetostrictive transducers depends upon the change which occurs in the permeability of magnetic materials when they are subjected to strain. The permeability decreases with positive strain & increases with negative strain.



Magneto-strictive transducer

(4) Digital Methods → Digital timing techniques can also be used for determination of relative displacement between two flanges A & B. Suppose the flanges are made in the form of single toothed wheels as shown in fig. The teeth produce voltage pulses in inductive pick offs C & D. When no torque is applied to the shaft, the teeth are perfectly aligned & hence the voltage pulses produced in C & D are in phase with each other.



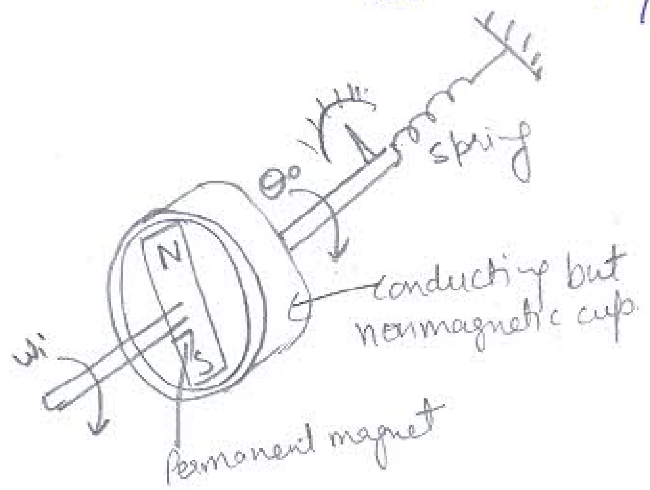
Torque transducer using single toothed flanges

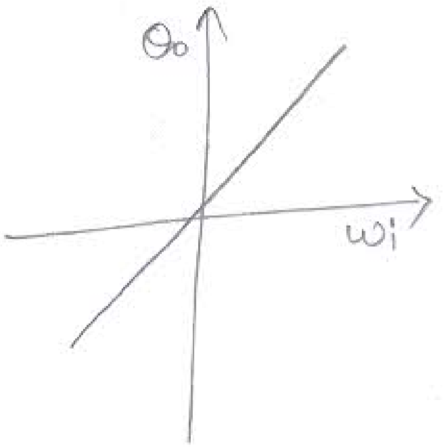
Q-12- What for Tachometer are used ? Explain the following Tachometer with neat Diagram

(i) Eddy Current drag Cup tachometer

Ans - Following figure shows schematically an eddy Current drag Cup tachometer. Rotation of the magnet induces voltages into the cup which thereby produce circulating eddy currents in the cup material. These eddy Currents interact with the magnetic field, to produce a torque on the cup in proportional to the relative velocity of magnet & cup. This causes the cup to turn through an angle θ_o, until the linear spring torque just ballances the magnetic torque.

$$\frac{\theta_o}{\omega_i}(D) = \frac{K}{D^2/\omega_n^2 + 2\xi D/\omega_n + 1}$$





Drag cup velocity pickup

(ii) Mechanical fly ball angular velocity sensor

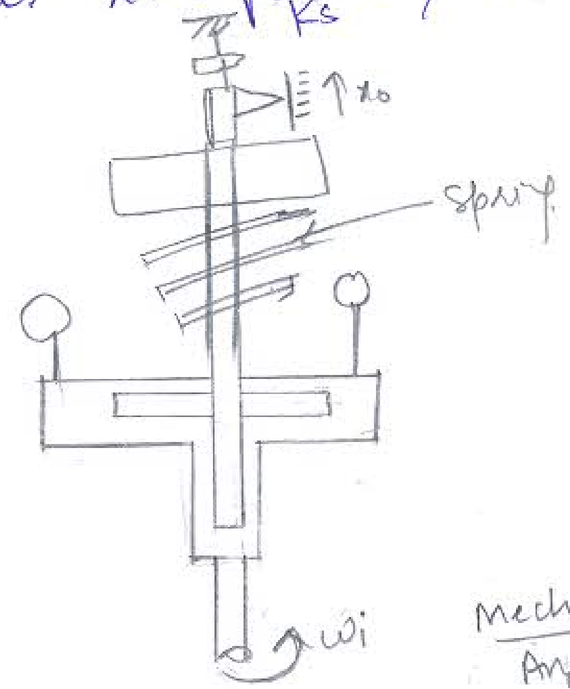
Following figure shows the general arrangement schematically. Since the centrifugal force varies as the square of input velocity ω_i, the output x_o will not vary linearly with speed if an ordinary linear spring is used.

$$\frac{x_o}{\omega_i}(D) = \frac{K}{D^2/\omega_n^2 + 2\xi D/\omega_n + 1}$$

Centrifugal force = spring force.

$$F_c = K_c \omega_i^2 = F_{spring} = K_s x_o^2$$

& thus $x_o = \sqrt{\frac{K_c}{K_s}\omega_i^2}$, a linear relationship.

