ENSC 387 – INTRODUCTION TO ELECTROMECHANICAL SENSORS AND ACTUATORS
QUIZ 2 – OCTOBER 16, 2014
TIME: 60 MINUTES - THE QUIZ IS CLOSED BOOK.

NAME: ..... STUDENT ID: .....

1- Answer the following questions briefly.

a. Define **Variable Reluctance Transducers**:

Variable inductance transducers that use a nonmagnetized ferromagnetic medium to alter the reluctance (magnetic resistance) of the magnetic flux path.

b. What is the main difference between Eddy Current and Variable Inductance proximity sensors in applications?

For eddy current proximity sensor the object can just have a conductor plate, while for the other one, the object should be from a ferromagnetic material.

c. What is the main reason of using semi-conductor strain gages rather than usual foil type strain gages?

For measuring very low strains, as they have very high sensitivity (gage factor).

d. What is the main disadvantage in using motor current sensing for torque measurement?

Motor torque is not exactly load transmitted torque, which we are measuring.

It also includes, rotor inertia and friction torques.

e. What is **Seebeck Effect**?

When temperature change at the junction formed by 2 unlike conductors, electron configuration

Changes due to heat transfer, which results in producing voltage.

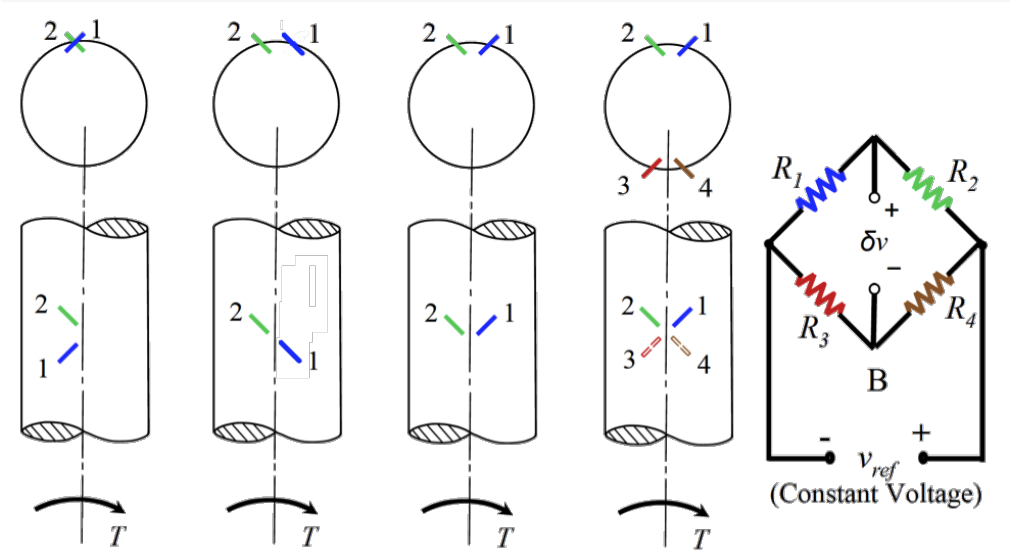
2- Which one of the followings is **NOT** a feature of LVDT?

a) Low mechanical wear
b) Low electrical loading
✓c) High output impedance
d) Fine resolutions available

3- Which one of the followings is **NOT** a feature of the piezoelectric sensors?

a) Light weight
b) Wide useful frequency range
b) High electrical loading
✓d) Low output impedance

4- In which of the following strain gage bridge configurations for torque measurement, axial or bending compensation is not happening?



(a) ✓ (b) (c) (d)

5- Which one is **NOT** correct?

a. ✓ Helical Tube is working based on balancing the pressure with an opposing force.

b. Bellows is working based on subjecting the pressure to a flexible front-end member and measuring the resulting deflection.

c. Diaphragm is working based on subjecting the pressure to a front-end auxiliary member and measuring the strain.

d. Pitot tube is working based on measuring the pressure, which brings the flow a static condition.

