Problem 1. A periodic voltage has the waveform shown. Use the integral expression for $V_{RMS}^2$ to determine the value of X (in volts) so that $V_{RMS} = 5$ Volts.

\[ V_{RMS}^2 = (6)^2 \cdot \frac{1}{3} + (X)^2 \cdot \frac{1}{6} + (2)^2 \cdot \frac{1}{3} + (0)^2 \cdot \frac{1}{6} \]

\[ V_{RMS}^2 = 25 = \frac{36}{3} + \frac{X^2}{6} + \frac{4}{3} \]

\[ \frac{X^2}{6} = 25 - 12 - \frac{4}{3} = 13 - 4 \frac{1}{3} = 11 \frac{2}{3} \]

\[ X^2 = 6 \left( \frac{35}{3} \right) = 70, \quad X = 8.37 \text{V} \]
Problem 2. A DBR is operating in steady state, powering a constant power load. Capacitor C is 18,000 μF. Capacitor C charges for 30° to the 40 Volt peak of the 60Hz AC voltage, and then discharges for 150°, where it repeats. Determine the load power (in Watts) for the constant power load.

\[
V_{min} = 40 \cos(-30°) = \frac{40\sqrt{3}}{2} = 20\sqrt{3}
\]

\[\frac{1}{2} C (V_p^2 - V_{min}^2) = P_L = P \left[\frac{\frac{1}{2} \cdot \frac{150°}{180°}}{2f} \right]
\]

\[P = \frac{\frac{1}{2} C (1600-1200)}{150} = \frac{2(60)(180)}{(2)(150)} \left(\frac{1600-1200}{400}\right)
\]

\[P = \frac{(60)(180)(400)}{(150)C} = 518 \text{ W}
\]

get 432W if you use 180° conduction
Problem 3. The firing circuit for a light dimmer is shown. The AC voltage is 220 Vrms (50 Hz). The connected triac will “fire” when the absolute peak voltage across the 0.1 μF capacitor reaches 60 V.

Initially, R is so large that the light bulb is fully off. As you very slowly decrease R, there is a point where firing will begin. At what value of R does this occur? Hint – work this problem with phasors. Recall that when “off,” the light bulb resistance is very small.

\[ V_f = (2\pi)(50) = 100\pi R_b \]

Then when 220 V:

\[ 1V_c = \sqrt{\frac{1}{1 + j\omega RC}} = \frac{1}{\sqrt{1 + (\omega RC)^2}} \]

\[ Z = \frac{(220V_{\text{rms}})^2}{(60)^2} = 26.89 \]

\[ Z = \frac{25.89}{(100\pi)^2(0.1 \times 10^{-6})^2} \]

\[ R = 162 \, k\Omega \]

Check - OK

\[ \frac{220V_{\text{rms}}}{\sqrt{1 + 25.90}} = 60 \, V \]
Problem 1. A periodic voltage has the waveform shown. Use the integral expression for $V_{RMS}^2$ to determine the value of $X$ (in volts) so that $V_{RMS} = 4$ Volts.

\[ V_{RMS}^2 = (6)^2 \cdot \frac{1}{3} + (X)^2 \cdot \frac{1}{6} + (2)^2 \cdot \frac{1}{3} + (0)^2 \cdot \frac{1}{6} \]

\[ V_{RMS}^2 = \frac{36}{3} + \frac{X^2}{6} + \frac{4}{3} \]

\[ \frac{X^2}{6} = V_{RMS}^2 - \frac{36}{3} - \frac{4}{3} = 16 - 12 - \frac{4}{3} \]

\[ X^2 = 6 \left[ 16 - 12 - \frac{4}{3} \right] = 6 \left( 4 - \frac{4}{3} \right) = 6 \left( \frac{8}{3} \right) \]

\[ X^2 = \frac{48}{3} = 16 \]

\[ X = 4 \text{ V} \]
**Problem 2.** A DBR is operating in steady state, powering a constant power load. Capacitor C is 15,000 µF. Capacitor C charges for 30° to the 40 Volt peak of the 60Hz AC voltage, and then discharges for 150°, where it repeats. Determine the load power (in Watts) for the constant power load.

\[
P = \frac{1}{2} C \frac{1600 - 1200}{1} = 432 W.
\]
Problem 3. The firing circuit for a light dimmer is shown. The AC voltage is 220 Vrms, 50 Hz. The connected triac will “fire” when the absolute peak voltage across the 0.1μF capacitor reaches 50V.

