Motivation: This problem set is designed to expose you to different uncontrolled (a.k.a passive) rectifier circuits that are available for ac-to-dc power conversion. Apart from practicing problem-solving, the key takeaways for you should include:

- sketching waveforms to clarify your understanding (this is an extremely important step to get insights in power-electronic circuits)
- comparing different available options (as a designer you will always have to make choices)
- getting exposed to simulation tools that are available to understand complex circuits (use these simulation tools to enhance, support, and verify your understanding)

Problem 1.1
Consider the full-wave bridge rectifier shown in Fig. 1.1, where $V_{in}$ is a 120 Vrms, 60 Hz sinusoidal voltage source. The load resistor $R$ is 5 Ω. The 20:1 ideal transformer steps down the line voltage.

![Fig 1.1: Full-wave bridge rectifier](image)

(a) Sketch the voltage labeled $V_{out}$, and the current drawn from the AC voltage source ($I_{in}$) over a full line cycle. Label maximum amplitudes of both voltage and current.
(b) Calculate the average power consumed by the resistor.
(c) Calculate the input power factor of this rectifier.
(d) Calculate the ripple factor of the output voltage.

Problem 1.2
Consider now the center-tapped rectifier shown in Fig. 1.2, where $V_{in}$ is a 120 Vrms, 60 Hz sinusoidal voltage source. The load resistor is 5 Ω. The secondary side of the transformer has a third connection at the center point (i.e., there are as many turns of winding above as below the connection).
Problem 1.3

Compare and contrast the three topologies of the passive single-phase rectifiers (a) Half-wave rectifier (discussed in class) (b) Full-wave bridge rectifier (Prob. 1.1), and (c) Center-tapped transformer rectifier (Prob. 1.2). Assume that the rectifiers are all connected to a purely resistive load driving identical power from a wall supply (120 V_{rms}, 60 Hz).

**Hint:** While some of the quantitative ways to compare them could be input power factor, ripple factor, number of devices, etc. rest depends on you.

Problem 1.4 (KSV 3.2)

Use the method of assumed states to show that diode D_1 and D_2 cannot be on simultaneously in the following rectifier circuit.

Fig 1.4: Half wave rectifier with an inductor (L) and a free-wheeling diode (D_2).
Problem 1.5
Find $V_{out}$ as a function of $V_{in}$ and $V_{dc}$ for the rectifier of Fig. 1.5. For simplicity, assume all resistors have identical values, i.e., $R=R_1$. Note that $V_{in}$ can have magnitude smaller or larger than $V_{dc}$. Your answer must handle both cases.
This circuit, for example, may be encountered in a battery charging application, where $R$ would represent the equivalent series resistance of the battery and $V_{dc}$ would represent the battery voltage.

Problem 1.6 (Krein Ch 4, Problem 1)
A full-wave bridge rectifier is to be designed to provide $5 \text{ V} \pm 3\%$ for a logic circuit, with output power of up to $12 \text{ W}$. The input is a conventional $120 \text{ V}$, $60 \text{ Hz}$ source (a wall plug). Choose a transformer ratio, diode configuration, diode voltage rating, diode current rating, and capacitor value ($C_{\text{designed}}$). Model the diodes as having a $1 \text{ V}$ forward drops.
Simulate the circuit in LTSpice. You can download and install LTSpice from the course website. Also there is a short “tutorial” in the homework section to help you to explore the software.

Hint: You do not need to include the transformer in the simulation model. Assuming that the transformer is ideal, you can model the transformer secondary as an ideal sinusoidal voltage source with appropriate magnitude and frequency.

(a) Plot the output voltage and the input current when the load is drawing $12 \text{ W}$. Compare the output voltage ripple to the design specification.
(b) Find out the power factor and the ripple voltage under the following cases:
   i. Output power $= 12 \text{ W}$, Output filter capacitance $= C_{\text{designed}}$
   ii. Output power $= 6 \text{ W}$, Output filter capacitance $= C_{\text{designed}}$
   iii. Output power $= 12 \text{ W}$, Output filter capacitance $= C_{\text{designed}}/10$
   iv. Output power $= 6 \text{ W}$, Output filter capacitance $= C_{\text{designed}}/10$
(c) What do you observe in part (b)? Justify your observation.