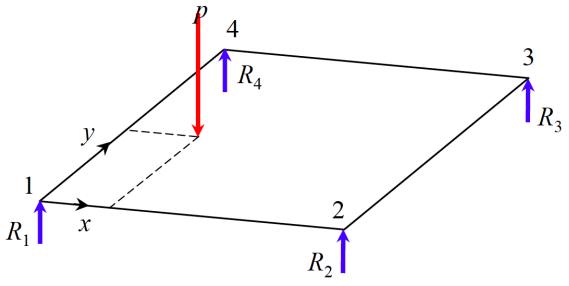
6- Assume that we have a strain gage tactile sensor. Tactile force P results in readings of $R_1 = R_2 = 10$, and $R_3 = R_4 = 5$, from the load cells. Assuming the square side is 30 mm, find the amplitude and position of P.

a) 15 , (15,10)

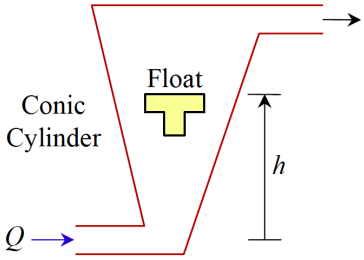
b) 15 , (10,15)

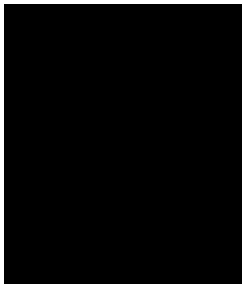
✓c) 30 , (15,10)

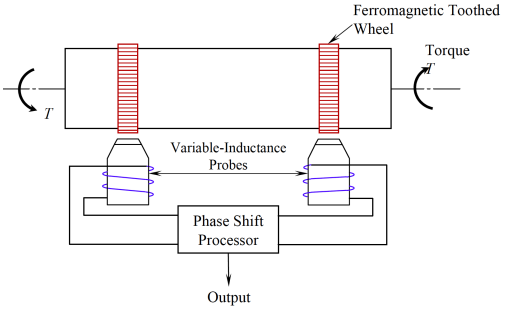
d) 30 , (10,15)



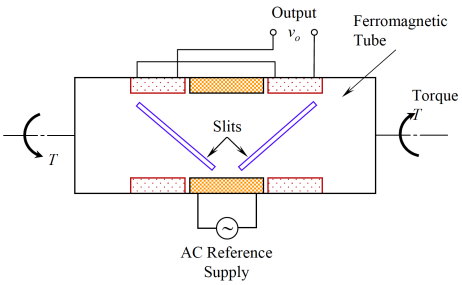
7- Write down the **complete** names of the following transducers.

