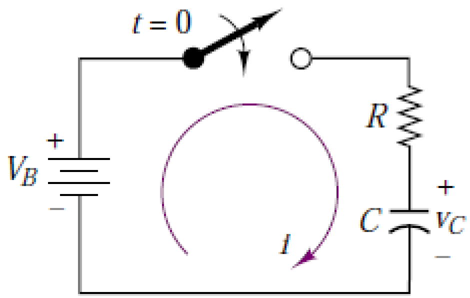
Question 1 (first order dynamics)

An capacitor C=1mF is used to store energy in a camera flash light.
A 6V battery is used to slowly charged up the capacitor (initially discharded, at time t=0) via a resistor R=1kΩ.



i. Write the equation of the electrical circuit in terms of Vc, the voltage across the capacitor.

ii. Determine the time constant of the circuit

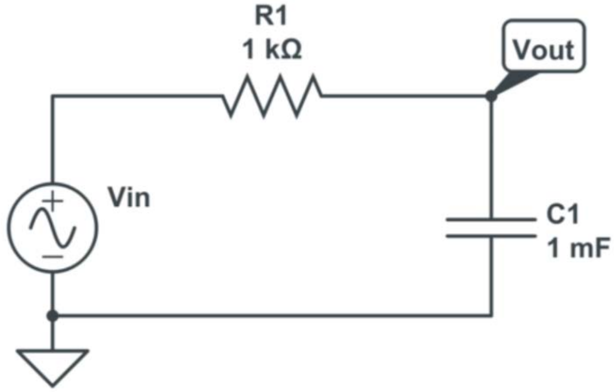
iii. Determine the response Vc(t) for t>0

iv. Use a software tool of your choice (e.g. type a function such as “t*sin(t)” in google) to plot the function

v. Determine the maximum energy stored in the capacitor (i.e. when fully charged)

vi. Determine the time required for the energy stored in the capacitor to reach 90% of its maximum,

Question 2 (1st order frequency response)
For the same RC circuit, consider now a sinusoidal input Vin



https://www.circuitlab.com/circuit/53fg86/rc/

i. Determine the AC steady-state solution Vout(t),i.e. a sinusoidal solution Vout(t) = A cos(ωt+ϕ), for any sinusoidal input Vin(t) = cos(ωt)

ii. Determine the frequency response of the system **H = Vout / Vin**

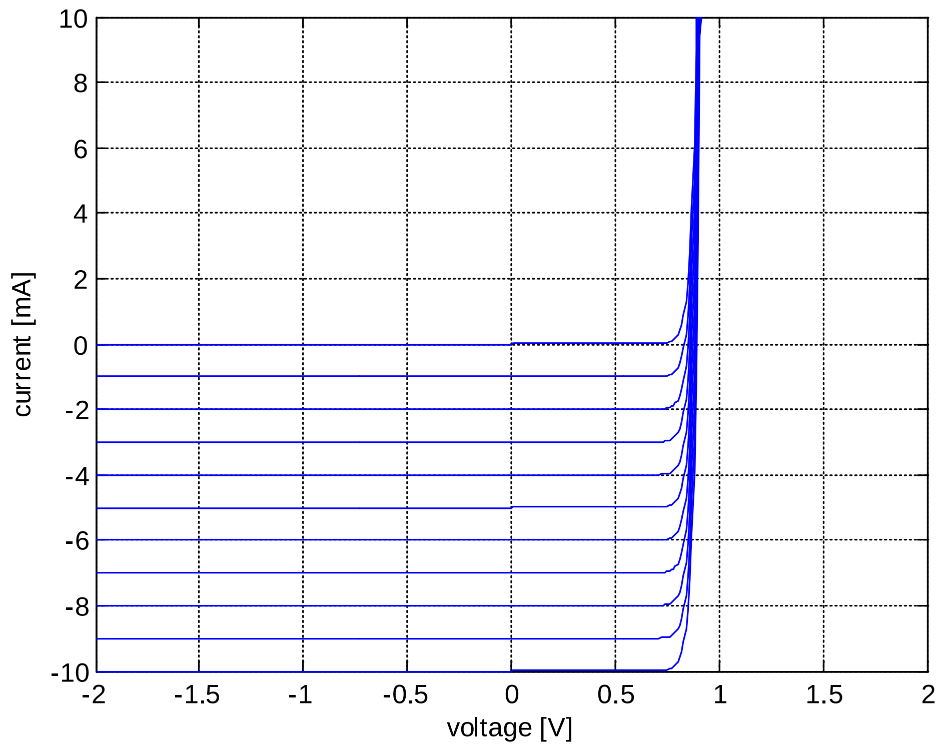
iii. Determine the cutoff frequency (i.e. the frequency at which |Vout| = |Vin|/ $\sqrt{2}$), what is tis relationship with the time constant computed in previous question?