Initially, R is so large that the light bulb is fully off. As you very slowly decrease R, there is a point where firing will begin. At what value of R does this occur? Hint – work this problem with phasors. Recall that when “off,” the light bulb resistance is very small.

\[
\begin{align*}
\tilde{V}_c & = \tilde{V}_{AN} \left[ \frac{\frac{1}{j\omega C}}{R + \frac{1}{j\omega C}} \right] = \tilde{V}_{AN} \left[ \frac{1}{1 + j\omega RC} \right] \\
\text{When } 50V
\end{align*}
\]

\[
\frac{50}{220\sqrt{2}} = \frac{1}{|1 + j\omega RC|} = \frac{1}{\sqrt{1^2 + (\omega RC)^2}}
\]

\[
\sqrt{1 + (\omega RC)^2} = \frac{220\sqrt{2}}{50}
\]

\[
(\omega RC)^2 = \left[ \frac{220\sqrt{2}}{50} \right]^2 - 1 = 37.72
\]

\[WRC = 6.142 \]

\[R = 195 \text{k\Omega} \]

Check: \[220\sqrt{2} \left[ \frac{1}{\sqrt{1 + 37.72}} \right] = 50 \text{ V} \]
Problem 1. A periodic voltage has the waveform shown. Use the integral expression for $V_{\text{RMS}}^2$ to determine the value of $X$ (in volts) so that $V_{\text{rms}} = 7$ Volts.

\[
V_{\text{RMS}}^2 = (6)^2 \cdot \frac{1}{3} + (X)^2 \cdot \frac{1}{6} + (2)^2 \cdot \frac{1}{3} + (0)^2 \cdot \frac{1}{6}
\]

\[
49 = \frac{36}{3} + \frac{X^2}{6} + \frac{4}{3}
\]

\[
\frac{X^2}{6} = 49 - 12 - \frac{4}{3} = 37 - \frac{4}{3} = 35\frac{2}{3}
\]

\[
X^2 = 6 \left(35\frac{2}{3}\right) \Rightarrow X = 14.63\text{v}
\]
Problem 2. A DBR is operating in steady state, powering a constant power load. Capacitor C is 10,000 μF. Capacitor C charges for 30° to the 40 Volt peak of the 60Hz AC voltage, and then discharges for 150°, where it repeats. Determine the load power (in Watts) for the constant power load.

\[
\frac{1}{2} C (V_p^2 - V_{min}^2) = P \quad \text{and} \quad t = \left(\frac{1}{60}\right) \left(\frac{1}{2}\right) \left(\frac{150}{180}\right) = 0.944 \text{ ms}
\]

\[
P = \frac{C (V_p^2 - V_{min}^2)}{2 \cdot t} = \frac{10^{-2} (1600 - 1200)}{2 \cdot 0.000944} = 288 \text{ W}
\]
Problem 3. The firing circuit for a light dimmer is shown. The AC voltage is 220 Vrms, 50 Hz. The connected triac will "fire" when the absolute peak voltage across the 0.1 \mu F capacitor reaches 40 V.