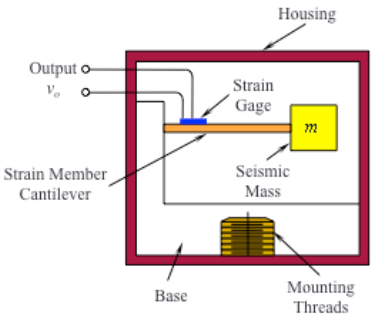




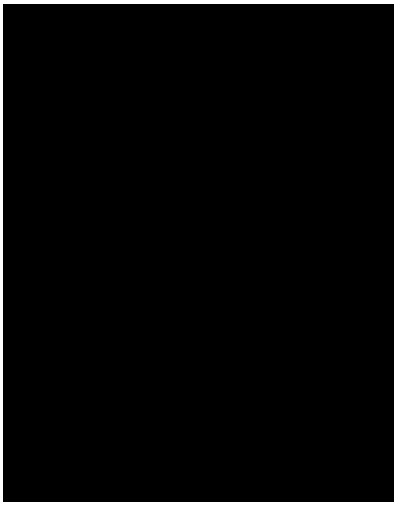


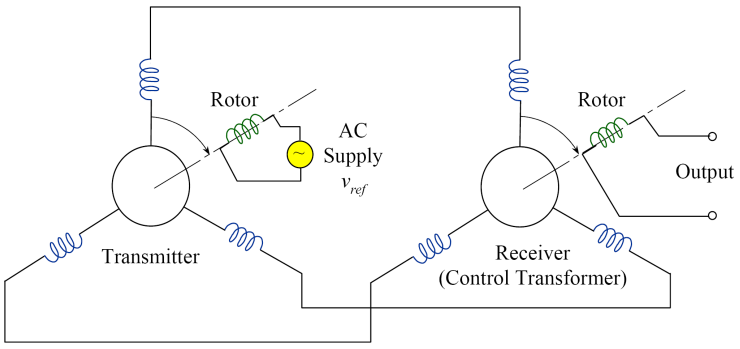
....Rotameter..... ..Bourdon tube.... Direct deflection torque sensor





Variable reluctance torque sensor .....Strain gage accelerometer.....





.....RVDT..... .....Synchro Transformer.....

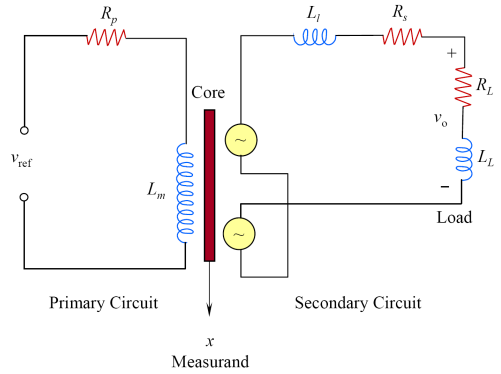
8- In the LVDT figure shown below, assume that the secondary circuit leakage inductance and the load inductances are zero. Assuming that the net secondary circuit voltage v_s equal to $v_p K x$, where v_p is the primary circuit voltage across L_p, K is a constant value, and x is the measurand, what is the phase shift between output voltage v_o and the reference voltage v_{ref}? Note that ω is the frequency of the reference voltage.

a) 90^o

b) $90^o + tg^{-1}\frac{\omega L_p}{R_p}$

✓ c) $90^o - tg^{-1}\frac{\omega L_p}{R_p}$

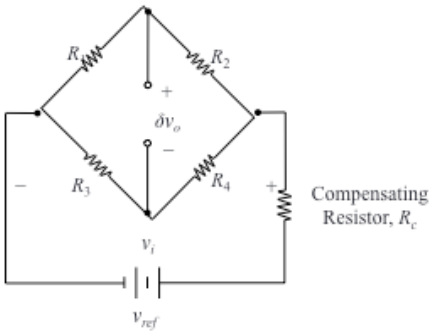
d) 0^o



9- In the ideal strain gage bridge with 4 active gages the relationship between bridge input and output voltages is $\frac{\delta v_o}{v_{ref}} = \frac{KS_s}{4}\epsilon$. Consider the following bridge with the compensating resistor R_c. If bridge resistors and S_s are changing with temperature as $R = 0.1\times(1 + 0.01.\Delta T)$ and $S_s = 100\times(1 - 0.005.\Delta T)$, find the value of R_c such that the output is not affected by temperature changes. You can ignore the terms than contains ΔT^2.

✓a) 0.1 Ω b) 1Ω

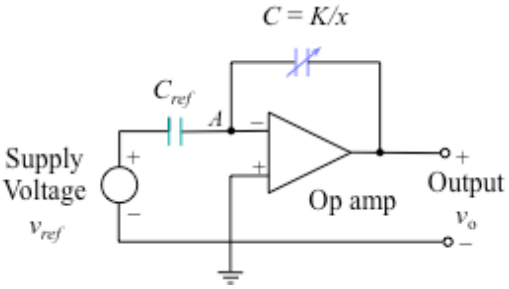
c) 10Ω d) 100Ω



10- In the linear charge amplifier shown below, assume that $C_{ref} = 1\ \mu F$, $x = 1\ cm$, $V_{ref} = 10\ V$, and $K = 4\times10^{-6}\ F.cm$. What is the value of output voltage V_o? Assume the Op amp is ideal.

a) 2.5 V ✓b) -2.5 V

c) 0.5 V d) -0.5 V



ENSC 387 – INTRODUCTION TO ELECTROMECHANICAL SENSORS AND ACTUATORS
QUIZ 3 – OCTOBER 30, 2014
TIME: 60 MINUTES - THE QUIZ IS CLOSED BOOK.

