Physics 334, Winter Quarter 2011, Examination #1

Name SOLUTIONS

1	/25
2	/25
3	/25
4	/25
TOTAL	/100

Exam notes: The exam is closed-book. You may use a calculator. You may not use your own equation sheet. Please check that you have a total of 5 pages, including this page. You may make reasonable assumptions based on standard component tolerances of 5%, which may save you some time. You may use scratch paper or the back of the exam, but it won't be graded.

Possibly Useful information and equations:

Ohm's Law: V = IR   Generalized Ohm's Law: V = IZ

Thévenin-equivalent circuits, conceptually:
Vth = Vout (open-circuit) and Rth = Vth/Isc (current through short-circuit)

Norton-equivalent circuits, conceptually:
In = Iout (short circuit) and Rn = Voc (voltage open-circuit)/In

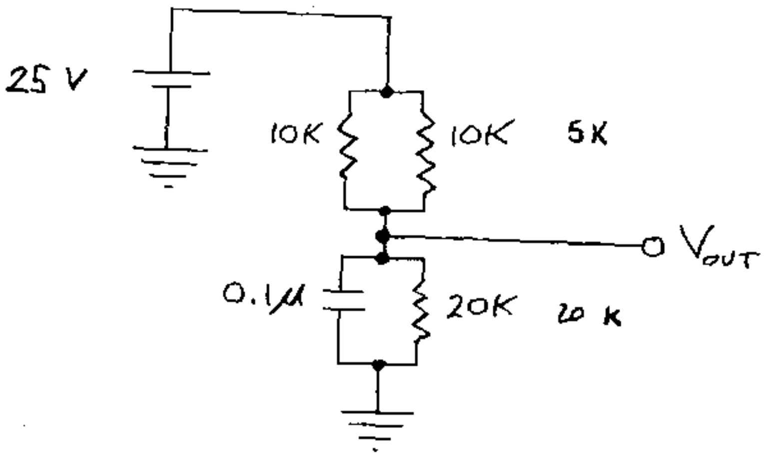
Impedance/reactance equations:
Resistor: Z=R   Capacitor: $Z = -i/(\omega C)$ Inductor: $Z = i\omega L$

Other equations:
$\omega = 2\pi f$ $e^{ia} = \cos(a) + i\sin(a)$ Power(t) = V(t) I(t)

Vrms = Vpeak/√2 $\omega(3db) = 1/RC$

Capacitor equations: Q = C V   I = C (dV/dt)

1. (25 points total) Thévenin and Norton equivalent circuits.
Consider the circuit shown below, consisting of an ideal DC voltage source and a divider chain containing resistors and a capacitor.



a. (5 points) Explain in 10 words or less what it means to say the voltage source is "ideal".

- gives same voltage regardless of current
- 0 output resistance.

} 5pts for 1 of these

b. (5 points) Explain in 10 words or less what it means to say the voltage source is "DC".

- no time dependence in output voltage – 5pts.

c. (7 points) For the circuit above, find the Thévenin voltage Vth and resistance Rth.

$V_{open\ circuit} = 25\ V \cdot \frac{20K\Omega}{5K\Omega + 20K\Omega} = \boxed{20\ V = V_{TH}}$ voltage divider.

$I_{short\ circuit} = 25V / 5K\Omega = 5mA$

$R_{TH} = \frac{V_{oc}}{I_{sc}} = \boxed{4K\Omega}$

or $\frac{5K \cdot 20K}{5K + 20K}$

d. (8 points) For the circuit above, find the Norton current In and resistance Rn.

