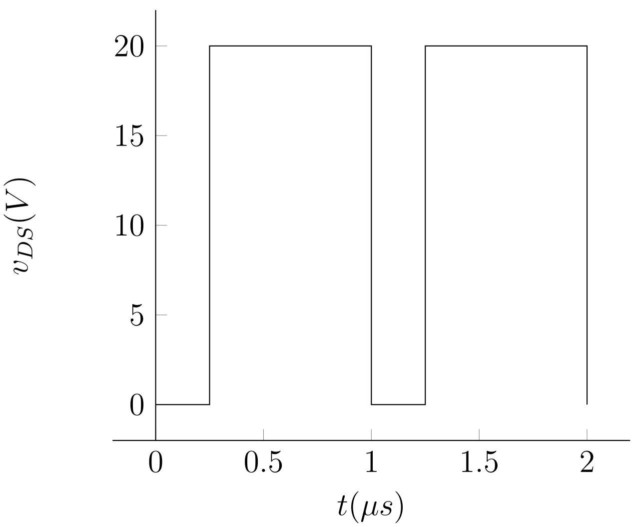
1.1:

(a) What is the duty ratio, D, of the converter?
since:

$$V = \frac{V_G}{1-D}$$

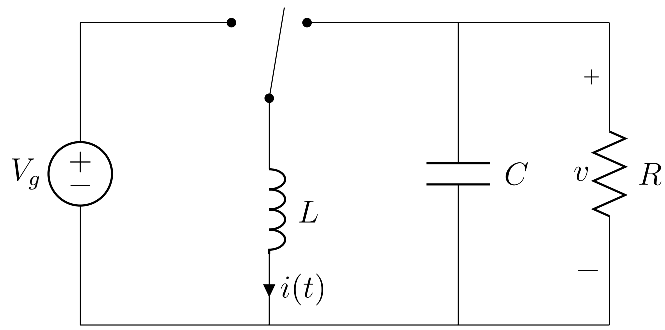
The duty ratio is $D = \frac{-V_G}{V} + 1 = -\frac{5}{20} + 1 = \frac{3}{4}$.

(b) Sketch the waveform of the MOSFET drain-to-source voltage, v_{DS}. Label the numerical values of all relevant times and voltages.
First we assume that the MOSFET is on, this means that the voltage accross the inductor is $V_L = V_{IN}$. And that means that $V_DS = 0V$. When the MOSFET is off, we can see that $V_L = V_{IN} - V_{OUT} = -15V$. In this case, $V_{DS} = 20V$



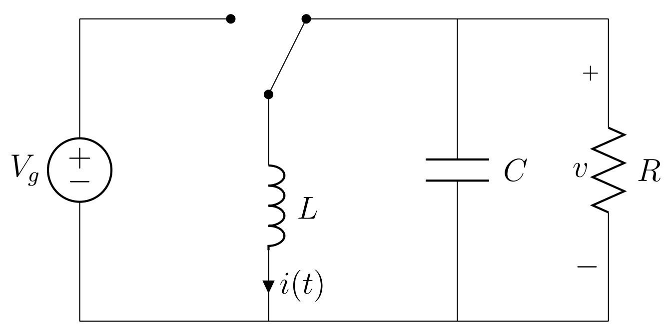
(c) Find the DC component of the voltage waveform of art (b). How does this value relate to the value of V_{IN}? Does this make sense and why?
The DC component of this waveform is $15V$. This input voltage is $5V$. We can do this because our output current will become lower than before. This fact maintains the same power.

1.2:



(a) Find the dependence of the equilibrium output voltage V and the inductor current i on the duty ratio D_s, input voltage V_g, and load resistance R. You may assume that the inductor current ripple and capacitor voltage ripple are small.