Initially, R is so large that the light bulb is fully off. As you very slowly decrease R, there is a point where firing will begin. At what value of R does this occur? Hint – work this problem with phasors. Recall that when “off,” the light bulb resistance is very small.

\[ W = \frac{2\pi}{50} = 100\pi \, \text{R/s} \]

\[ \text{Steady-state AC, 50Hz, No Firing.} \]

\[ V_c = \frac{1}{\omega C} \quad V_{an} = \frac{1}{1 + j\omega RC} \]

\[ |V_c| = \left| \frac{1}{1 + j\omega RC} \right| \quad V_{an} \]

\[ \text{peak} = 40 \quad \text{when firing begins} \]

\[ \left| \frac{1}{1 + j\omega RC} \right| = \frac{40}{220\sqrt{2}} = 0.1286 \]

\[ |1 + j\omega RC| = \frac{220\sqrt{2}}{40} = 7.989 \]

\[ 1^2 + (\omega RC)^2 = (5.5)^2 \cdot 2 \]

\[ (\omega RC)^2 = (5.5)^2 \cdot 2 - 1 = 59.5 \]

\[ R = \frac{59.5}{(\omega RC)^2} \]

\[ R = 246 \, \text{kΩ} \]
Problem 1. Assume that a solar panel pair has the P-V curve shown.

a. There are two values of load resistance $R$ that will draw $20 \text{ W}$ from the panel pair. Find both values. (Hint – for every $P,V$ point on the curve, there is a corresponding $R = V^2/P$)

b. If you connect only a $5 \Omega$ resistor as a load, how much power will it draw?

\[ R = \frac{V^2}{P} = \frac{(38.3)^2}{20} = 73.5 \Omega \]

\[ R = \frac{V^2}{P} = \frac{(3.7)^2}{20} = 0.68 \Omega \]

\[ P = \frac{V^2}{R} = \frac{V^2}{5} = 0.2V^2 \]

\[ \text{On graph, about 122W} \]

\[ V = 10, P = 20 \text{ W} \]
\[ V = 20, P = 80 \text{ W} \]
\[ V = 30, P = 180 \text{ W} \]
Problem 2. In this problem, a solar panel pair powers a buck converter that drives a car stereo at the lake. The output voltage is 13.6 Vdc. \( L = 100 \mu \text{H}, \quad f = 100 \frac{\text{Hz}}{\text{kHz}} \) and \( C \) is very big. The solar input voltage varies from 30V to 40V, depending on cloud conditions.

a. If your stereo draws 3A, determine the highest RMS current that you can expect in \( L \) for the 30-40V input range. Include DC and ripple current in your calculation.

\[
\text{IL}_\text{avg} = \text{I}_{\text{out}} = 3 \text{A}
\]

\[
\frac{\text{d}i_L}{\text{d}t} = \frac{V_{\text{IN}} - V_{\text{out}}}{L}, \quad \text{I}_{\text{pp}} = \frac{V_{\text{IN}} - V_{\text{out}}}{L} (DT)
\]

Switch closed, \( \frac{\text{d}i_L}{\text{d}t} = \frac{V_{\text{IN}} - V_{\text{out}}}{L} \), \( \text{I}_{\text{pp}} = \frac{V_{\text{IN}} - V_{\text{out}}}{L} (DT) \)

Switch open, \( \frac{\text{d}i_L}{\text{d}t} = -\frac{V_{\text{out}}}{L} \), \( \text{I}_{\text{pp}} = \frac{V_{\text{out}}}{L} (1 - D)T \)

From \( \text{I}_{\text{pp}} = \frac{V_{\text{out}}}{L} (1 - D)T \) we see that \( \text{I}_{\text{pp}} \) is greatest for the smallest \( D \). Since \( V_{\text{out}} = DV_{\text{IN}}, \quad D = \frac{V_{\text{out}}}{V_{\text{IN}}}, \) so the smallest \( D \) is when \( V_{\text{IN}} = 40 \), \( D = \frac{13.6}{30} = 0.45 \).

