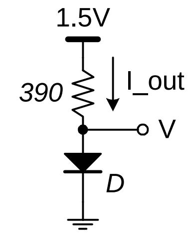
# EE42 - Problem Set #11 Solution

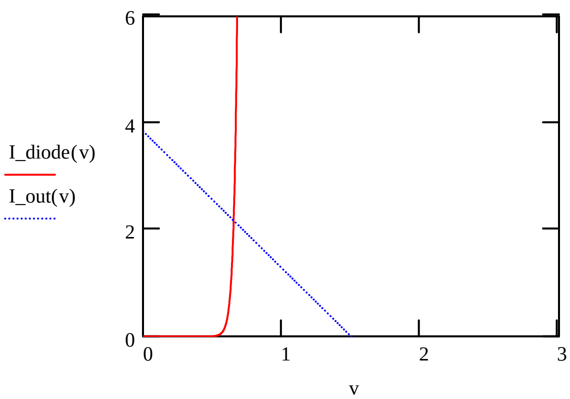
11.1.a-c output voltage: $v := 0, 0.001 .. 3$

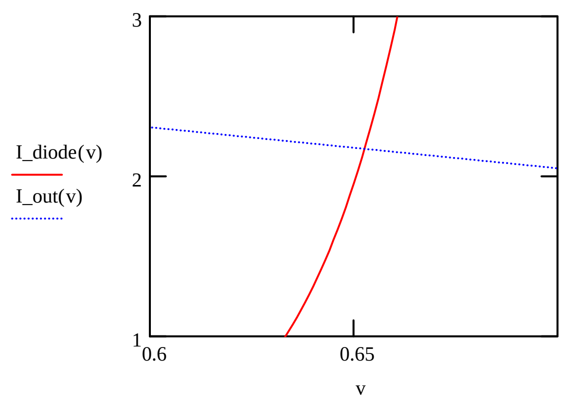
Diode current: $I\_diode(v) := 1000 \times 10^{-14} \cdot \left( e^{\frac{v}{0.025}} - 1 \right)$ mA

Resistor current: $I\_out(v) := 1000 \dfrac{(1.5 - v)}{390}$ mA



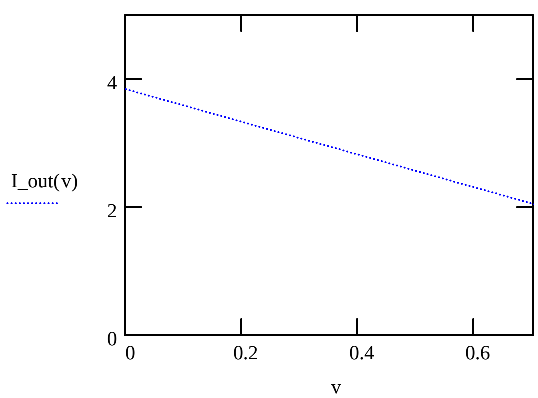

11.1




The soln read from the zoom-in plot is: $I\_diode = I\_out = 2.2\text{mA}$

11.1.d-e




d) intercept to V=0.7 line is large-signal diode model soln: $I\_out = 2.1\text{mA}$

e) intercept to V=0 line is perfect rectifier model soln: $I\_out = 3.8\text{mA}$

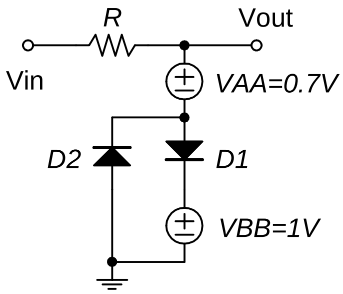
Note, obviously, the large-signal diode model yields a better accuracy.

**11.2.a-b**

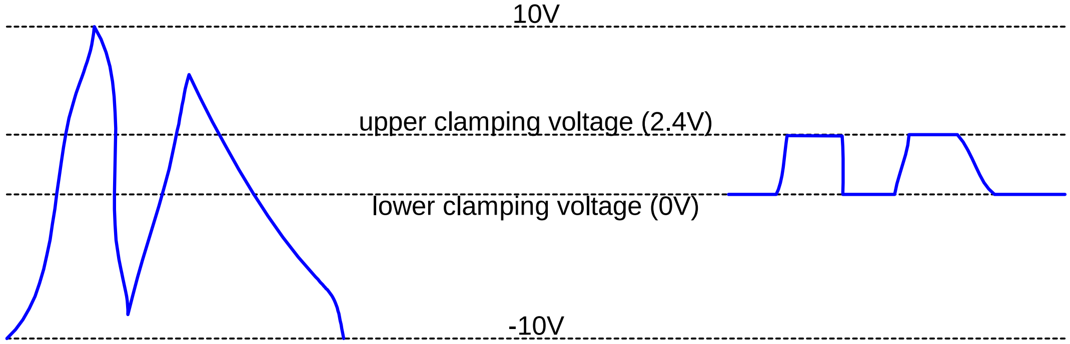
D1 turns on when:
Vout=VAA+V_turn_on_D1+VBB=0.7+0.7+1=2.4V
=> sets the upper clamping voltage

D2 turns on when:
Vout=0.7-0.7=0V
=> sets the lower clamping voltage

Note that R value does not matter in the problem as diode is treated as "ideal".

