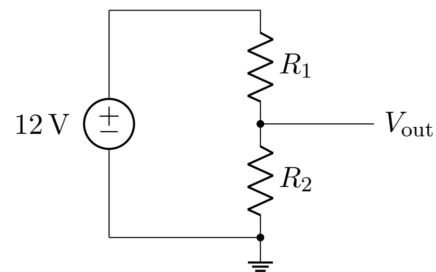
Physics 127A — Practice Exam

Spring 2026 Professor Everett Lipman

Thursday, June 11, 12:00–3:00 p.m. Phelps 2524

Problem 1. Resistive network, Thevenin equivalent, and power [10 pts]

The circuit below is driven by an ideal 12 V source. $R_1 = 1\,\mathrm{k\Omega}$ and $R_2 = 2\,\mathrm{k\Omega}$.



(a) With nothing connected at V_{out}, find V_{out}. [2]

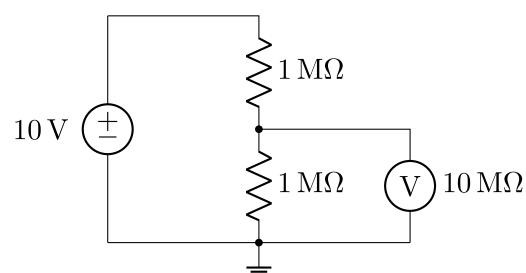
(b) Find the Thevenin equivalent resistance seen looking back into the V_{out} terminal (source replaced by its internal impedance). [2]

(c) A load $R_L = 1\,\mathrm{k\Omega}$ is now connected from V_{out} to ground. Find the new value of V_{out}. [4]

(d) For the loaded circuit of part (c), find the power dissipated in R_1. [2]

Problem 2. Non-ideal measuring instruments [10 pts]

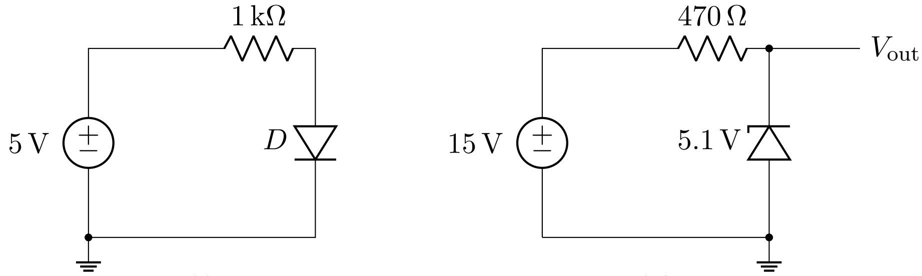
(a) A divider is built from two equal $1\,\mathrm{M\Omega}$ resistors across a 10 V source; the midpoint is the output. An analog voltmeter with input resistance $10\,\mathrm{M\Omega}$ is connected from the midpoint to ground. What voltage does it read, and what is the percentage error relative to the unloaded midpoint voltage? [4]



(b) An ammeter with $1\,\Omega$ of internal resistance is placed in series with a $100\,\Omega$ resistor across a 10 V source. What current does it read, and by what percentage does this differ from the true (meterless) current? [3]

(c) An oscilloscope input is modeled as $1\,\mathrm{M\Omega}$ in parallel with 20 pF. At what signal frequency does the magnitude of the capacitive reactance equal the $1\,\mathrm{M\Omega}$ resistance? State the qualitative consequence for high-frequency measurements. [3]

Problem 3. Diodes and a Zener regulator [10 pts]



(i) (ii)

(a) In circuit (i), find the current through the diode. [2]

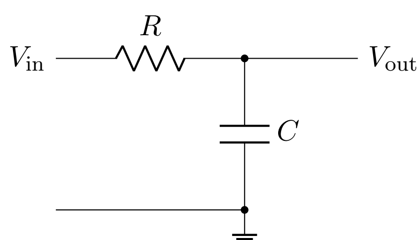
(b) In circuit (ii) with *no* load attached at V_{out}, find the current through the series resistor and the power dissipated in the Zener diode. [3]

(c) A load is now attached at V_{out} that draws 10 mA. Find the Zener current and state whether the output is still regulated. [2]

(d) What is the largest load current the circuit can supply before the output falls below 5.1 V? [3]

Problem 4. Reactive circuit: passive filter [10 pts]

For the network below, $R = 1\,\mathrm{k\Omega}$ and $C = 0.1\,\mu\mathrm{F}$.



