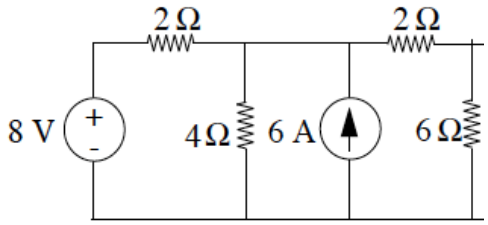
Final Exam (BMEN-321)

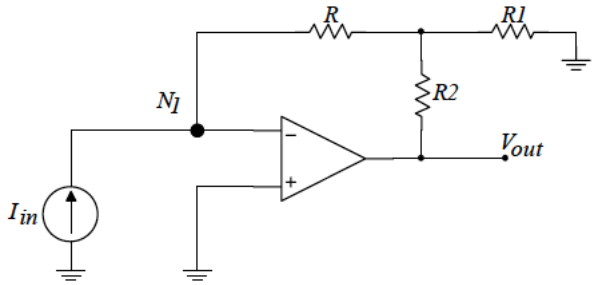
NOTES: 1) There are problems on BOTH the front and back pages of the exam. 2) You need to show ALL the work done and not just answers in order to get full credit.

1) Two batteries rated at 1 ampere-hour with a nominal voltage of 1.5 V are connected in series to supply energy to a flashlight. The flashlight lamp has a resistance of $5\ \Omega$. When the flashlight is on, the voltage across the lamp is 2.5 V. How many hours of use would the battery supply? (15 pts)

2) In the circuit below, determine the power dissipated by the 4 Ω resistor. (15 pts)



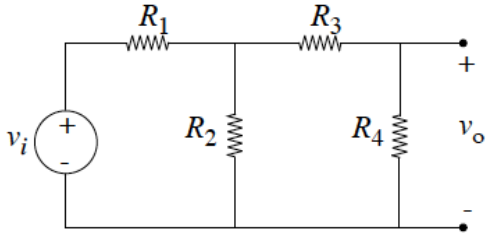
3) In the circuit below:



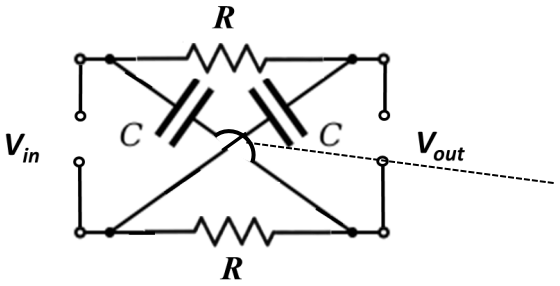
a) Derive the expression for the output voltage *Vout* in terms of the input current I_{in}. (10 pts)
b) Assuming that R=R1=R2=1000 ohms, and the power supplies of the op-amp at 10 V and -10V, sketch the output voltage if the input current is $I_{in}\ (t) = 4\cos(20\pi t)$ mA. (5 pts)

4) A transducer output signal has a bandwidth of 30 Hz and spans in the range of -200 to 200 mV.
a) Design a circuit that will condition the filtered signal, so that it can be applied to the input of an Analog-to-Digital Converter (ADC) that accepts voltage signals in the range of 0-5 V. Specify the value for each of the circuit components and voltage levels. (15 pts)
b) Select the sampling frequency of the ADC and the number of bits if you want an amplitude resolution of 5 mV. (5 pts)

5) Design a resistor attenuator to make $v_o = v_i/1000$ using the circuit configuration below. This problem is under-constrained and has many possible answers. (10 pts)



8) The circuit shown below is widely used in the design of audio equalizers. For the given circuit, derive the transfer function: $H(s) = \frac{V_{out}(s)}{V_{in}(s)}$ and plot the magnitude and the phase responses. (10 pts)



Wires **<u>do not</u>** touch each other here.

6) One of the most common industrial applications of strain gauges is in the design of a pillar load cell shown in the figure below (on the left). A pillar load cell consists of 4 strain gauges mounted on a metallic post, such that two strain gauges measure the longitudinal strain (strain gauges 2 and 4 in the figure below) and the remaining two strain gauges measure the transverse strain (strain gauges 1 and 3 in the figure below). To measure a force (*F*), the strain gauges are connected in a Wheatstone bridge configuration shown on the right in the figure below, where the strain gauges are represented as resistances (R_1 corresponds to strain gauge 1, R_2 corresponds to strain gauge 2; R_3 corresponds to strain gauge 3, and R_4 corresponds to strain gauge 4).

Assuming:

Unstrained resistance = R (for all strain gauges)
Gauge factor = G (for all strain gauges)
Cross-sectional area of the metallic post = A
Young's Modulus of the metallic post = Y
Poisson's ratio of the metallic post = ν
Input Voltage of the Wheatstone bridge = V_s

Obtain an expression for the applied force *F* in terms of the output voltage V_0 and the variables defined above. (15 pts)

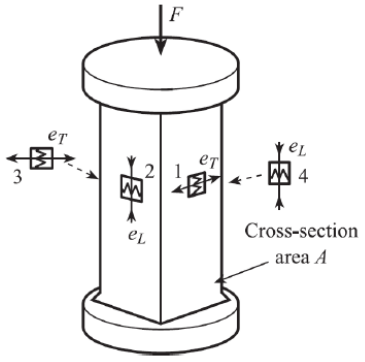
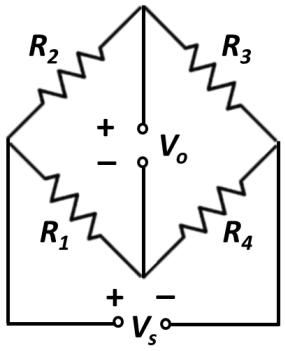


Figure Source: Bentley, 4e, Pearson



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