NAME: ..... STUDENT ID: .....

1- Answer the following questions briefly.

a. Name **four** advantages of using digital signals instead of analog signals.

Digital signals are less prone to noise and disturbances.

Complex signal processing with high speed & accuracy is possible.

They will increase the reliability of the system.

They enable storage of large amount of data, easily.

Fast data transmission with no attenuation is possible.

Overall, they have lower costs.

b. Name the **two** main types of shaft encoders.

Absolute encoders / Incremental Encoders

Note that optical, sliding contact, magnetic, and proximity-based systems are different SIGNAL GENERATION methods for encoders. They ARE NOT specific encoder types.

c. What is the advantage of using **Gray code** instead of binary code?

Each transition in Gray Code involves one bit switch; hence, less prone to errors.

d. What is **eccentricity**?

Distance between center of rotation of the track and the geometric center of the circular code track.

Note that eccentricity error is the error that arises because of the existence of eccentricity.

e. Describe how we can find the direction of rotation with checking the edges of the encoder pulses?

Check the edge of v_1 when v_2 is high. Rising edge in v_1 when v_2 is high, means CW rotation, while falling edge in v_1 when v_2 is high means CCW rotation.

2- Which one of the following configurations has the disadvantages of friction and wear?

a) Optical encoder ✔b) Sliding contact encoder

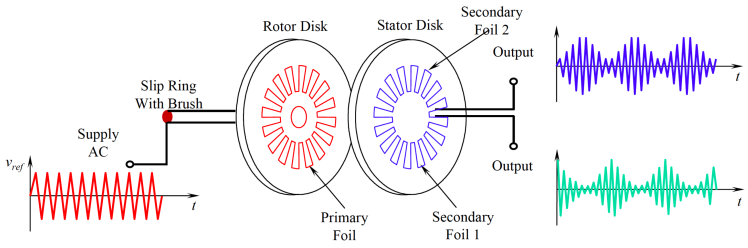
c) Magnetic encoder d) Proximity based encoder

3- What is the physical resolution of an optical encoder that has **N** number of bits and **r** number of bits in the output register, and also both quadrature signals and rising and falling edges are being considered for measurement?

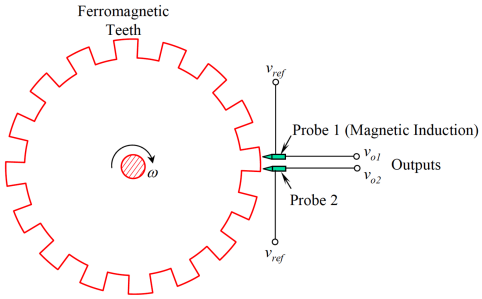
a) $\frac{360}{2^{r-1}}$ b) $\frac{180}{2^{r-1}}$

b) $\frac{360}{N}$ ✔d) $\frac{360}{4N}$

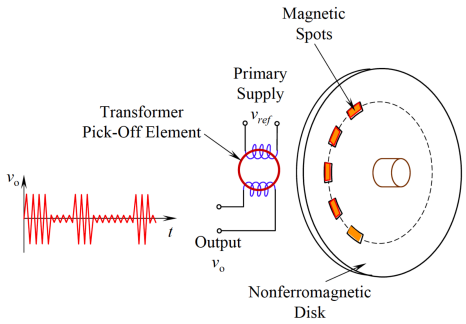
4- Write down the **complete** names of the following transducers.



