Midterm Review (Part 2)

In this voltage regulator circuit:
a) How much power is dissipated in the voltage regulator (you can neglect the few mA of current that flow through the regulator ground pin)?
There is a 10Ω resistor on the 5V output so the load current is 5V/10Ω = 0.5A
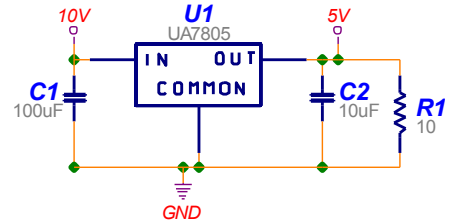Power is V*I so the power dissipated in the regulator is:
(Vin-Vout)*I = (10V-5V)*0.5A = 2.5W
b) How much power is dissipated in the load (R1)?
5V*0.5A = 2.5W
c) What is the efficiency of this regulator with the given input and output voltages?
The input power is 10V*0.5A = 5W, the output power is 2.5W (from part B).
Efficiency = Pout/Pin = 2.5W/5W = 50%

The LM7805 in the TO-220 package has the following thermal impedance:
4°C/W junction to case
50°C/W case to ambient.
a) If no heatsink is used, how far above ambient will the junction temperature get when dissipating 2W of power?
Temp rise = (4°C/W + 50°C/W)*2W = 108°C (above ambient)
b) If the ambient temperature is 25C, what size heatsink (in °C/W) should be used to keep the junction temperature below 70C?
If the ambient is 25C and the max junction temp is 70C the temp rise is 70C-25C = 45C
45°C = (4°C/W + X°C/W)*2W,   X = (45°C/2W) - 4°C/W = 18.5°C/W
A heatsink with a thermal resistance less than 18.5°C/W is needed to keep the junction temp below 70C (w/ambient = 25C).

In the circuit below the load draws 1A from the 12V regulator.
a) How large should C1 be to limit the ripple voltage on C1 to 2V?
C = IΔt/ΔV = (1A*8.33ms)/2V = 4,150uF, rounding up to the closest available size, C = 4,700uF.
b) Assuming C1 has a ripple voltage of 2V what are the minimum voltage requirements for the transformer that will allow the regulator to still provide 12V to the load? Give your answer in AC Volts (rms).
12V output + 2V headroom for the regulator + 2V ripple on C1 + 1.5V drop across the bridge = 17.5V peak = 12.4VAC (rms)
Note: If I ask you to design power supply to produce 12V@1A you should be able to come up with the schematic below and label the parts accordingly (including the transformer output voltage).
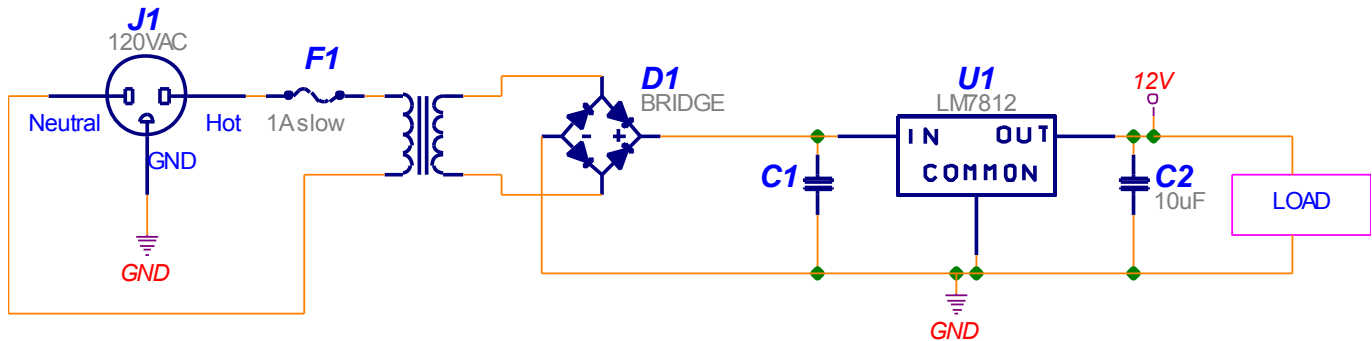
You need to control a DC load (24VDC@2A) from a computer. The signal from the computer is a 0-5V TTL signal with a source impedance of 1KΩ (see block below). Use any parts to the right and what's shown below and as many resistors, capacitors, and diodes as needed to complete the circuit. Draw the schematic and add a few sentences that explain how the circuit works.
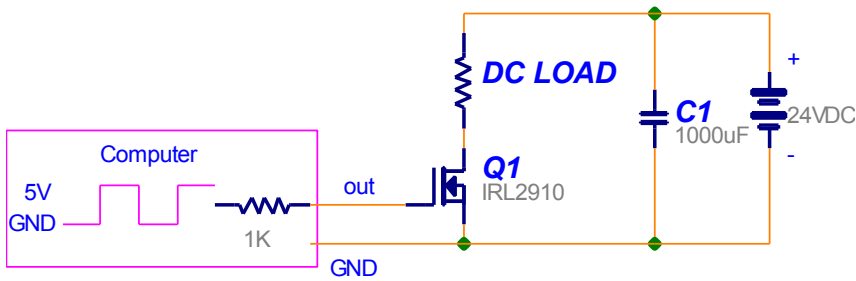
2N3904
Vce max = 60V
Ic max = 200mA
hfe = 50