\[
\text{I}_{\text{pp}} = \frac{13.6}{100 \times 10^{-6}} (1 - 0.34) (10 \mu\text{sec}) = 0.90 \text{A}
\]

\[
\text{I}_{\text{L RMS}}^2 = \text{I}_{\text{DC}}^2 + \frac{1}{12} \text{I}_{\text{PP}}^2 = (3)^2 + \frac{1}{12} (0.90)^2 = 9.068
\]

\[
\text{I}_{\text{L RMS}} = 3.01 \text{A}
\]

\[
\text{I}_{\text{PP}} \uparrow 3 + \frac{0.90}{2} = 3.45 \text{A}
\]

\[
\text{I}_{\text{PP}} \downarrow 3 - \frac{0.90}{2} = 2.55 \text{A}
\]

\[
DT = 0.34 T
\]

\[\text{Page 3 of 4}\]
Problem 3. When selecting a MOSFET, important parameters include peak voltage, peak current, and RMS current. Consider peak current in this problem.

a. If a boost converter is providing 200W, $V_{in} = 40V$, $V_{out} = 120V$, $L = 100\mu H$, $f = 100kHz$, what will be the peak current in the MOSFET? Consider only the ideal case with DC and ripple, but ignore any possible ringing transients.

b. Draw the MOSFET current waveshape.

$\text{CURRENT FLOWS IN THE MOSFET } V_{in}$

$\text{WHEN IT IS "ON." IN THAT CASE, } \frac{di_L}{dt} = \frac{V_{in}}{L}$

$F = 100kHz \rightarrow T = \frac{1}{f} = 10\mu s$

When switch is closed, $\Delta I = \frac{\Delta x_L}{PP}$, $\Delta T = \frac{V_{in}}{L}$. $\Delta T = \frac{40}{100\mu H} (0.667)(10\mu s) = 2.67\mu A$

$5 + \frac{2.67}{2} = 6.34\mu A$

Peak MOSFET Current

$AVG = 5A$

$5 - \frac{2.67}{2} = 3.67\mu A$
Problem 1. Assume that a solar panel pair has the P-V curve shown.

a. There are two values of load resistance $R$ that will draw $60 \sqrt{\text{W}}$ from the panel pair. Find both values. (Hint – for every $P,V$ point on the curve, there is a corresponding $R = \frac{V^2}{P}$)

b. If you connect only a $15\Omega$ resistor as a load, how much power will it draw?

$$
\begin{align*}
\text{PV Pair, Bright Sun} \\
\text{V(panel) - volts} & \\
\text{P(panel) - watts} & \\
11.3\text{V} & \quad 36.8\text{V} \\
\end{align*}
$$

a) $P = \frac{V^2}{R}$, $R = \frac{V^2}{P}$

\[
\frac{(11.3)^2}{60} = 2.15\Omega
\]

\[
\frac{(36.8)^2}{60} = 23.52\Omega
\]

b) $P = \frac{V^2}{R} = \frac{V^2}{15}$

\[
\begin{array}{c|c|c}
V & P & \text{W} \\
10 & 6.7 & \\
20 & 27 & \\
30 & 60 & \\
40 & 107 & \\
35 & 82 &
\end{array}
\]

About $35\frac{1}{2}$ V, 85 W
Problem 2. In this problem, a solar panel pair powers a buck converter that drives a car stereo at the lake. The output voltage is 13.6Vdc. \( L = 100\mu H, \ f = 100\text{Hz}, \) and \( C \) is very big. The solar input voltage varies from 30V to 40V, depending on cloud conditions.

a. If your stereo draws 5A, determine the highest RMS current that you can expect in \( L \) for the 30-40V input range. Include DC and ripple current in your calculation.

\[
I_{PP} = \frac{V_{out}}{L} (1-D) T \\
I_{PP} = \frac{13.6}{100} (1-0.34)(10) = 0.136(0.66)(10) = 0.90\text{A}
\]

\[
I_{rms} = \sqrt{I_{avg}^2 + \frac{1}{2} I_{pp}^2} = (5)^2 + \frac{1}{2} (0.90)^2 = 25.07
\]

\[
I_{rms} = 5.01\text{A}
\]

b. Draw the corresponding inductor current waveform.
Problem 3. When selecting a MOSFET, important parameters include peak voltage, peak current, and RMS current. Consider peak current in this problem.