(a) Is this a high-pass or low-pass filter? Find its -3 dB (corner) frequency f_c in hertz. [3]

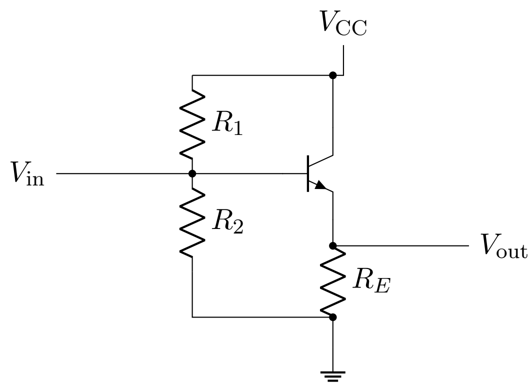
(b) Write the complex transfer function V_{out}/V_{in} and evaluate its magnitude in dB at $f = f_c$. [3]

(c) Find the gain in dB and the phase shift one decade above f_c, i.e. at $f = 10f_c$. [2]

(d) A sinusoid of amplitude 2 V at $f = f_c$ is applied at V_{in}. Give the amplitude and phase of V_{out}. [2]

Problem 5. BJT emitter follower [10 pts]

$V_{CC} = 15$ V, $R_1 = R_2 = 100\,\mathrm{k\Omega}$, $R_E = 6.8\,\mathrm{k\Omega}$. The transistor is an NPN with $\beta = 100$.



(a) Find the quiescent base voltage V_B, emitter voltage V_E, and collector current I_C. [3]

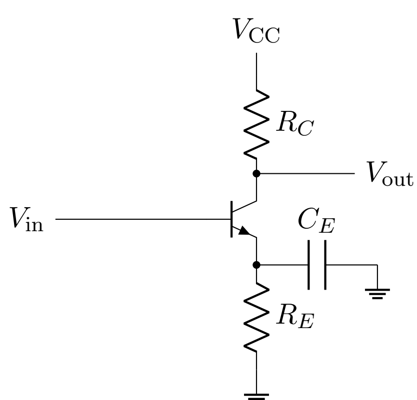
(b) Find the small-signal input impedance looking into the base, and then the input impedance of the whole stage (including the bias resistors). [3]

(c) The stage is driven from a source of resistance $R_s = 1\,\mathrm{k\Omega}$. Estimate the output impedance at the emitter. [2]

(d) Find the small-signal voltage gain V_{out}/V_{in}. [2]

Problem 6. BJT common-emitter amplifier [10 pts]

$V_{CC} = 15\,\mathrm{V}$, $R_C = 5\,\mathrm{k\Omega}$, $R_E = 2\,\mathrm{k\Omega}$. The bias network (not all shown) holds the base at $V_B = 2.6\,\mathrm{V}$. For AC signals the emitter is connected to ground through a large bypass capacitor.