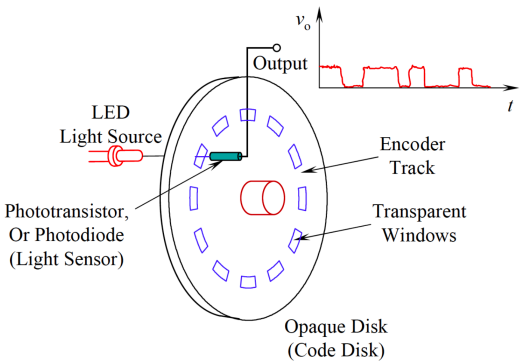
.....Digital Resolver.....



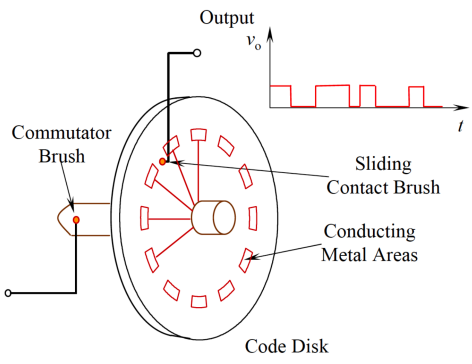
.....Digital Tachometer.....



.....Magnetic Encoder.....



.....Optical Encoder.....



.....Sliding Contact Encoder.....

5- Assume v_1 and v_2 are the two output pulses of an optical encoder. Also, assume that we are timing the pulses with a high frequency clock signal. Suppose that the time starts when v_1 starts to rise. If n_1 is defined as the number of cycles until v_2 rises, and n_2 is the number of cycles until v_1 rises again, what can be inferred if $n_1 < n_2 - n_1$?

a) CW rotation b) CCW rotation

✔c) No information can be inferred for the direction of rotation.

Note that the rotation direction depends on the position of the sensors (i.e., which one is leading the other one).

6- Suppose that an incremental encoder has 900 windows on code disk, as well as 10 bits of output word size. What is the final resolution of the encoder if quadrature signals are used and both falling and rising edges are considered?

a) 0.1^{o} ✔b) 0.35^{o}

c) 0.17^{o} d) 0.4^{o}

7- What is the minimum number of tracks, and number of output word size for an absolute encoder, if the desired resolution is 0.1^{o} ?

a) 11 , 11 b) 11 , 12

✔c) 12 , 12 d) 12 , 13

Note that for the absolute encoder, as you have a code for each position in the revolution, you do need more bits than the tracks number.

8- Assume the shaft, track, and assembly eccentricities mean and standard deviation as (0.1, 0.002), (0.2, 0.004), and (0.2, 0.004), respectively. All the data points are in millimeter. Estimate the overall eccentricity at a confidence level of 90%.

a) 0.3 mm b) 0.306 mm

✔c) 0.312 mm d) 0.318 mm

ENSC 387 – INTRODUCTION TO ELECTROMECHANICAL SENSORS AND ACTUATORS
QUIZ 4 – NOVEMBER 13, 2014
TIME: 45 MINUTES - THE QUIZ IS CLOSED BOOK.

NAME: ..... STUDENT ID: .....

1- Answer the following questions briefly.

a. What is **Ampere's Law**?

$\sum i = \oint H \cdot dl$ The magnetic field intensity around a closed counter C_1 is equal to the total current passing through any surface S linking that Counter.

b. What is the **Lorentz Force**?

When a current carrying conductor is placed in a magnetic field, it is subjected to a force called Lorentz Force.

c. What is the most common method to decrease the eddy current loss in magnetic system cores?

Using Laminated Core sheets.

d. What are the main **three** types of stepper motors?

Variable Reluctance (VR)
Permanent Magnet (PM)
Hybrid (HB)

e. What is the main draw back of the microstepping technique?

Reduction of Motor Torque

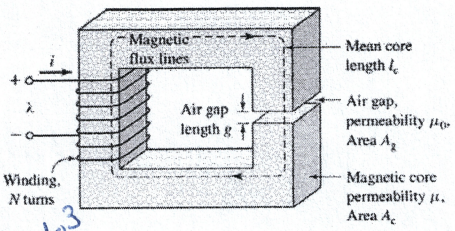
f. What is the **detent position** of stepper motors?

Stable equilbrium position at each step.

g. What is the description of **Unifilar Windings**?