IRL2910
Vds max = 100V
Id max = 55A
Rds(on) = 0.026 (Vgs=10V)
Rds(on) = 0.035 (Vgs=5V)

Coil: 12V@50mA
Contacts: 125VAC@10A.
24VDC@5A

DC LOAD

C1 1000uF

Q1 IRL2910

Computer
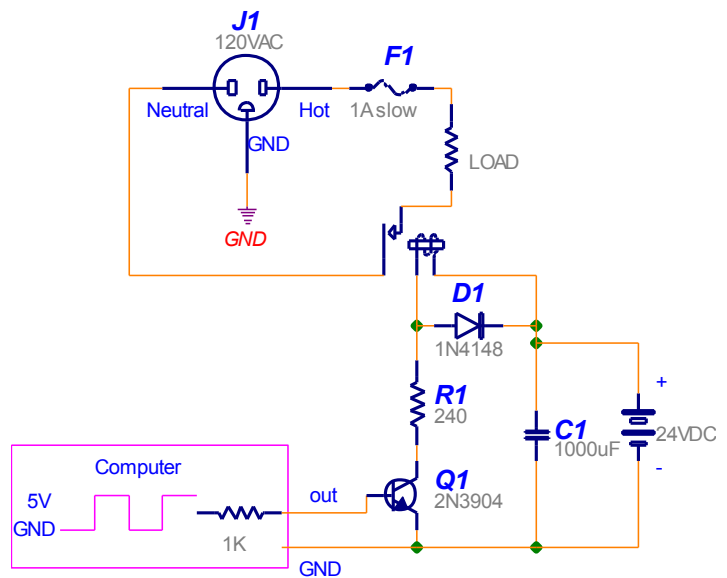5V
GND
out
1K
GND

+ 24VDC −

The simplest solution is to use the FET because the DC load current and voltage are less than that of the FET and the computer's output voltage and current is sufficient to fully turn on the FET. With a 5V gate drive the on resistance of the FET is 0.035Ω. This is much less than the load resistance (~12Ω if it draws 2A@24V). Because of the extremely low on-resistance a heatsink won't be needed. $P = I^2R = (2A)^2 0.035Ω = 0.14W$.

Note: C1 helps smooth the power supply ripple when the load is turned on & off. The value depends on the load current. The larger the load current the larger the capacitor should be. 1000uF was chosen arbitrarily.

Re-design the circuit to switch an AC load instead of a DC load. The AC load runs off 120VAC and draws 1A. Add a few sentences explaining how the circuit works. You still have the 24VDC power source available to use.

For an AC load the relay needs to be used. Luckily the relay contacts are rated for enough voltage and current to switch the load. The coil voltage is 12V and we're given a 24V power supply. A resistor can be used to drop the extra 12V. Putting 24V across a 12V coil would damage it. We're given that the coil draws 50mA at 12V so we need a 12V/50mA = 240Ω resistor in series with the relay. A flyback diode is also placed across the coil to clamp the inductive kickback when the coil is turned off. Note: Because the computers output impedance is 1KΩ we don't need to add a separate base resistor. The base current should be about (5V-0.7V)/ 1KΩ = 4.3mA. With an h_{fe} of 50 the transistor will try and let 4.3mA*50 = 215mA flow through the collector. Since we want 12V across the relay coil the current should be 50mA. The transistor is switched fully on and 24V is dropped across the relay and the 240Ω resistor. Note: You could also use the FET(IRL2910) instead of the BJT(2N3904). The circuit would be identical except the FET would replace the BJT.

J1 120VAC

Neutral   Hot

F1 1A slow

GND

GND

LOAD

D1 1N4148

R1 240

C1 1000uF

+ 24VDC −

Computer
5V
GND
out
1K
GND

Q1 2N3904

Note: R1 will get warm. Resistor power dissipation = 12V*0.05A = 300mW.