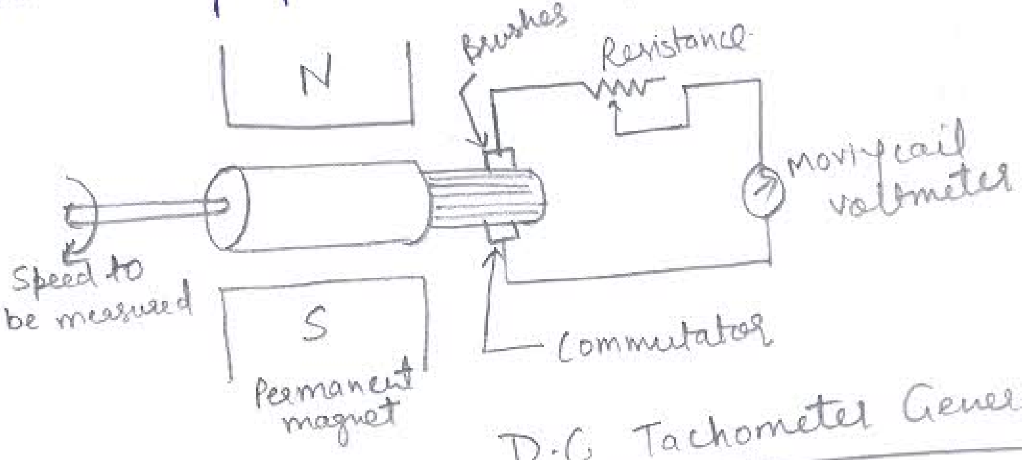


Mechanical flyball Angular velocity sensor

(iii) AC & DC Tachometer

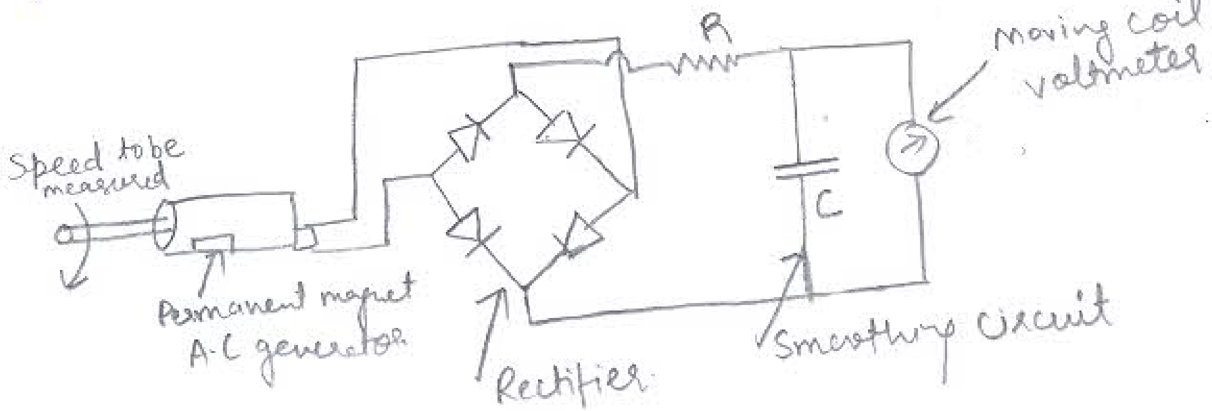
DC Tachometer → DC tachometer generator consist of a small armature which is coupled to the machine whose speed is to be measured.

This armature revolves in the field of permanent magnet. The emf generated is proportional to the product of flux and speed. Since the flux of the permanent magnet is constant, the voltage generated is proportional to speed.



D.C Tachometer Generator

A.C Tachometer Generator → In order to overcome some of the difficulties mentioned above, a.c tachometer generators are used. The tachometer generator has rotating magnets which may be either a permanent magnet or an electromagnet.



A.C. Tachometer Generator