iv. Plot the amplitude response (i.e. |Vout|/|Vin|) and the phase response (i.e. phase difference between Vout and Vin) for any radian frequency in the range 10mHz - 10Hz

Mechatronics - Part II - Tutorial 2

Question 1

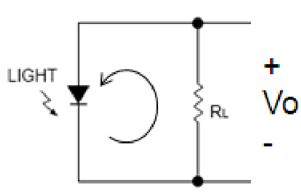
The following diagram shows the super-imposed IV (current-voltage) characteristics of a photodiode for linearly increasing light intensities (for higher intensities the characteristic shifts downwards; in the dark the photodiode behaves as a regular diode):



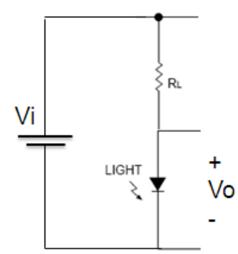
Determine the magnitude of the *short-circuit* current for all the light intensities in the diagram.

[0, 1, 2, … 10 mA]

Consider now the following two configurations:



a)



b)

For the configuration a), draw the load lines on the I-V diagram for two possible loads:

- RL = 100Ω
- RL = 200Ω

and determine, for RL=100Ω, the power *generated* by the photodiode when the light intensity is exactly in between the minimum (dark) and the maximum light conditions shown in the diagram.

[2.5mW]

For configuration b), determine a safe value for Vi to guarantee linearity of Vo with respect to the light intensity.

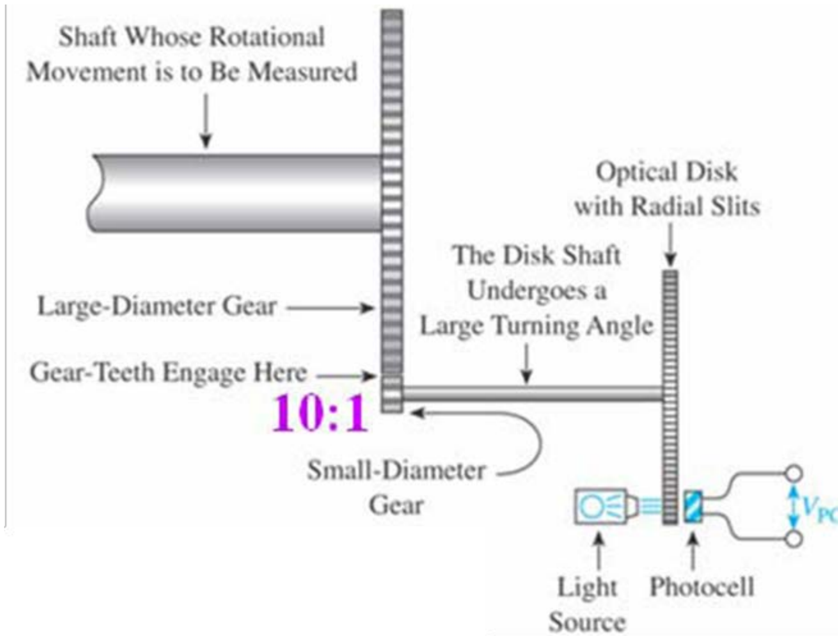
[Vi = -1.5V]

Question 2

A thermistor is placed in a 100°C environment, and its resistance measured as 20,000 Ω. The material constant, β, for this thermistor is 3650 K. If the thermistor is then used to measure a particular temperature, and its resistance is measured as 500 Ω, determine the thermistor temperature.

