Design of a flyback converter using a zero-voltage switching quasi-square wave resonant switch. Figure 1 illustrates a flyback converter based on the quasi-square wave zero-voltage switching resonant switch analyzed in class. The transformer magnetizing inductance operates as the resonant tank inductor. The transformer leakage inductances are much smaller than the magnetizing inductance, and can be neglected. The MOSFET and diode output capacitances are modeled in Fig. 1 by the single lumped capacitance $C$; this capacitance functions as the tank capacitance of the QSW-ZVS resonant switch. Output filter capacitance $C_F$ is large and has negligible ripple.

(a) Write the complete set of equations that can be solved to find the steady-state output voltage $V$. It is not necessary to re-derive the QSW-ZVS equations that were derived in lecture.

(b) It is desired to design the converter to operate with the following:

- $V_g = 30$ V
- Output: 45 V at 60 W
- Switching frequency: 500 kHz
- Turns ratio $n = 0.5$
- $Q = \text{Load} / \text{Characteristic impedance} = 5$. (Be sure to refer both quantities to the same side of the transformer.)

Choose element values to achieve the required design. Specify: $\mu$, $f_0$, $R_0$, $L$, $C$, and the resulting peak inductor current. Refer all quantities to the primary side of the transformer.

Analysis of a quasi-square wave zero-voltage switching resonant switch that employs a synchronous rectifier. Figure 2 illustrates a buck converter containing a synchronous rectifier. This converter employs an extension of the quasi-square wave resonant switch, to achieve zero-voltage switching of both the origi-
nal transistor and the synchronous rectifier. As discussed in lecture, it is possible to operate this converter at constant switching frequency, and to obtain zero-voltage switching not only for $\mu > 0.5$, but also for $\mu < 0.5$.

(a) Use state-plane analysis to derive the complete set of equations that can be solved for the output characteristics of the converter. Explicitly show all steps in your derivation. It is not necessary to solve your equations.

(b) Write the conditions that guarantee zero-voltage switching of all semiconductor devices.

3 A buck converter contains a QSW-ZVS resonant switch, with a single transistor (i.e., no synchronous rectifier). This converter is controlled using peak current-mode control with a variable switching frequency, as follows:

   - The MOSFET is turned on when the controller senses that the drain-to-source voltage is close to zero.
   - The MOSFET is turned off when the controller senses that the drain current is equal to a reference control value $i_c$.

(a) Write the complete set of equations that can be solved for the output characteristics of the converter.

(b) Use your results of part (a) to plot the normalized output characteristics of the converter. Plot the complete characteristics (over the entire range where they are valid) for the values $i_c R_0 / V_g = 2, 5, \text{and } 10$. 