\[ T_{\text{IN\,AVG}} = 4.5 \text{ A} \]

a. If a boost converter is providing 225W, \( V_{\text{in}} = 50\text{V} \), \( V_{\text{out}} = 120\text{V} \), \( L = 100\mu\text{H} \), \( f = 100\text{kHz} \), what will be the peak current in the MOSFET? Consider only the ideal case with DC and ripple, but ignore any possible ringing transients.

\[ D = 1 - \frac{V_{\text{IN}}}{V_{\text{out}}} = 1 - \frac{50}{120} = 0.583 \]

\[ \Delta I_{pp} = \frac{V_{\text{IN}}}{L} \cdot DT = \frac{50}{100\mu\text{H}} (0.583)(10\mu) = 2.92 \text{ A} \]

When switch closes, inductor current rises from \((4.5 - \frac{2.92}{2})\) to \((4.5 + \frac{2.92}{2})\), 3.04A to 5.96A

MOSFET current same as inductor when closed, else, zero.

b. Draw the MOSFET current waveshape.

See Key #1
Problem 1. Assume that a solar panel pair has the P-V curve shown.

a. There are two values of load resistance $R$ that will draw 40 W from the panel pair. Find both values. (Hint – for every P,V point on the curve, there is a corresponding $R = V^2/P$)

b. If you connect only a 10Ω resistor as a load, how much power will it draw?

\[
\begin{align*}
V &= \frac{V^2}{R} = P \\
R &= \frac{V^2}{P} = \frac{(7.5)^2}{40} \\
R &= 1.41 \Omega \\

R &= \frac{(37.7)^2}{40} \\
R &= 36 \Omega
\end{align*}
\]

\[
\begin{align*}
P &= \frac{V^2}{R} = \frac{V^2}{10} = 0.1V^2 \\
V = 10, P &= 10 \\
20, & 40 \\
30, & 90 \\
35, & 123 \\
33, & 109
\end{align*}
\]

About 33.3 V
\[
\frac{33.3^2}{10} = 111 W
\]
Problem 2. In this problem, a solar panel pair powers a buck converter that drives a car stereo at the lake. The output voltage is 13.6 Vdc. L = 100μH, f = 100Hz, and C is very big. The solar input voltage varies from 30V to 40V, depending on cloud conditions.

a. If your stereo draws 4A, determine the highest RMS current that you can expect in L for the 30-40V input range. Include DC and ripple current in your calculation.

b. Draw the corresponding inductor current waveform.

\[
I_{PP} = \frac{V_{out}}{L} (1-D) T_{max \ when \ D \ is \ min}
\]

\[
I_{PP} = \frac{13.6 \ (1-0.34)(10\mu)}{100\mu} = 0.898 \ A
\]

\[
I_{RMS} = I_{avg} + \frac{1}{2} I_{pp} = (4)^2 + (0.898)^2 = 16.067
\]

\[
I_{RMS} = 4.101 \ A
\]

See Key #1,  

Two D's. \( D = \frac{V_{out}}{V_{in}} \)

\[
D = \frac{13.6}{30} = 0.453
\]

\[
D = \frac{13.6}{40} = 0.340 \ \text{min}
\]

\[
4 + \frac{0.898}{2} = 4.45 \ A
\]

\[
AVG = 4
\]

\[
4 - \frac{0.898}{2} = 3.55 \ A
\]
Problem 3. When selecting a MOSFET, important parameters include peak voltage, peak current, and RMS current. Consider peak current in this problem.

\[
I_{\text{IN}} = 6.25 \text{A}
\]

a. If a boost converter is providing 250W, Vin = 40V, Vout = 120V, L = 100\mu H, f = 100kHz, what will be the peak current in the MOSFET? Consider only the ideal case with DC and ripple, but ignore any possible ringing transients.

b. Draw the MOSFET current waveshape.