(325.9 °C)

Question 3



An optical shaft-encoder has a gear ratio of 10:1 and 180 slits on its disk.

a) How far must the measured shaft move in order to increment the counter by 1 bit?

b) What is the resolution of this transducer?

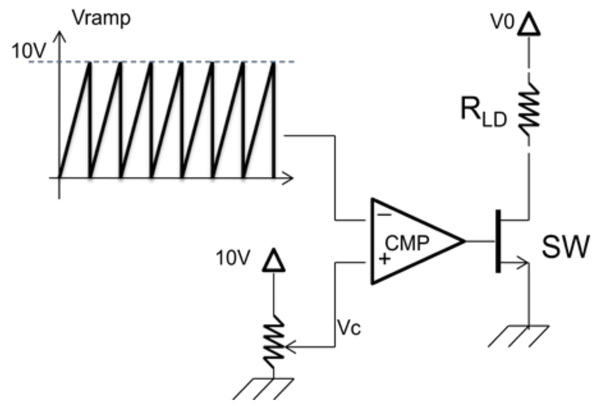
c) If the measured shaft moves positive 87.4°, what is the binary content of the counter? Assume 12-bit counter construction, with eleven magnitude bits and one sign bit.

d) What amount of movement will produce a binary content of 0011 0111 1010?

e) Specify direction and magnitude.

a) 0.2° ; b) 0.2° ; c) 0001.1011.0101 ; d) positive 178°

Question 1



Consider the circuit in figure. A resistive load R_{LD}=10Ω is connected to a high voltage supply (V0=100V) via an ideal switch (SW) which is turned on and off by a comparator (CMP). The two inputs of the comparator are fed with a saw-tooth waveform (Vramp) between 0 and 10V and with control-voltage (Vc) which can be manually set via a potentiometer.

Determine:

i. can we achieve maximum duty-cycle?

[Yes, we can!]

ii. maximum power into the load;

[1kW]

iii. the power into the load in the case Vc=4V;

[400W]

iv. what control voltage Vc should be set to double the power into the load?

[twice as much]

v. How would you generate a saw-tooth waveform?

Question 2

A permanent magnet DC motor (model 108-105 from Precision Microdrives, Inc.) has the following chartacteristics:

- nominal voltage: 3V
- no-load speed: 18108 rpm
- no-load current: 46mA
- stall torque: 0.7 mNm
- stall current: 422 mA

Determine:

i. the maximum mechanical power output;

[332 mW]

ii. the armature resistance;

[7.1Ω]

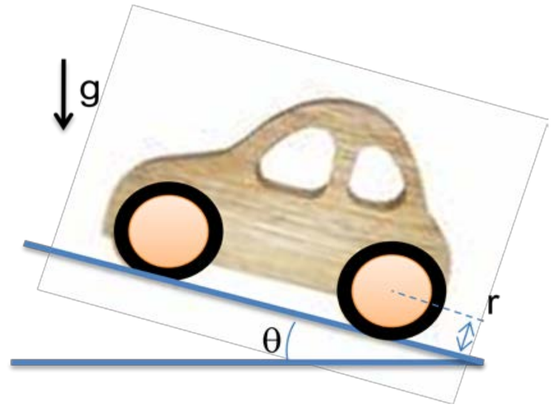
iii. the armature constant Ka;

[0.0017 Nm/A]

iv. If the measured maximum efficiency occurs for a load T=0.17 mNm, what is then such a value of efficiency?