Only 1 set of winding per group of stator poles.

2- In the magnetic circuit shown below, assume that *air gap length*, $l = 1\ cm$, *air gap area*, $A_g = 1\ cm^2$, and *magnetic flux density in the air gap*, $B_g = 1\ Tesla$. What is the value of input current i, if the coil has 100 turns? Neglect the iron reluctance.



a) $250\pi\ A$ b) $\frac{250}{\pi}\ A$

c) $25000\pi\ A$ d) $\frac{25000}{\pi}\ A$

$N i = \mathcal{R}_g \Phi_g = \frac{l_g}{\mu_0 A_g} \cdot B_g A_g \rightarrow 100\, i = \frac{10^{-2} \times 1}{4\pi \times 10^{-7}} \rightarrow i = \frac{10^3}{4\pi}$

3- In question 2, what would be the self-inductance of the windings?

a) $4\pi \times 10^{-5}$ b) $4 \times \frac{10^{-5}}{\pi}$

b) $\pi \times 10^{-5}$ d) $\frac{10^{-5}}{\pi}$

$L = \frac{N^2}{\mathcal{R}} = \frac{N^2}{\frac{l_g}{\mu_0 A_g}} = \frac{N^2 \mu_0 A_g}{l_g} = 4\pi \times 10^{-7}$

$L = \frac{N\Phi}{i} = \frac{N B_g A_g}{i}$

4- Calculate the mutual inductance between two toroidal windings which are closely wound of an iron core of $\mu_r = 1000$. This means radius of the toroid is 8cm and the radius of its cross section is 1cm. Each winding has 2000 turns.

a) $0.1\pi\ H$ b) $0.5\pi\ H$

c) $5\pi\ H$ d) $\pi\ H$

$Area = \pi \times 1\ cm^2 = 10^{-4}\pi\ m^2$

$M = \frac{N_1 N_2}{\mathcal{R}} = \frac{4\pi \times 10^{-7} \times \pi \times 10^{-4} \times 2000^2 \times 1000}{16\pi \times 10^{-2}} = \pi$

$l = \pi \times 16\ cm$

5- A coil with 100 turns is placed in a magnetic field density of 1 *Tesla*. If the cress section area of the coil is 1 cm^2, find average induced emf if the coil is moved in 0.1 second from the given field density to a field of 2 *Tesla*.

a) 0.1 *V* b) 1 *V*

c) 100 *V* d) 1000 *V*

$e = N \frac{d\Phi}{dt}$

$\rightarrow e = N \frac{d BA}{dt} = NA \frac{dB}{dt} = 100 \times 10^{-4} \times \frac{2-1}{0.1} = 0.1$

6- In a stepper motor with toothed-pole configuration, assume the stator teeth equal to 48, and rotor teeth number equal to 50. If the number of stator phases is 4, and the number of poles per phase is 2, what is the resolution of the motor step size?

$n_s = 48,\ n_r = 50,\ m = 2,\ p = 4$

a) 0.75^o b) 7.5^o

c) 3.25^o d) 1.8^o

$\rightarrow \theta_r = 7.2,\ \theta_s = 7.5$

$\rightarrow \Delta\theta = \frac{n_s}{mp}(\theta_r - \theta_s) = 1.8^\circ$

7- The energy loss caused by hysteresis in a magnetic core is 1000 W per unit volume. Assume that the hysteresis area of B-H curve is 10 cm^2 and the scales are as 1 cm = 1 At/m, and 1 cm = 1 Wb/m^2. What is the frequency of excitation?

a) 1 *Hz* b) 10 *Hz*

c) 100 *Hz* d) Given information is not enough.

$W_h = 10 \times 1 \times 1 = 10$

$P_h = f W_h \rightarrow 100 = f \cdot 10$

$\rightarrow f = 10$

The correct answer 2/2

ENSC 387 – INTRODUCTION TO ELECTROMECHANICAL SENSORS AND ACTUATORS
QUIZ 5 – NOVEMBER 27, 2014
TIME: 30 MINUTES - THE QUIZ IS CLOSED BOOK.