Switch Closed, MOSFET CURRENT = I_L,

Switch Open, MOSFET CURRENT = 0.

Switch Closed

\[
\Delta I = \frac{V_{\text{IN}}}{L} \cdot DT = \frac{40}{100\mu} \cdot \left(\frac{2}{3}\right) \cdot 10\mu
\]

\[
\Delta I = 2.67\text{A}
\]

Range from \(6.25 - \frac{2.67}{2}\) to \(6.25 + \frac{2.67}{2}\)

\[
4.92\text{A} \quad 7.59\text{A}
\]
Problem 1. H-Bridge as a High Voltage Pulse Generator.

By applying +12V and 0V directly to the A+/A- and B+/B- inputs of your H-bridge optocoupler circuits, your H-bridge will produce a string of powerful output pulses.

The desired H-bridge output is shown below. It has three states (i.e., +Vdc, 0, and −Vdc). Carefully sketch the required A+/A- and B+/B- signals on the graph provided.

One signal for \( A^+ / A^- \), one signal for \( B^+ / B^- \).

\( A^+ \) on \( A \) is on, but not both

\( B^+ \) or \( B^- \) is on, but not both

Do the \( A^+ , B^- \) first,
Then the \( A^- , B^+ \),
Then the \( A^+ , B^+ \) (or \( A^- , B^- \))
Problem 2. Green H-Bridge Goes to the Lake.

You take your H-bridge to the lake and power it with a 15W, 12V portable solar panel. The power output curve of the solar panel in full sun is shown in the graph. You will use the H-Bridge to amplify a mono music signal and drive two parallel 8Ω speakers.

What value of \( m_a \) will give you the loudest music in full sun?

\[
|\tilde{V}_{ac}\| = m_a \frac{V_{dc}}{\sqrt{2}}, \quad P_{speakers} = 15W = \left(\frac{V_{ac, rms}}{4\Omega}\right)^2
\]

**General Form**

\[
P_{speakers} = \frac{Nac l^2_{rms}}{R_{speaker}} = \left[ m_a \frac{V_{dc}}{\sqrt{2}} \right]^2
\]

\[
m_a \frac{V_{dc}}{\sqrt{2}} = \sqrt{P_{speaker} R_{speaker}}
\]

\[
m_a = \frac{\sqrt{2 P_{speaker}} R_{speaker}}{V_{dc}} = \sqrt{\frac{2(15)(4)}{16}} = 0.685
\]

**Note** — with \( R = 16\,\Omega \) (our setup in the lab), you can't get max power because the \( m_a > 1 \) (and the \( m_a \frac{V_{dc}}{\sqrt{2}} \) assumption is invalid).
Problem 3. H-Bridge Disguises as a Negative Resistor

Equation:

\[ V_{ac} = \frac{m_a V_{dc}}{\sqrt{2}} \sin(\omega t) \]

\[ V_{outlet} = \frac{120}{\sqrt{2}} \sin(\omega t) \]

\[ I_{rms} = \frac{V_{ac_{rms}} - V_{outlet_{rms}}}{R_{HB}} = \frac{m_a \frac{V_{dc}}{\sqrt{2}} - V_{out+}}{R_{HB}} \sin(\omega t) \]

\[ I_{rms} R_{HB} = \frac{m_a \frac{V_{dc}}{\sqrt{2}} - V_{out+}}{R_{rms}} \]

\[ M_a = \frac{\sqrt{2}}{V_{dc}} \left[ I_{rms} R_{HB} + V_{out+} \right] = \frac{\sqrt{2}}{250} \left[ 12(1) + 120 \right] \]

\[ M_a = 0.747 \]
Problem 1. A number of our solar panels are combined in series and parallel to create a large PV array. For bright sun, the array has the following I-V curve.

