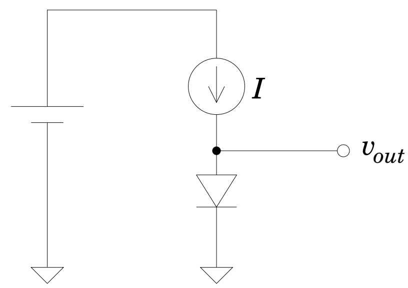
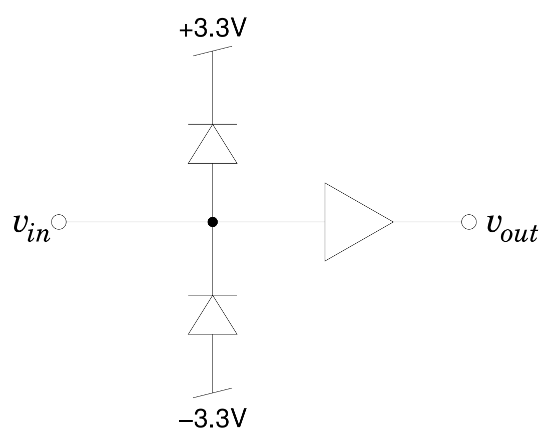
Physics 536 - Assignment #5

1. Consider the following circuit consisting of a diode and a current source.



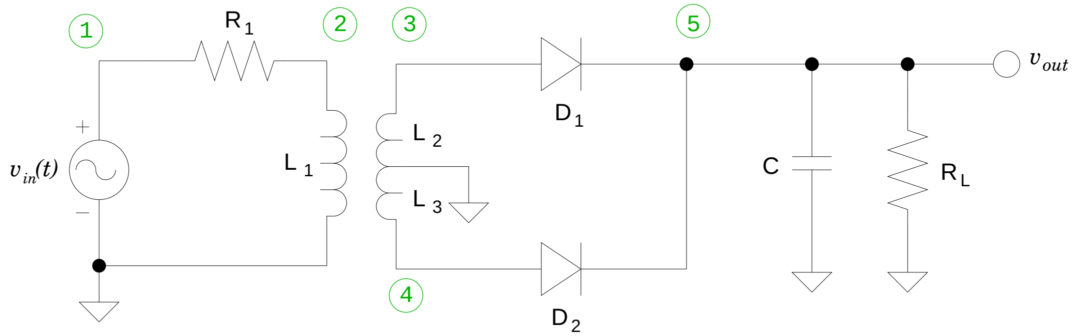
(a) If the diode as a reverse saturation current of $I_0 = 10^{-10}$ A, and the current source provides $I = 10$ mA, calculate the voltage v_{out} as a function of temperature, T.
(b) If the current through the diode provided by the current source fluctuated by a small amount, δI, what would the resulting fluctuation in v_{out} be?

2. A sensitive amplifier uses two diodes for input protection as shown:



Assuming $V_D \approx 0.7$ V, what are the maximum and minimum input voltages that will be presented at the input to the amplifier?

3. Consider the following a power supply circuit:



This circuit can be modeled using SPICE in the following way:

- $v_{in}(t)$ represents a 60 Hz, 110 VAC (RMS) power source, modeled using:
  `VIN 1 0 0 AC SIN(0 160V 60Hz 0 0)`

- R_1 is a *small* resistance (*eg*, $R_1 \sim 0.1\ \Omega$), intended only to ensure numerical stability of the simulation. However, it could also represent a finite impedance of the voltage source.