$R_n = R_{TH} = \boxed{4K\Omega}$

$I_n = I_{sc} = \boxed{5mA}$

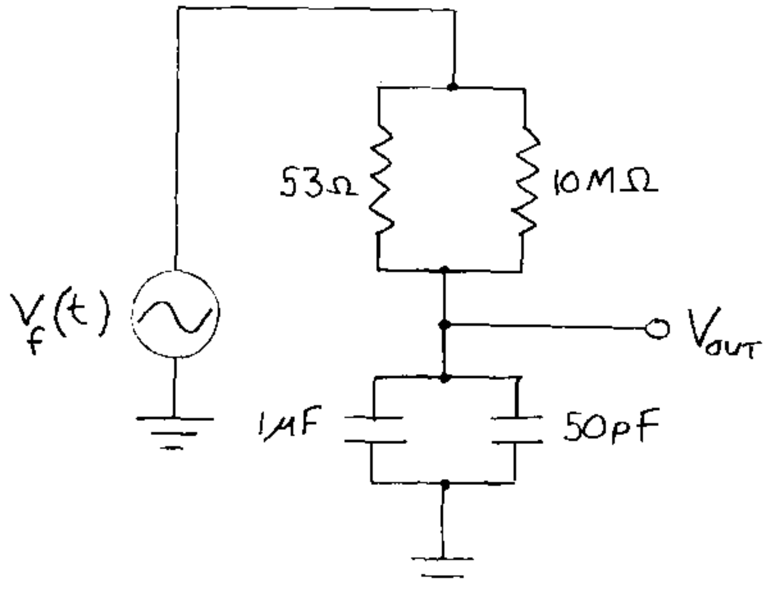
V_{TH}, R_{TH} / I_N, R_N { 3pts for formulas, 1 pt for answers

-1 total for bad units

-1 each problem for order of magnitude issues

2. (25 points total) Filters.

Consider the filter circuit shown below.



a. (2 points) Is this a high-pass, low-pass, band-pass or notch filter?

Low pass -> caps block DC, & "short" high freq into ground

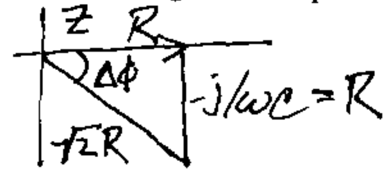
b. (2 points) Find the "3dB" frequency f_{3dB}.

$R_{tot} \approx 53\Omega$, $C_{tot} \approx 1\mu F$ $f_{3dB} = (2\pi RC)^{-1} \approx 3kHz$

c. (7 points) At this "3dB" frequency, what's the ratio of the magnitude of the output voltage to the magnitude of the input voltage?

$-3 = 20 \log_{10}(V_{out}/V_{in}) \Rightarrow V_{out} \approx 1/\sqrt{2}\, V_{in}$

d. (7 points) At this "3dB" frequency, find the phase (in radians) of the output voltage relative to the input voltage? (Be careful to note whether the output voltage leads, lags, or is in phase with the input voltage.) W/ a phase diagram:



$\Delta\phi = -45°$

e. (7 points) Suppose you replace the two capacitors by a single resistor and discover the magnitude of the output voltage is the same as the magnitude of the output voltage for the original circuit at the "3dB" frequency. What's the value of this single resistor?

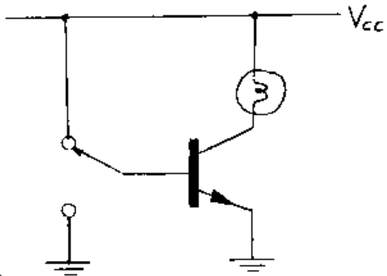
$V_{out} = (V_{in}/\sqrt{2}) = V_{in} \frac{R_{new}}{(R_{new}+R_1)}$ $(R_1 \approx 50\Omega)$

$\sqrt{2} R_{new} = R_{new} + 50\Omega \Rightarrow 50 \approx R_{new}(\sqrt{2}-1)$

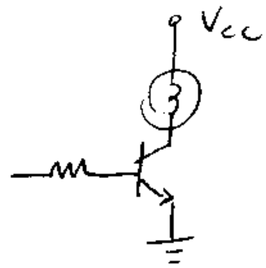
$50\Omega \approx 0.4 R_{new} \Rightarrow R_{new} \approx 125\Omega$

3. (25 points total) "Bad circuits." Each circuit below has a serious fault that makes it "bad". To the right of each circuit, (i) explain in 10 words or less (no more) why the circuit is bad and, (ii) sketch the corresponding corrected "good" circuit. need: (i): 3 , & (ii): 3

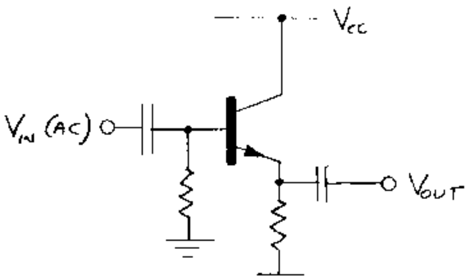
a. (6 points) Transistor-switch driving a light-bulb



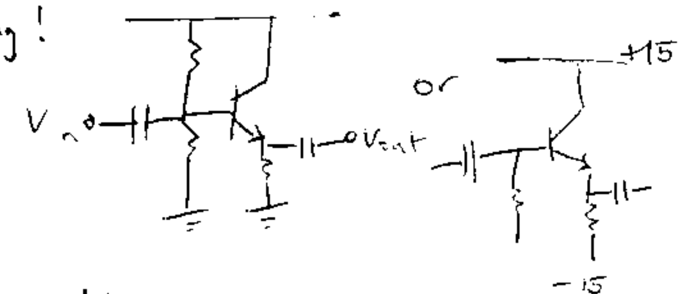
I_B unlimited!