![I-V Curve Graph]

Suppose that you want to use the PV array and a buck converter to power a large DC load. A PI controller is employed to adjust duty cycle \( D \) to keep the load voltage at 13.2V. For the I-V curve shown, what range of duty cycle \( D \) will provide 500W and greater?

For the 83V point, \( D = \frac{13.2}{83} = 0.159 \)

For the 23V point, \( D = \frac{13.2}{23} = 0.574 \)

\[ 0.159 \leq D \leq 0.574 \]
Problem 2. Green H-Bridge Goes to the Lake.
You take your H-bridge to the lake and power it with a portable solar panel. P-V curve shown below.

Suppose that you borrow the four 8Ω speakers from the power lab (with permission, of course). Your objective is to play the loudest music possible, with 0.80 ≤ m<sub>a</sub> ≤ 1.0 so there is not much distortion. How should you configure the four 8Ω speakers (i.e., series, parallel, series/parallel) to get the loudest music? How many Watts can you get?

Load panel to 6.375Ω to get MAX power

Power Balance

\[ P_{\text{max}} = \frac{(m_a V_{\text{MP}})^2}{R_{\text{speakers}}} \]

For 0.8 ≤ m<sub>a</sub> ≤ 1.0,

\[ \frac{(0.8)^2(14.5)^2}{2(33)} \leq R_{\text{speakers}} \leq \frac{(1)^2(14.5)^2}{2(133)} \]

\[ 2.03 \Omega \leq R_{\text{speakers}} \leq 3.19 \Omega \]

4 speakers in parallel = 2.5Ω (OK)
3 speakers in parallel = \( \frac{8}{3} \)Ω = 2.67Ω (great!)
Problem 3. Design a Boost Converter

Design a boost converter that meets the following specs: $V_{in}$ (range) = 35-40Vdc, 
$V_{out}$ (fixed) = 120Vdc, $P_{out}$ (range) = 100-200W, $f$ = 50kHz.

- Determine the smallest inductor $L$ (step sizes of 10μH) that guarantees continuous conduction.
- Determine the output capacitor $C$ (step sizes of 100μF) that holds the peak-to-peak ripple voltage below 0.5V.
- Determine the peak MOSFET and diode currents.

Discontinuous current is most likely to occur at low $P$, when $I_{in}$ is smallest, and for high $V_{in}$ (thus smallest $D$) so the $L$ discharge is longest.

So, $P = 100W$, $V_{in} = 40V$, $D = \frac{2}{3}$, for this condition, $I_{in} = \frac{100W}{40V} = 2.5A$. Switch closed, $\Delta I_{in} = \frac{V_{in}D}{L}$. Set $\Delta I_{in} = 2I_{in} = 5A$.

$$L = \frac{V_{in}D}{F\Delta I_{in}} = \frac{40(\frac{2}{3})}{(50\times10^3)(2)(2.5)} = 106.7 \mu H$$

So, pick $L = 110 \mu H$

$\Delta V$ on the cap is highest for high power load, and max $D$. Max $D = 1 - \frac{35}{120} = 0.708$

$$\Delta Q = C \Delta V, \Delta V = \frac{\Delta Q}{C} = \frac{I_{out}(DT)}{C} = \frac{I_{out}D}{FC}$$

$$C = \frac{I_{out}D}{F \Delta V} = \frac{200W (0.708)}{120V} = \frac{35(0.708)}{(50\times10^3)(0.5)} = 47.2 \mu F$$

Use 100μF

Peak MOSFET current = Peak L current = $\frac{AVG}{V_{out}} = \frac{200W}{35V} + \frac{AT}{2} = 5.71 + \frac{8.2}{2} = 8.2A$

Peak Diode current same as peak L current = 8.2A
Problem 1. A number of our solar panels are combined in series and parallel to create a large PV array. For bright sun, the array has the following I-V curve.

