ECEG 350 **Electronics I** **Fall 2025**

Homework Assignment #4 – due via Moodle at 11:59 pm on Monday, Oct. 20, 2025

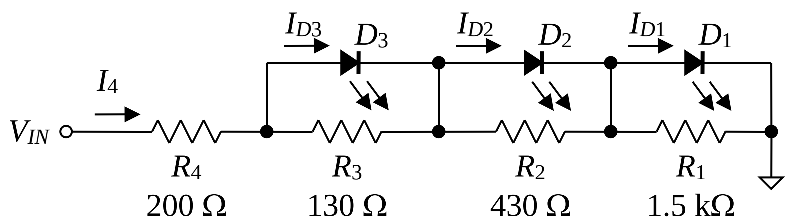
***Instructions, notes, and hints*:**

You may make reasonable assumptions and approximations to compensate for missing information, if any. Provide the details of all solutions, including important intermediate steps. You will not receive credit if you do not show your work.

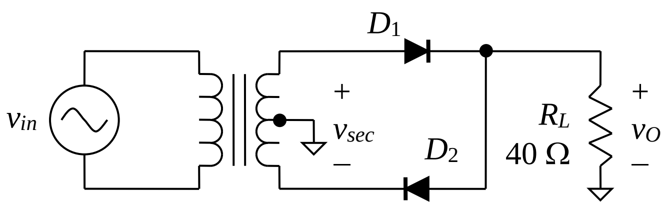
The first few problems will be graded and the rest will not be graded. Only the graded problems must be submitted by the deadline above. Do not submit the ungraded problems.

***Graded Problems*:**

1. The circuit shown below is a simple bar graph display that uses red LEDs. It acts like a crude voltage level indicator. As voltage V_{IN} rises from zero, first D_1 turns on, then D_2 at a higher voltage, and finally D_3 at a still higher voltage. Find the value of V_{IN} at which diode D_2 just starts to turn on (and at which D_1 is also on). Also find the diode current I_{D1} at that value of V_{IN}. Assume that the constant-voltage model applies to the diodes with V_F = 2.0 V.



2. As shown below, a manufacturing error has resulted in diode D_2 being installed backwards in a standard full-wave rectifier circuit. The transformer's secondary voltage has a value of 6.0 V rms and is split evenly between the upper and lower windings (i.e., 3.0 V rms per winding). The voltages across the upper and lower windings are in phase. The turn-on voltage of each diode is 1.0 V. Sketch or describe the resulting output waveform $v_O(t)$. If necessary, include a plot of $v_{sec}(t)$ above the v_O plot to provide reference points. Label all important voltage values on the sketch. Also explain why the error would very likely lead to the failure of one or more components in the circuit.



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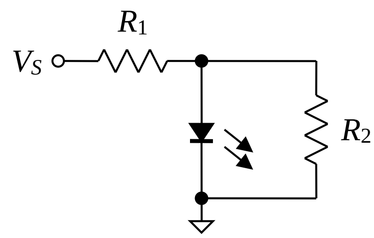
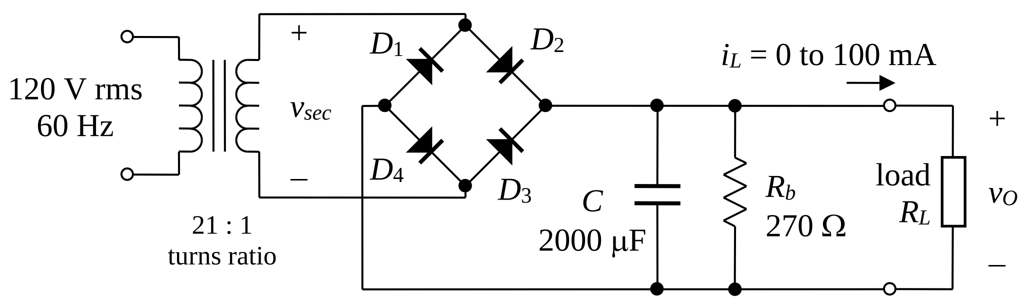
3. Suppose that an air pressure monitor generates a voltage V_S that follows the relationship $V_S = 0.333P$, where P is the pressure in pounds per square inch (psi). The circuit shown below is connected to the V_S output of the sensor. The LED (light-emitting diode) is supposed to turn on if the air pressure rises above about 15 psi. The LED should remain off for pressure levels below that level. The LED's turn-on voltage V_F is 2.0 V and its maximum safe current is 25 mA. (A safety factor has already been applied, so 25 mA really is the LED's maximum safe operating current.) Find the values of R_1 and R_2 that will cause the LED to turn on when the pressure reaches approximately 15 psi and that will allow the LED to stay just within (or slightly above) its safe current rating for all possible values of the sensor voltage V_S up to 10 V (corresponding to 30 psi). Specify the closest standard values for the resistors, assuming 5% tolerance. A table of standard resistor values is available on the Laboratory page at the course web site. Use the constant-voltage model for the LED.