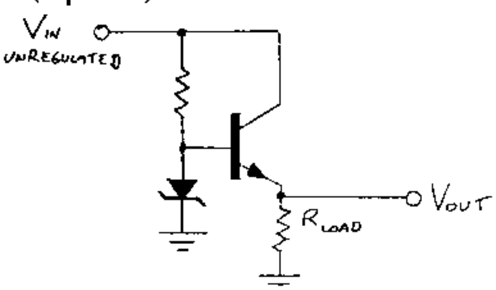
b. (6 points) Follower with AC-coupled input and output



clipping!

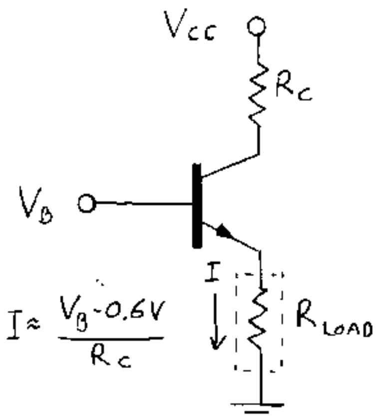


c. (6 points) Zener-diode and emitter-follower voltage regulator

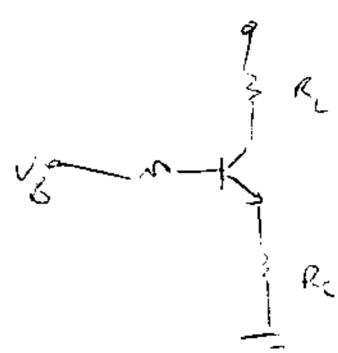


diode backwards!

d. (7 points) Current source (from fixed voltage V_B) through a varying load R_{load}



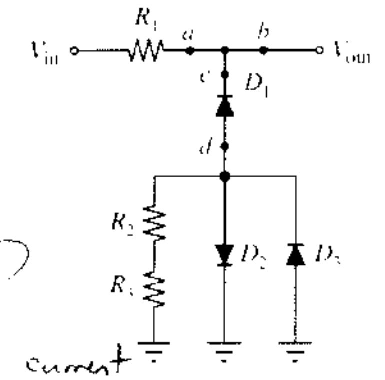
$R_C \longleftrightarrow R_{LOAD}$!



4. (25 points total) Conceptual problem

This question consists of two unrelated parts, A and B

A. In the circuit at right, all resistors (R_1, R_2, and R_3) are identical. All diodes (D_1, D_2, and D_3) are identical and ideal. Assume that the power supply is ideal and that *no load* is connected to the output. Both V_{in} and V_{out} are measured with respect to ground. V_{in} is constant and is equal to +10.0 V.



1. Is the current at **point *a*** *to the right, to the left*, or *equal to zero?* Explain.

   D_1 blocks current in reverse bias

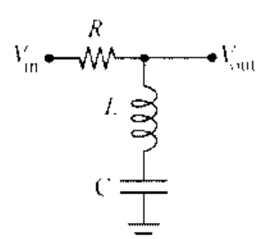
2. Rank, from largest to smallest, the absolute values of the currents at points a, b, c, and d. If any of the currents are equal in absolute value or are equal to zero, state so explicitly. Explain.

   $a = b = c = d = 0$

3. Rank, from largest to smallest, the absolute values of the voltages across diodes D_1, D_2, and D_3. If any of the voltages are equal in absolute value or are equal to zero, state so explicitly. Explain.

   [illegible]

B. Consider the circuit at right. The circuit is driven by an ideal AC sinusoidal voltage source with a peak-to-peak amplitude of 3 V. Assume that the frequency of the input signal is neither equal to nor very close to the resonant frequency of the circuit. No load is attached.



The current through the source is represented by $I_{in}(t)$. The voltage across the source is represented by $V_{in}(t)$.

Are the quantities $I_{in}(t)$ and $V_{in}(t)$ *in phase* or is there *a phase difference between them?* Explain.

yes → $f \neq f_{res}$.

$\Rightarrow \angle X_L - \angle X_C \neq 0$