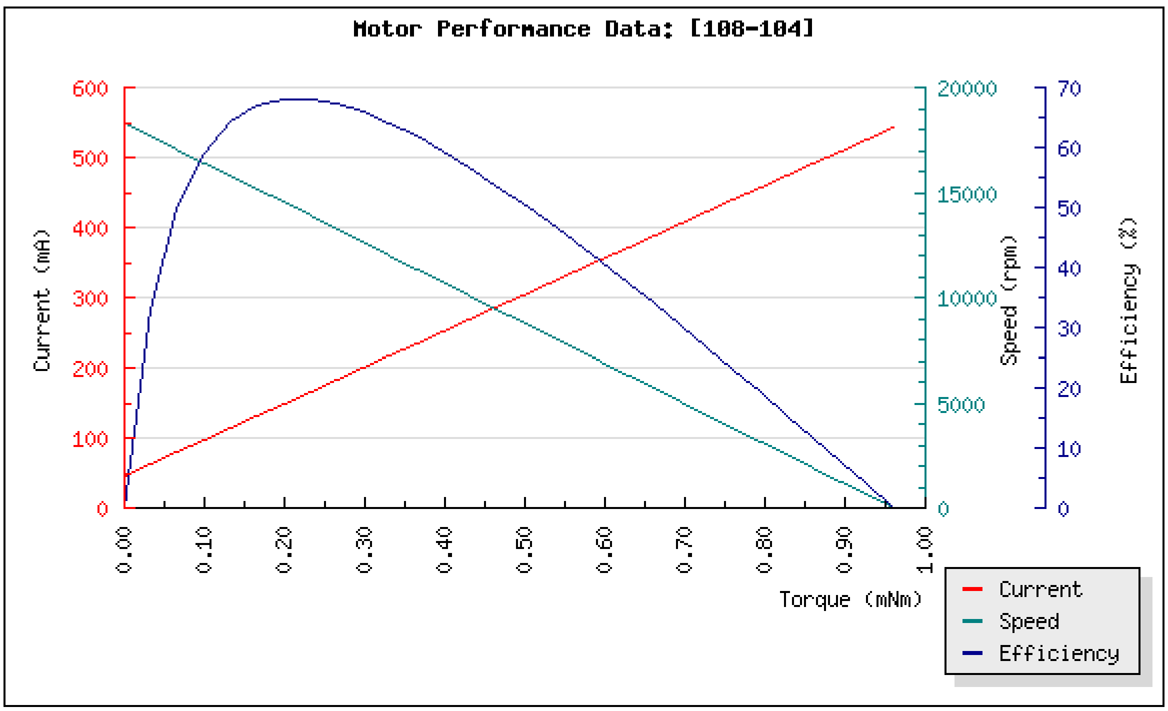
[59%]

Question 3



You should build a radio-controlled toy car, as in the figure. To make it steer, the easiest way is to use two motors directly mounted on the axes of the rear wheels (one per wheel).
The final estimated weight of the car is M=20g.
As a requirement, it should be able to run on a θ=30 degrees slope.