NAME: ..... STUDENT ID: .....

1- Answer the following questions briefly.

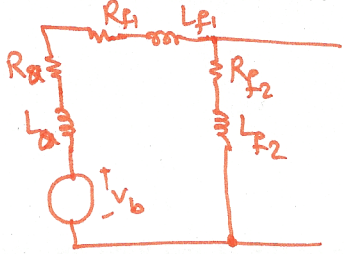
a. Name **two** methods of increasing the DC motor's torque?

Increase the number of turns per each armature windings
Increase number of coils in armature
Use Electromagnets to produce stronger stator field.

b. Name **four** of main problems with brushed DC motors?

Mechanical loading
Rapid wear out
Heating
Contact Bounce
Noise
Oxidation

c. Draw the electrical connections of the compound-wound DC motor?

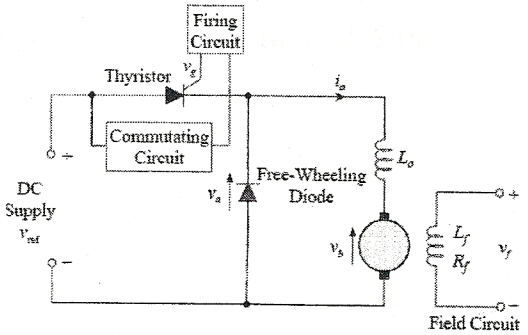


d. Describe why in Armature control model of the DC motor we can neglect the electrical time constant with respect to the mechanical time constant, but in Field control model we are not usually doing that?

In armature Control we can neglect its small leakage inductance, so the τ_e is very small compared to τ_m.
But the field inductance is Large and so τ_e cannot be easily neglected

e. What is the purpose of the free-wheeling diode in the following circuit?

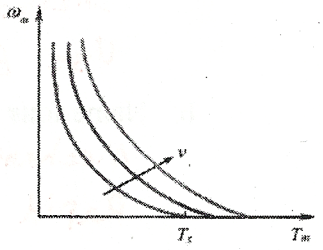
When switch is off, inductor current will be discharged through diode, to avoid Large voltage buildup in armature.



2- Which one has the **best** speed controllability?

a) Series-wound DC motor
b) Shunt-wound DC motor
c) Compound-wound DC motor
d) All are the same.

3- Which one of the followings has the speed-torque characteristics as shown?



a) Series-wound DC motor
b) Shunt-wound DC motor
c) Compound-wound DC motor
d) None of them are correct.

4- Which of the following parts of PID is mainly responsible for reduce steady state error (usually makes it zero) while degrading stability and speed?

a) P
b) I
c) D
d) None of them are correct.

5- A series connected DC motor has an armature resistance of 0.5 Ω and field resistance of 1.5 Ω. In driving a certain load at 1200 rpm, the current drawn by motor is 20 A from a 220 V power supply. The rotational losses are 150 W. Find the output power of the motor.

a) 3600 W
b) 4400 W
c) 3450 W
d) 4250 W

$P_{in} = V_T I_a = 220 \times 20 = 4400\ W$

$v_b = V_T - (R_a + R_f) I_a = 180\ V$

$P_{dev} = v_b I_a = 3600\ W \rightarrow P_{out} = P_{dev} - P_{rot}$

6- A DC shunt-wound motor delivers power to a load at 1200 rpm. If the developed power at rotor is 3800 W and the rotational losses are 300 W, what is the value of output torque?

a) $87.5\pi\ N.m$
b) $\frac{87.5}{\pi}\ N.m$
c) $2.91\ N.m$
d) $0.097\pi\ N.m$

$P_{out} = P_{dev} - P_{rot} = 3800 - 300 = 3500\ W$

$T_m = \frac{P_{out}}{\omega_m}$, $\omega_m = \frac{2\pi}{60} \times 1200$ $\rightarrow T_m = \frac{3500 \times 60}{2\pi \times 1200} = \frac{87.5}{\pi}\ N.m$