Short Answer Questions:

1. (12 points) **Fill in the blanks.**

a) A certain transconductance amplifier has a short circuit gain of 100mA/V. Ideally, the input resistance of this amplifier is ∞ Ω, and its output resistance is 0 Ω.

b) The voltage characteristic of a Schmitt Trigger is represented by a hysteresis loop. It is the result of positive feedback.

c) Diodes that are intended to operate in reverse breakdown are called zener diodes.

2. (6 points) **Circle true or false.**

a) **True/(False)** Since a capacitor is used to block DC, increasing the value of the capacitance at the output of a rectifier circuit increases the magnitude of the ripple voltage.

b) **True/(False)** Capacitors are placed in parallel between each stage of an AC-coupled amplifier cascade.

c) **(True)/False** With negative feedback the differential input voltage and the input current of a real operational amplifier are forced toward zero.

3. (4 points) **Circle the correct answer.** The differential gain of a certain amplifier is 60dB, and the common mode gain is -80dB. The common mode rejection ratio for this amplifier is

a) -20dB b) -140dB (c) +140dB d) +20dB e) none of the above

60dB − (−80dB) = 140dB

4. (4 points) Briefly explain why a load line is used in the analysis of a diode circuit.

A load line is used to find the operating point on the nonlinear i-v characteristic of a diode.

5. (4 points) Briefly explain the meaning of the term "**Peak Inverse Voltage (PIV)**".

PIV is the minimum allowable reverse breakdown voltage of a diode used in a rectifier circuit.

Problems:

1. (20 points) An electronic speedometer generates a voltage signal $v_{in}(t)$ that is proportional to the velocity. The signal increases by 1V if the velocity increases by 10 mph. Design an accelerometer circuit that produces an output voltage $v_{out}(t)$ that is proportional to acceleration. The circuit should generate an output signal of 0V if the velocity is constant. A change in the output of +1V should correspond to an acceleration +2 mph/s.

$$V_{in}(t) = \frac{1V}{10mph} \cdot x'(t)$$

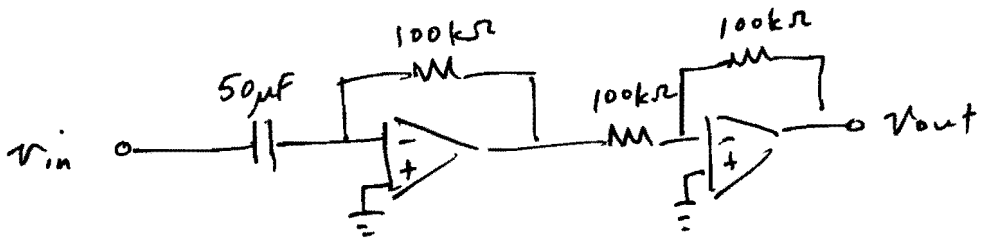
USING A DIFFERENTIATOR AND AN INV. AMP WITH GAIN OF -1 :

$$v_{out}(t) = (-1)\,RC\,\frac{dv_{in}}{dt} = (-1)\,RC \cdot \frac{1V}{10mph} \cdot x''(t)$$

$$+1V = RC \cdot \frac{1V}{10mph} \cdot \left(+2\,\frac{mph}{s}\right) \quad \text{so} \quad RC = 5$$

CHOOSE $R = 100k\Omega$

$$C = \frac{5}{100k} = 50\mu F$$



2. (30 points) A certain audio amplifier should pass frequencies up to 10kHz. The specifications of the LM741 op-amp used in the amplifier are as follows:

Maximum Output Voltage Swing:	±13V
Maximum Short Circuit Current:	±25mA
Slew Rate:	0.5V/μs
Unity Gain Bandwidth:	1.5MHz
Input Bias Current:	80nA
Input Offset Current:	20nA
Input Offset Voltage:	1mV

a) (6 points) In a non-inverting configuration, what is the largest gain that can be expected with a single amplifier stage?

$$f_t = 1.5\text{MHz} = A_{0,CL} \cdot f_{BCL}$$

$$A_{0CL} = \frac{1.5M}{f_{BCL}} = \frac{1.5M}{10k} = \boxed{150}$$

b) (12 points) If the load is an 8Ω speaker, what is the largest output voltage amplitude for a 10kHz sine wave without distortion? (Hint: Consider voltage, current and slew rate limits.)

VOLTAGE LIMIT: +13V

CURRENT LIMIT: $(0.025A)(8\Omega) = 0.2V$

SLEW RATE LIMIT: $V_{omax} = \frac{SR}{2\pi f_{FP}} = \frac{0.5 \times 10^6 V/s}{2\pi (10k)} = 7.96V$

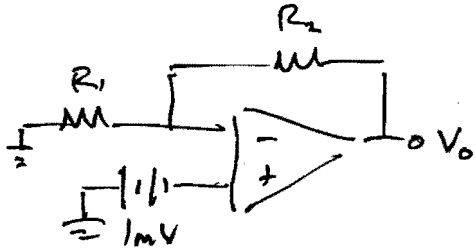
$\Rightarrow$ CURRENT LIMITED $\boxed{0.2V}$

c) (12 points) If resistors in the circuit are limited to 10kΩ or less and the required gain in the non-inverting configuration is at least 100, which DC impairment has the most significant impact on the amplitude of the output? Quantitatively justify your answer.

WORST DC IMPAIRMENT DUE TO I_B OR I_{OFF} :

$(80nA)(10k\Omega) = 0.8\,mV$

FOR V_{OFFSET} VOLTAGE:



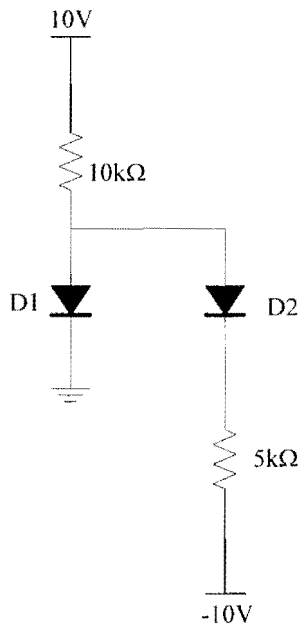
$V_{O_{VOFF}} = \left(1 + \frac{R_2}{R_1}\right)(-V_{OFF})$

$= -100\,V_{OFF} = -100mV$

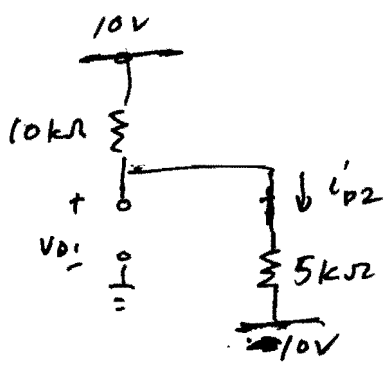
↑ 1mV

OFFSET VOLTAGE HAS WORST EFFECT ⇒ MOST IMPACT!

3. (20 points) Determine the voltage and current for each diode in the circuit shown below. Assume the diodes are ideal. **Clearly indicate your answers.**



ASSUME D1 OFF, D2 ON:



$$i'_{D2} = \frac{10-(-10)}{15k} = \frac{20}{15k} = 1.33\,mA \quad > 0 \checkmark$$

$$v_{D1} = 10 - (1.33m)(10k)$$

$$= -3.33V < 0 \checkmark$$

$\therefore$ $i'_{D2} = 1.33\,mA$, $v_{D2} = 0V$

$v_{D1} = -3.33\,V$, $i'_{D1} = 0A$