4. The peak secondary winding voltage in the power supply circuit shown below is approximately 8.1 V. The rectifier diodes each have a turn-on voltage of 1.0 V and a maximum PIV (peak inverse voltage) or PRV (peak reverse voltage) rating of 100 V. The load draws a variable amount of current that can range from zero to 100 mA. Bleeder resistor R_b ensures that the filter capacitor discharges quickly when the power is shut off even if no load is present (i.e., if $R_L \to \infty$). A bleeder resistor is a safety feature included in most power supplies. Find the worst-case percentage ripple (relative to the peak voltage) on the output voltage v_O for the component values shown. Also find the percentage of the AC waveform's period T during which any one of the rectifier's diodes conducts.



5. The diagram at the top of the next page depicts a standard full-wave bridge rectifier circuit. Assume that the constant-voltage diode model with a turn-on voltage of $V_F = 1.0$ V is valid for diodes D_1 through D_4. Suppose that diode D_4 fails so that it acts like an open circuit. Sketch and label the resulting output voltage waveform $v_O(t)$ underneath a sketch of the secondary voltage waveform $v_{sec}(t)$ for reference. You should label all voltages in the v_{sec} and v_O waveforms at important transition points, but you do not have to label the times (relative or absolute) at which they occur. Be sure to include details such as brief periods (if any) when the output voltage is zero.

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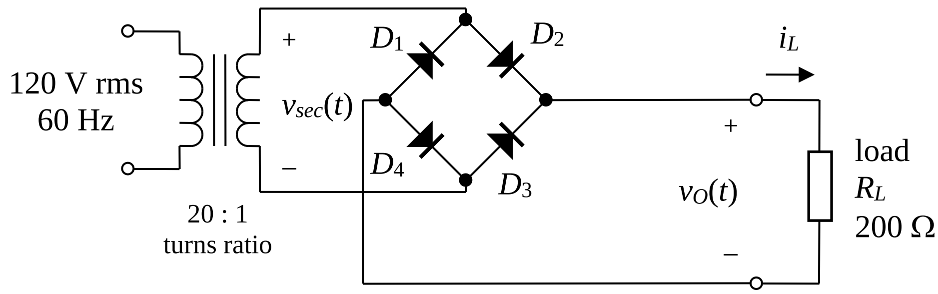
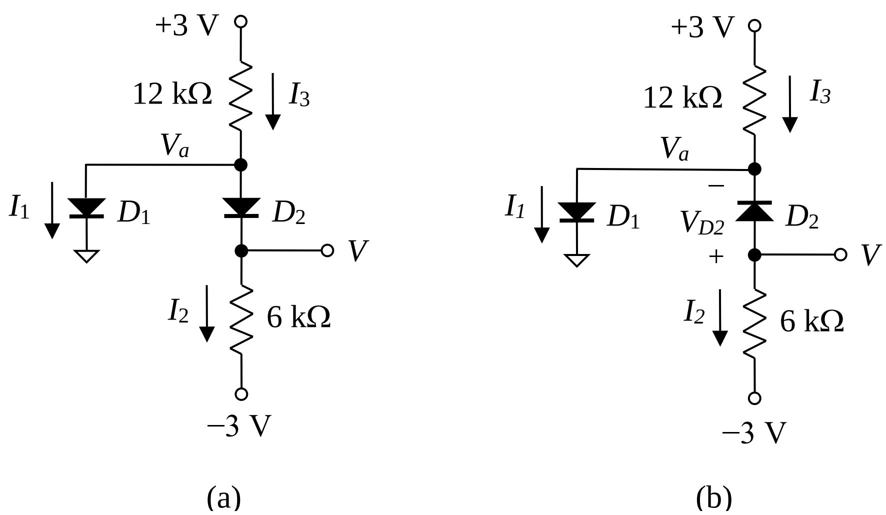


Circuit diagram for Graded Prob. 5

***Ungraded Problems*:**

The following problems will not be graded. They are intended to serve as practice problems and examples. The solutions to these problems will be posted along with those to the graded ones.

1. Find the labeled current I_1 and node voltage V in diagram (a) below. You may apply the constant-voltage diode model with $V_F = 0.7$ V. The nodes marked "+3 V" and "–3 V" are connected to voltage sources not shown, so current can flow into and out of those nodes. The node marked "V" is a test point, so it is not connected to anything except diode D_2 and the 6 kΩ resistor. Note that V is referenced to the ground node.



2. Find the labeled current I_1 and node voltage V in diagram (b) above. You may apply the constant-voltage diode model with $V_F = 0.7$ V. The explanatory notes given in the previous problem apply to this one as well.