When the switch is in the closed position (to the right), the circuit will look like:



We know that

$$\frac{dI_L}{dt} = \frac{V_g}{L}$$

The change in I_L can thus be approximated by:

$$\Delta I_L = \int_0^{DT} \frac{V_g}{L} = \frac{V_g DT}{L}$$

When the circuit is in the open position, the current will flow through the inductor:

$$\frac{dI_L}{dt} = \frac{V}{L}$$

and similarily the change in the current will be:

$$\Delta I_L = \int_0^{(1-D)T} = \frac{V(1-D)T}{L}$$

Since we are in periodic steady state we know that these must be equal, and:

$$\frac{V(1-D)T}{L} + \frac{V_g DT}{L} = 0 \Rightarrow \frac{V(1-D)T}{L} = -\frac{V_g DT}{L}$$

$$\frac{V}{V_g} = \frac{-D}{1-D} \Rightarrow V = \frac{DV_g}{D-1}$$

To find the current we must first find the current throught the capacitor $i_C(t)$. In the closed and open position these are:

$$i_c(t) = \frac{-V}{R}, \text{ and } i_c(t) = -i_L - \frac{V}{R}$$

Respectively. Since we are in periodic steady state we know that the average current through the capacitor is going to be 0. This means that

$$\int_0^{DT} \frac{-V}{R} dt = \int_0^{(1-D)T} i_L + \frac{V}{R} dt$$

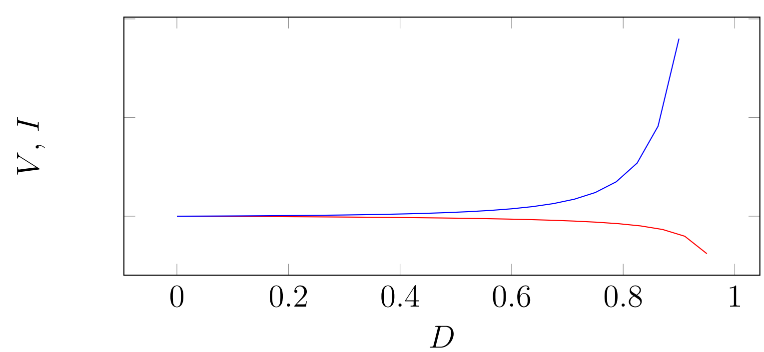
$$\frac{-VDT}{R} = \frac{V(1-D)T}{R} + (1-D)Ti_L$$

$$i_L = -\frac{VD + V(1-D)}{R(1-D)} \Rightarrow i_L = -\frac{V}{R(1-D)}$$

and using our expression for the output voltage V we find:

$$i_L = \frac{V_g D}{R(1-D)^2}$$

(b) Plot your results of part (a) over the range $0 \le D \le 1$



Where the red value is the voltage and the blue value is the current.

(c) DC design: for the specifications:

$$\begin{array}{ll} V_g = 30V & V = -20V \\ R = 4\Omega & f_\Delta = 40kHz \end{array}$$

(i) Find D and I.

We can use what we know from the last problem:

$$V = \frac{DV_g}{D-1}$$

$$D = \frac{V}{V - V_g} = \frac{-20}{-50} = \frac{2}{5}$$

To find I:

$$I \approx i_L = \frac{V_g D}{R(1-D)^2} = \frac{30 \cdot \frac{2}{5}}{4 \cdot \frac{9}{25}} = \frac{25}{3}$$

(ii) Calculate the value of L that will make the peak inductor current ripple Δi equal to ten percent of the average inductor current I.

Using our result:

$$\Delta I_L = \frac{V_g DT}{2L}$$

$$(0.10)\frac{25}{3} = \frac{30 \cdot \frac{2}{5}}{2L \cdot 40000} \Rightarrow L = 180\mu H$$

(iii) Choose C such that the peak output voltage ripple Δv is $0.1V$.

First we find i_c:

$$i_c = C\frac{dV_c}{dt} \Rightarrow \Delta V_c = \frac{IDT_s}{2C} \Rightarrow 0.1 = \frac{25}{3}\frac{\frac{2}{5}}{2C \cdot 40000}$$

$$C = 417\mu F$$