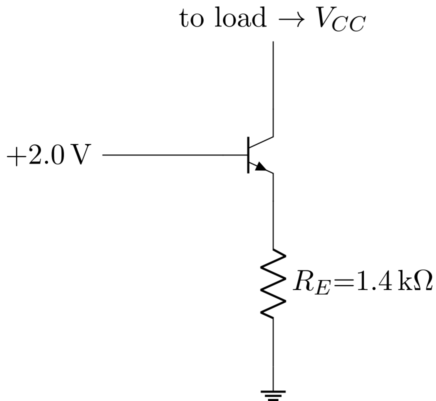
(a) Find the quiescent collector current I_C and collector voltage V_C. Confirm the transistor is in the active region. [3]

(b) With the emitter fully bypassed, find the small-signal voltage gain. Use $r_e = 25\,\Omega/I_C(\mathrm{mA})$. [3]

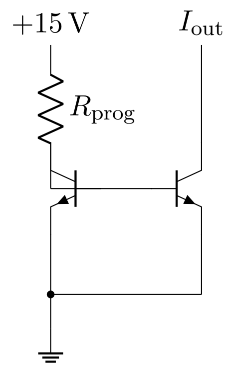
(c) Express the magnitude of the gain from part (b) in decibels. [2]

(d) Now suppose a $100\,\Omega$ resistor is left *unbypassed* in series with the emitter. Find the new voltage gain. [2]

Problem 7. BJT current source and current mirror [10 pts]



(i) current source



(ii) current mirror

(a) Starting from the Ebers–Moll relation, derive the intrinsic emitter resistance $r_e = V_T/I_C$ and evaluate it at $I_C = 1\,\text{mA}$, 20°C. [3]

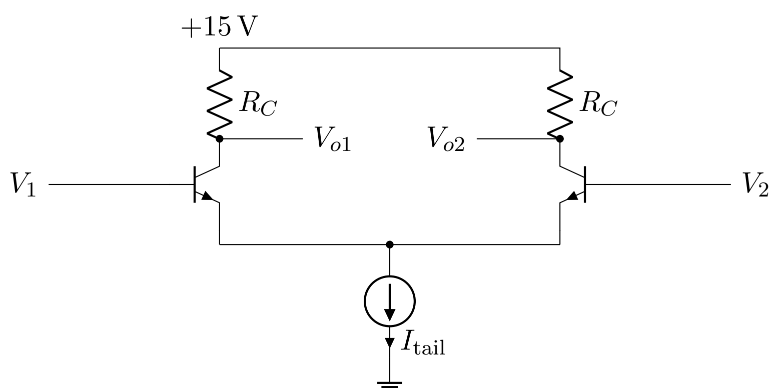
(b) In current source (i) the base is held at 2.0 V. Find the output current delivered to the load. [2]

(c) For a 15 V supply, over what range of load voltage does the source in (i) maintain a nearly constant current? (Take the saturation limit as $V_{CE} \geq 0.2\,\text{V}$.) [2]

(d) In mirror (ii), choose R_{prog} so that $I_{\text{out}} = 1\,\text{mA}$, and explain in one or two sentences why the output current mirrors the programming current. [3]

Problem 8. BJT differential amplifier [10 pts]

Two matched NPN transistors share a tail current source $I_{\text{tail}} = 2\,\text{mA}$. Each collector resistor is $R_C = 7.5\,\text{k}\Omega$ to a 15 V supply. $\beta = 100$.



(a) Find the quiescent collector current in each transistor and the DC voltage at each collector. [2]

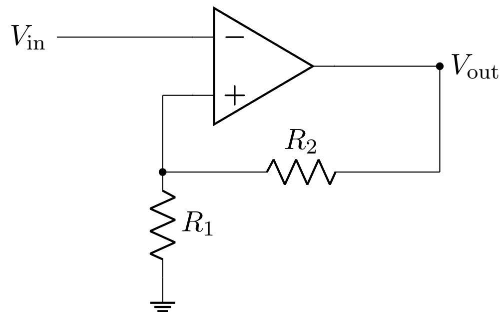
(b) Find the differential gain to a single collector, $v_{o1}/(V_1 - V_2)$, and the collector-to-collector differential gain. [3]

(c) The tail current source has an output resistance $R_{\text{tail}} = 500\,\text{k}\Omega$. Find the single-ended common-mode gain and the common-mode rejection ratio (CMRR) in dB. [3]

(d) Find the small-signal input impedance at one base and the output impedance at one collector. [2]

Problem 9. Schmitt trigger [10 pts]

The comparator below uses positive feedback. The op amp output saturates at $\pm 12\,\mathrm{V}$. The resistor $R_1 = 10\,\mathrm{k\Omega}$ runs from the non-inverting input to ground and $R_2 = 20\,\mathrm{k\Omega}$ runs from the output back to the non-inverting input; the signal V_{in} drives the inverting input directly.