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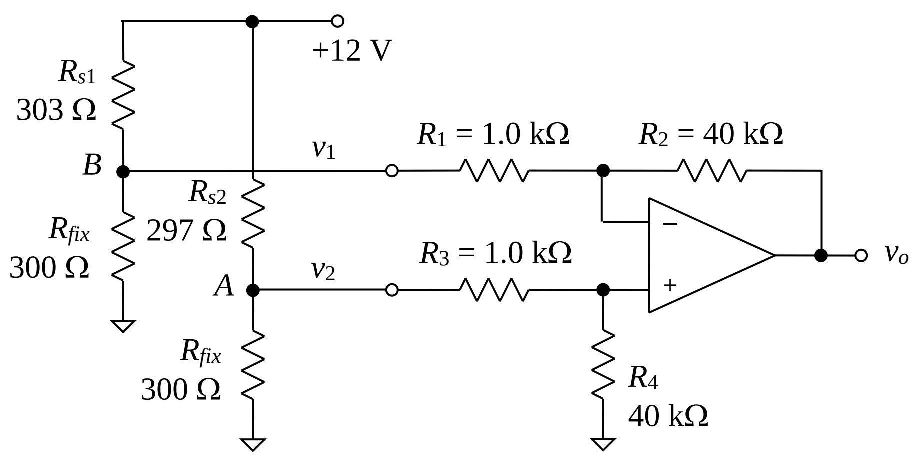
3. The standard diode equation is given by the expression below left, and an approximation of the equation for "large" values of v_D (the forward bias case) is given below right. Assuming that $\eta = 1$ and that the diode is at room temperature (20 °C), find the forward voltage v_D at which the "1" term in the parentheses in the diode equation can be ignored. The "1" is insignificant if ignoring it changes the calculated forward current i_D by less than 1%. Repeat the analysis for $\eta = 2$.

$$i_D = I_S\left(e^{v_D/\eta V_T} - 1\right) \qquad\qquad i_D \approx I_S e^{v_D/\eta V_T}$$

4. The diff amp circuit shown below is meant to scale up the differential voltage produced by a pair of strain gauges arranged in a Wheatstone bridge. Each strain gauge resistance R_{s1} and R_{s2} has a nominal value of 300 Ω at the neutral position. The gauge factor is 2.0, which means that the fractional resistance change $\Delta R/R_{nom}$ from nominal is twice that of the strain (e.g., 0.1% strain yields $\Delta R/R_{nom} = 0.002$). The two strain gauges are mounted so that when one gauge's resistance increases in value, the other's resistance decreases. The other two resistors (labeled R_{fix}) are fixed and have the indicated values to a very high precision. At a strain of 0.5%, the differential voltage $v_2 - v_1$ would be equal to 60 mV if an infinite resistance were connected across the bridge (i.e., between the nodes *A* and *B*). The diff amp is designed to amplify the bridge voltage by a factor of 40. Thus, for a bridge voltage of 60 mV, the diff amp output voltage should be 2.4 V. Using the differential input resistance of the diff amp, estimate the output voltage actually obtained at a strain of 0.5%, and compare it to the ideal value of 2.4 V. The power supply voltages for the op-amp are ±12 V (not shown for clarity). *Hint*: Replace the Wheatstone circuit with a floating Thévenin equivalent circuit connected between nodes *A* and *B*.



5. Suppose that the resistors in the diff amp and Wheatstone bridge in the previous problem have values that are exactly as labeled. Use the superposition principle to find the actual output voltage. That is, find the output voltage due to the +12 V source, R_{fix}, and R_{s1} connected to node *B* and the output voltage due to the +12 V source, R_{fix}, and R_{s2} connected to node *A*, and then add them together. The value found in this problem and the one from the previous problem do not exactly match, but they are close.

