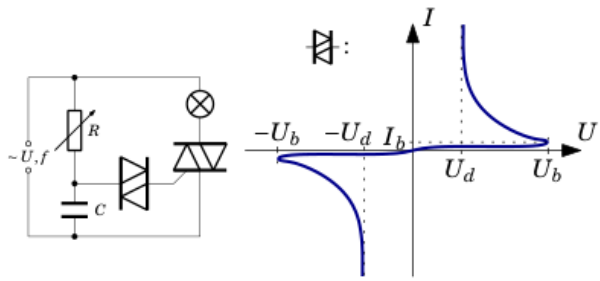
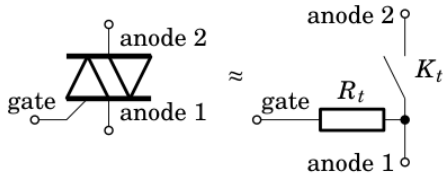
4. DIMMER (9 points) — *Siim Ainsaar.* A dimmer for controlling the brightness of lighting consists of a rheostat, a capacitor, a diac and a triac, connected as in the schematics.



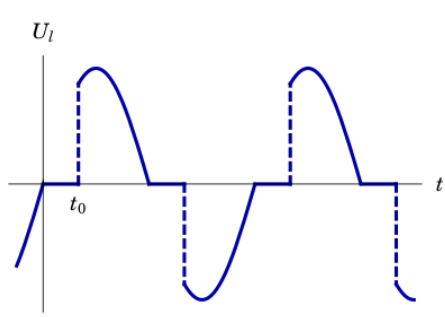
A diac is a component whose behaviour is determined by the voltage-current diagram shown above. A triac, on the other hand, can be thought of as a switch controlled by current — look at the following equivalent schematics.



The switch K_t is open as long as the current through the triac's gate stays under the threshold current I_t; closes when the threshold current is applied (in either direction) and stays closed while a current is flowing through the *switch* K_t (the gate current is irrelevant until the switch opens again).

i) *(3 points)* Assume that the resistance R_t is large enough that the charge moving through the diac can be neglected. Let the sinusoidal supply voltage have a maximum value of U and a frequency of f; the rheostat be set to the resistance R and the capacitor's capacitance be C. Find the maximum value of the voltage U_C on the capacitor, and its phase shift φ with respect to the supply voltage.

ii) *(2 points)* What inequality should be satisfied by the diac's characteristic voltages U_b and U_d, triac's threshold current I_t and gate resistance R_t to ensure that when the diac starts to conduct (while the voltage on the capacitor rises), then the triac would also immediately start to conduct? You may assume that $I_b < I_t$ and that the diac's voltage at current I_t is U_d.



iii) *(2 points)* The voltage U_l on the lamp follows the plot above. Let's assume that the assumption of part i) and the inequality of part ii) hold. Find the time t_0 during which the voltage on the lamp is zero.

iv) *(2 points)* Express through t_0 and f, how many times the average power of the lamp is lower than the one of a lamp without a dimmer, assuming that the resistance of the lamp is unchanged.