(a) Explain why returning the feedback to the non-inverting input produces *positive* feedback, and state the input impedance this circuit presents to the source driving V_{in}, with a one-line justification. [3]

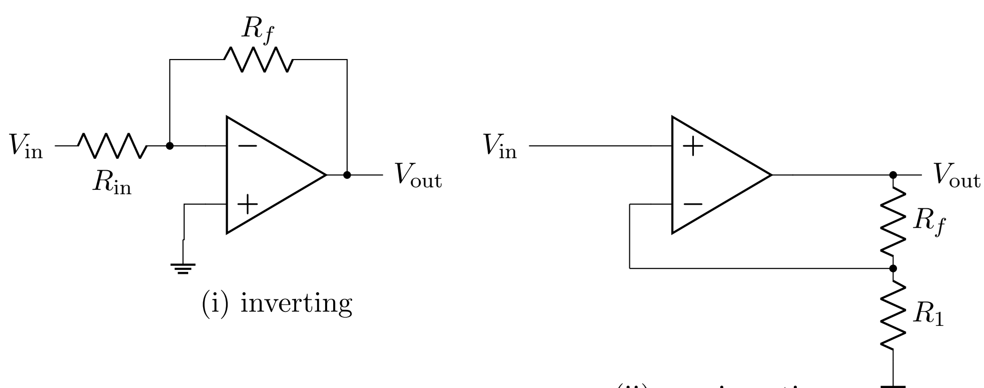
(b) Find the voltage at the non-inverting input in each of the two output states, and hence the two input threshold voltages at which the output switches. [3]

(c) Give the width of the hysteresis. [2]

(d) Keeping $R_1 = 10\,\mathrm{k\Omega}$, choose a new value of R_2 that would halve the hysteresis width. [2]

Problem 10. Operational amplifiers [10 pts]

Assume ideal op amps unless stated otherwise.



(i) inverting

(ii) non-inverting

(a) State the two standard design approximations ("golden rules") for an op amp operating with negative feedback. [2]

(b) In the inverting amplifier (i), $R_{\text{in}} = 10\,\mathrm{k\Omega}$ and $R_f = 100\,\mathrm{k\Omega}$. Find the voltage gain and the input impedance seen by the source. [2]

(c) In the non-inverting amplifier (ii) with the same two resistor values ($R_1 = 10\,\mathrm{k\Omega}$, $R_f = 100\,\mathrm{k\Omega}$), find the voltage gain. How does its input impedance compare with that of (i)? [2]

(d) Replace R_f in the inverting circuit with a capacitor $C_f = 0.01\,\mu\mathrm{F}$ to make an integrator. Write $V_{\mathrm{out}}(t)$ in terms of $V_{\mathrm{in}}(t)$, and find the frequency at which the magnitude of the gain equals unity. [2]

(e) The op amp has a slew rate of $1\,\mathrm{V}/\mu\mathrm{s}$. What is the highest frequency at which it can produce an undistorted sine wave of $10\,\mathrm{V}$ amplitude at the output? [2]

Constants and relations.
$V_T \approx 25\,\mathrm{mV}$ at $20°\mathrm{C}$. Ebers–Moll: $I_C = I_S\big(e^{V_{\mathrm{BE}}/V_T} - 1\big)$, $I_S \approx 10^{-13}\,\mathrm{A}$.
Intrinsic emitter resistance: $r_e \approx \dfrac{25\,\Omega}{I_C(\text{in mA})}$. Impedances: $Z_C = \dfrac{1}{i\omega C}$, $Z_L = i\omega L$.

Good luck.