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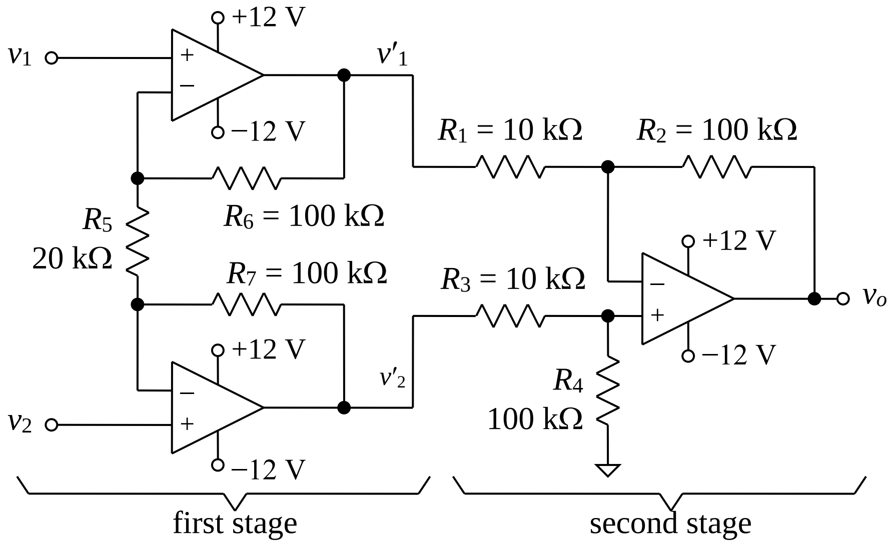
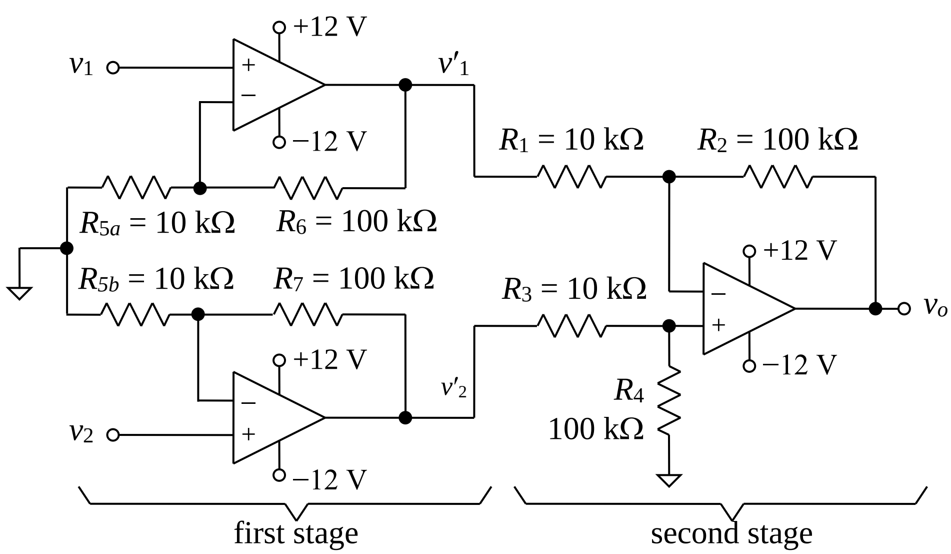
6. The instrumentation amplifier shown below is to be assembled using 5% tolerance resistors in the first stage, but the second stage will incorporate resistors manufactured using a precision laser cutting method. The resistor values shown are the nominal values. Find the resistor tolerance in the second stage required to guarantee that the overall CMRR will be at least 120 dB.



7. Now suppose that resistor R_5 in the previous problem is split into two resistors of equal value (i.e., each is 10 kΩ) and a connection to ground is added to the node between them. The new circuit would have the form shown below. Find the constraint on the resistor tolerances in the second stage that would be necessary to again achieve a CMRR of at least 120 dB. The first-stage resistors would still have 5% tolerances. Compare this answer to the one for the previous problem.



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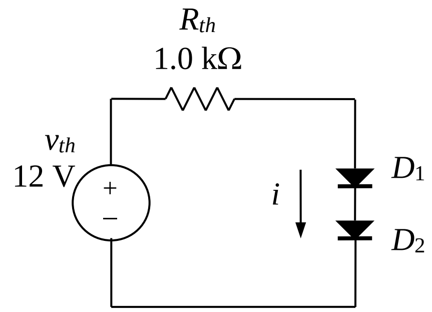
8. Find the current i that flows through the circuit shown below. The two diodes are identical and have the parameter values I_S = 1.0 nA, η = 2.0, and V_T = 26 mV. This problem requires the solution of a transcendental equation. You may use your calculator to solve it if it has that capability; however, you should check that its solution is correct. Alternatively, you may use mathematical analysis software such as *Matlab*; if you do, include a copy of your session or script with your solution. *Hint*: The diodes are identical and share the same current because they are in series; what does that imply about the voltage across each diode?



9. Find the voltage at the node marked v_O in the diagram below for the three indicated values of the voltage v_{IN}. The nodes labeled "+2.8 V" and "–2.8 V" are connected to the positive terminals of voltage sources that are not shown; the sources' negative terminals are connected to ground. Thus, current can flow into and out of those nodes. Assume that the constant-voltage diode model with a turn-on voltage of V_F = 0.7 V applies and that any external circuitry connected to the terminal labeled v_O draws negligible current. Voltage v_O is a node voltage and is therefore referenced to the ground node. This is an example of a circuit that can protect the input port of a 3.3 V digital system from excessive voltage magnitudes coming from the signal source modeled by the TEC consisting of v_{IN} and R_1.

a. v_{IN} = 7.0 V
b. v_{IN} = −2.0 V
c. v_{IN} = −4.0 V