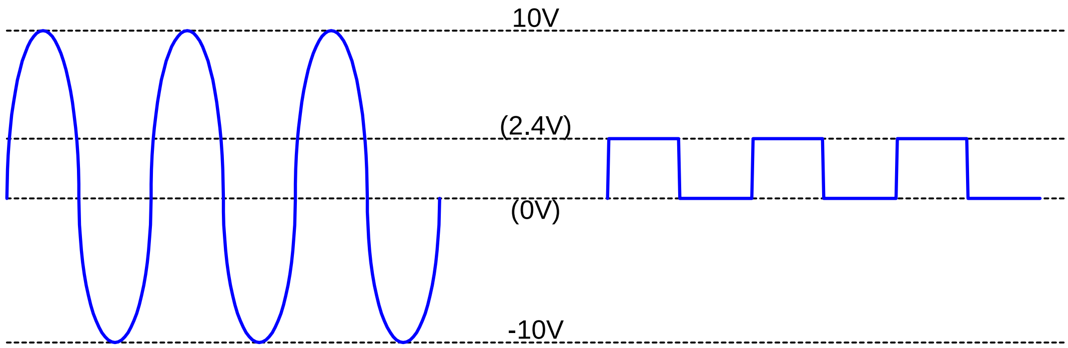



11.2




**11.2.c**

The slow varying top and bottom of the sinewave will be clipped, so the output waveform is more square-waving.




**11.3.a**

Assume every donor atom is ionized and each donor contributes one electron,

$$N = \frac{10^{13}\text{cm}^{-2}}{t} = \frac{10^{13}\cdot\text{cm}^{-2}}{0.1\mu\text{m}} = 10^{18}\text{cm}^{-3}$$

**11.3.b**

$$\sigma = q\cdot\mu\cdot N = 1.6\cdot 10^{-19}\text{C}\cdot 400\frac{\text{cm}^2}{\text{V}\cdot\text{s}}\cdot 10^{18}\text{cm}^{-3} = 64\frac{\text{C}}{\text{V}\cdot\text{s}\cdot\text{cm}} = 64\cdot\frac{1}{\Omega\cdot\text{cm}}$$

**11.3.c**

$$R_{\text{square}} = \frac{\rho}{t} = \frac{1}{\sigma\cdot t} = \frac{1}{64}\cdot\Omega\cdot\text{cm}\cdot\frac{1}{0.1\mu\text{m}} = 1562.5\Omega$$

**11.3.d**

$$R = \frac{L}{W}\cdot R_{\text{square}} = \frac{3\mu\text{m}}{0.2\mu\text{m}}\cdot 1562.5\Omega = 23.4\text{k}\Omega$$

11.4.a $$C_{ox} = \frac{\varepsilon_R \cdot \varepsilon_0}{t} = 3.9 \cdot 8.85 \cdot 10^{-14} \frac{F}{cm} \cdot \frac{1}{10nm} = 3.45 \cdot 10^{-7} \frac{F}{cm^2} = 3.45 \cdot \frac{fF}{\mu m^2}$$

11.4.b $$C_G = (LW) \cdot C_{ox} = 1\mu m \cdot 0.25\mu m \cdot 3.45 \cdot 10^{-7} \cdot \frac{F}{cm^2} = 0.8625fF$$

11.4.c $$Q_G = C_G \cdot \left(V_{GS} - V_T\right) = 0.8625 \cdot fF \cdot (3V - 1V) = 1.725fC$$

11.4.d $$N_e = \frac{Q_G}{e} = \frac{1.725fC}{1.6 \cdot 10^{-19}C} = 10781$$

11.4.e $$R_{square} = \frac{1}{q \cdot \mu \cdot N \cdot t} = \frac{1}{1.6 \cdot 10^{-19}C \cdot 1000 \frac{cm^2}{V \cdot s} \cdot \frac{10781}{0.25 \cdot \mu m^2}} = 1449.3 \cdot \Omega$$

$$R = \frac{W}{L} \cdot R_{square} = \frac{1\mu m}{0.25\mu m} \cdot 1449.3\Omega = 5.8k\Omega$$

Note the conduction of a MOSFET is along the width direction by definition.

11.4.f $$k_D = \frac{W}{L} \cdot \mu \cdot C_{ox} = \frac{1\mu m}{0.25\mu m} \cdot 1000 \frac{cm^2}{V \cdot s} \cdot 3.45 \frac{fF}{\mu m^2} = 1.38 \cdot \frac{mA}{V^2}$$

Note that $V_{D\_SAT}$ is not useful in deriving $k_D$ in this problem.