Suppose that you want to use the PV array and a buck converter to power a large DC load. A PI controller is employed to adjust duty cycle $D$ to keep the load voltage at 13.2V. For the I-V curve shown, what range of duty cycle $D$ will provide 400W and greater?

For the 19V point, $D = \frac{13.2}{19} = 0.695$

For the 84V point, $D = \frac{13.2}{84} = 0.157$

$0.157 \leq D \leq 0.695$
Problem 2. Green H-Bridge Goes to the Lake.
You take your H-bridge to the lake and power it with a portable solar panel. P-V curve shown below.

Suppose that you borrow the four 8Ω speakers from the power lab (with permission, of course). Your objective is to play the loudest music possible, with 0.90 ≤ \( M_a \) ≤ 1.0 so there is not much distortion. How should you configure the four 8Ω speakers (i.e., series, parallel, series/parallel) to get the loudest music? How many Watts can you get?

\[
\frac{V^2}{R_{eq}} = \frac{P}{R_{eq}} = \frac{V^2}{6.37\, \Omega}
\]

To deliver max power, the solar panel should see 6.37Ω.

Conservation of power:

\[
\frac{V_{panel}^2}{R_{eq}} = \left( \frac{M_a \cdot V_{panel}}{\sqrt{3}} \right)^2, \quad \text{so} \quad \frac{1}{R_{eq}} = \frac{M_a^2}{2 R_{speakers}}
\]

So

\[
R_{speakers} = \frac{M_a^2 \cdot R_{eq}}{2}
\]

For 0.9 ≤ \( M_a \) ≤ 1.0

\[
0.81 \frac{R_{eq}}{2} \leq R_{speakers} \leq \frac{R_{eq}}{2}
\]

\[
2.58 \, \Omega \leq R_{speakers} \leq 6.37 \, \Omega = 3.19 \, \Omega
\]

4 in parallel = 2.5Ω (no)
3 in parallel = \( \frac{8}{3} \, \Omega = 2.67 \, \Omega \) (yes!)
Problem 3. Design a Boost Converter

Design a boost converter that meets the following specs: Vin (range) = 35-40Vdc, Vout (fixed) = 180Vdc, Pout (range) = 100-200W, f = 50kHz.

- Determine the smallest inductor L (step sizes of 10μH) that guarantees continuous conduction.
- Determine the output capacitor C (step sizes of 100μF) that holds the peak-to-peak ripple voltage below 0.5V.
- Determine the peak MOSFET and diode currents.

Reasoning given in V1 Key

\[ P = 120W; \quad V_{\text{in}} = 40; \quad D = 1 - \frac{40}{100} = 0.60 \]

\[ I_{\text{in}} = \frac{120W}{40} = 3A \]

\[ L = \frac{V_{\text{in}} D}{f \cdot A_{\text{in}}} = \frac{40(0.6)}{(50 \times 10^{-3})(5.0)} = 96\mu H, \quad \text{so use } 100\mu H \]

\[ \Delta V = \frac{A_{\text{out}} \cdot (D)}{C} \quad \Rightarrow \quad C = \frac{I_{\text{out}} \cdot D}{f \cdot \Delta V} \]

Use \( \text{MAX} \) \( D = 1 - \frac{35}{100} = 0.65 \)

\[ C = \frac{200W}{100V} \cdot 0.65 \]

\[ = \frac{200W}{180V} \cdot (50 \times 10^{-3})(0.5) = 52\mu F \quad \Rightarrow \quad \text{Use } 100\mu F \]

Peak diode & MOSFET currents same as peak L current. Add the ripple to \( I_{\text{in}} \) for \( \text{MAX} P \).

\[ I_{\text{in}} = \frac{200W}{35V} = 5.71 \]

\[ \text{MAX} = 5.71 + \frac{5}{2} = \approx 8.2A \]