- L_1, L_2 and L_3 represent a center-tapped transformer. Such a transformer with a 10:1 turns ratio can be represented in terms of coupled inductors using:

```
L1 2 0 1MH
L2 3 0 10UH
L3 0 4 10UH
K1 L1 L2 0.99
K2 L1 L3 0.99
K3 L2 L3 0.99
```

- Assume that D_1 and D_2 are 1N4001 rectifier diodes which have properties described by the SPICE model:

```
 .MODEL D1N4001 D IS=29.5E-9 RS=73.5E-3 N=1.96 CJO=34.6P VJ=0.627
+M=0.461 BV=60 IBV=10U
```

  and which can then be included in the netlist using the following statements:

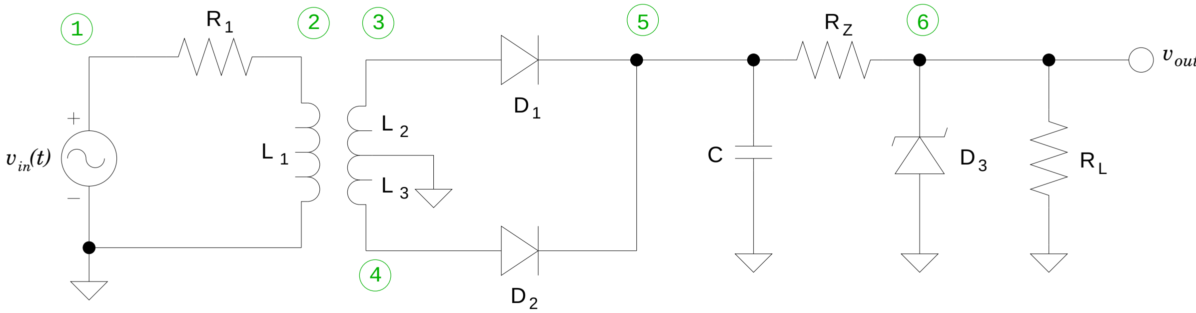
```
D1 3 5 D1N4001
D2 4 5 D1N4001
```

- Suppose the capacitor has a capacitance of 1000 μF.

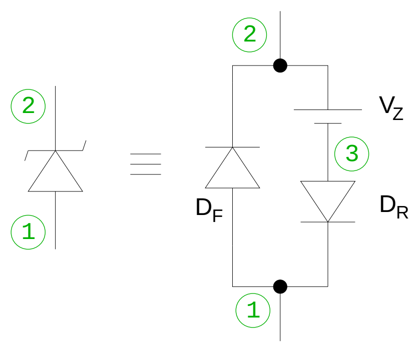
(a) Perform a transient analysis of this circuit using

```
.TRAN 1MS 500MS 0 100US
```

for $R_L = 1000\ \Omega$, $100\ \Omega$ and $10\ \Omega$. Provide the graphs of the output voltage, v_{out} as a function of time and tabulate the average voltage and ampltiude of the ripple for each value of R_L.
(b) Next, consider the following circuit which uses a zener diode to provide a stable voltage reference:



Suppose the zener diode, D_3, is a 1N4740A device, which has a zener voltage of $V_Z = 10$ V at $I_Z = 25$ mA. If the load resistance is $R_L = 1\ \text{k}\Omega$, calculate the maximum value for R_Z that will allow the D_3 to provide a stable voltage v_{out}. The zener diode can be modeled by the equivalent subcircuit:



in which D_F represents the behavior when the zener diode is forward biased and D_R in series with V_Z represent the behavior when the zener diode is reverse biased, as it would normally be operated. The SPICE subcircuit that describes the 1N4740A zener diode is

```
.SUBCKT DI_1N4740A  1 2
*  Terminals    A   K   (K is the pointy end)
D1 1 2 DF
DZ 3 1 DR
VZ 2 3 9.02
.MODEL DF D ( IS=41.2p RS=0.620 N=1.10 CJO=68.9p VJ=0.750 M=0.330 TT=50.1n )
.MODEL DR D ( IS=8.24f RS=0.403 N=1.30 )
.ENDS
```

which can then be included in the netlist for the power supply using

```
X1 0 6 DI_1N4740A
```

Simulate the circuit shown above using $R_L = 1\ \text{k}\Omega$ and using the value for R_Z calculated above and provide a graph of the voltage $v_{out}(t)$.

(c) Calculate the current through the zener diode when $R_L = 400\ \Omega$ and $200\ \Omega$ and provide graphs to demonstrate that the zener diode fails to provide a stable voltage reference with these loads.