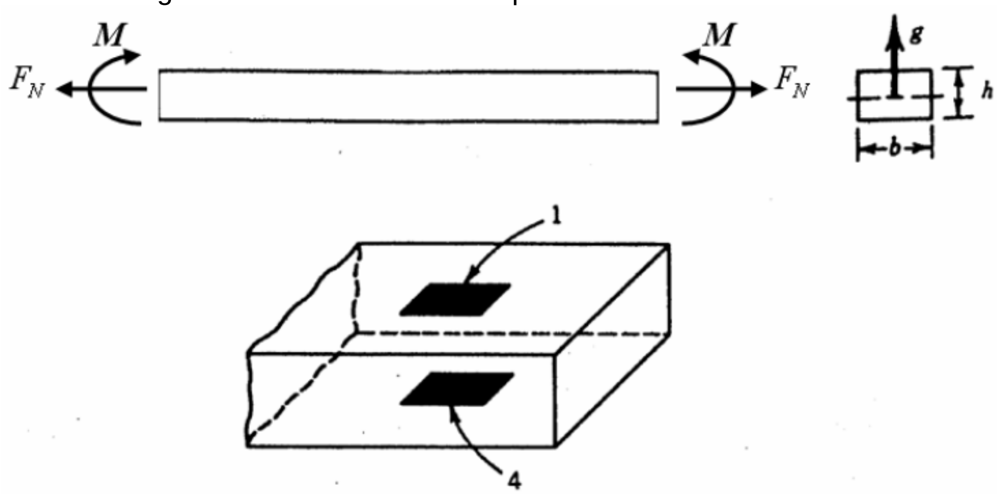
Neglecting friction, determine the radius of the wheels r that allows the car to move at maximum output power and the output linear speed when the motor has the following characteristics:



[r=9.4mm; v=8.86 m/s]

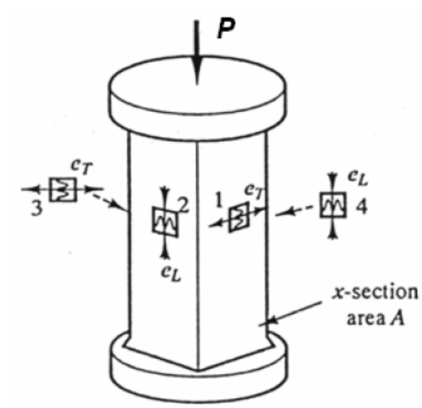
Question 1

Consider a structural member subject to loads that produce both axial and bending stresses as shown below. Two strain gauges are to be mounted on the member and connected in Wheatstone bridge in such a way that the bridge output indicates the axial component of strain only (the installation is bending compensated). Show that the installation of the gauges will not be sensitive to bending. Will it be sensitive to temperature?



Question 2

A load cell consists of a domed vertical steel cylinder 20 cm high and 15 cm in diameter. Four flat surfaces, at right angles to each other, are cut on the vertical surface so as to form 10 cm squares. Resistance strain gauges are attached to these flat surfaces so that two gauges (on opposite faces) suffer longitudinal compression and two gauges (on the other pair of opposite faces) suffer transverse tension. The strain gauges have the following specification:



Resistance = 100 Ω
Gauge factor = 2.1
Maximum gauge current = 30 mA

The gauges are connected in a temperature compensated bridge and the out-of-balance signal is input to a differential amplifier.

Determine the maximum input voltage supply to the bridge and the minimum amplifier gain if the amplifier output voltage is to be 1 V for a compressive force of 10^5 N

Young's modulus for steel = 210 GPa
Poisson's ratio for steel = 0.29

(6 V; 2584)

Question 3

In class, we have shown that for a rectangular conductor (length ‘L’, width ‘w’ and thickness ‘h’) the relative change of resistance (dR/R) is related to the strain S via the following equation:

$$\frac{dR}{R} = \left(\frac{d\rho}{\rho}\frac{1}{S} + 1 + 2\nu\right) S$$

where ρ is the resistivity and ν is the Poisson ratio.
Show that this relationship also holds conductors with circular cross-section.

Question 4

A young engineer, on his very first day of work, is asked to climb up a very tall mechanical structure and attach a constantan strain gauge (Rg, with nominal resistance R0=120Ω) somewhere on its top. Electrically, the strain gauge shall then be connected in one branch of a Wheatstone bridge with other three resistors (R1=R2=R3=120Ω) on the other legs. The bridge is initially balanced.
The strain gauge is subjected to a 100μS initial loading which causes unbalance. To regain balance, a resistor Rx=1MΩ is used in parallel to one of the regular resistors.

What is the effective gauge factor G* of the strain gauge?

(G*=1.2)

Considering that for constantan we would expect a gauge factor G=2.1, can you name a few possible causes for such a difference?