$\boxed{11.1}$ a) $\psi(x) = e^{ikx}\left(Ae^{i(q-k)x} + Be^{-i(q+k)x}\right)$

$$\left[E + \frac{\hbar^2}{2m}\frac{d^2}{dx^2}\right]\psi = \sum_{n=-\infty}^{\infty} V_0\,\delta(x-n\Delta)\,\psi$$

$$E\psi + \frac{\hbar^2}{2m}\frac{d^2\psi}{dx^2} = \sum_{n=-\infty}^{\infty} V_0\,\delta(x-n\Delta)\,\psi$$

$$\int_{-\epsilon}^{\epsilon}\left(E\psi(x) + \frac{\hbar^2}{2m}\frac{d^2\psi}{dx^2}\right)dx = \sum_{n=-\infty}^{\infty} V_0\int_{-\epsilon}^{\epsilon}\left(\delta(x-n\Delta)\,\psi(x)\right)dx$$

$$E\int_{-\epsilon}^{\epsilon}\psi(x)\,dx + \frac{\hbar^2}{2m}\frac{d\psi}{dx} = E\cdot\frac{1}{q}\,2(A+B)\sin(\epsilon\cdot q) + \frac{\hbar^2}{2m}\frac{d\psi}{dx}$$

$$\delta(x-n\Delta)\,\psi(x) = \delta(x-n\Delta)\,e^{ikx}\left(Ae^{i(q-k)x} + Be^{-i(q+k)x}\right)$$

$$= A\delta(x-n\Delta)\,e^{iqx} + B\delta(x-n\Delta)\,e^{i(2k-q)x}$$

?

$\boxed{11.2}$ $f(E_c) = \dfrac{1}{1+e^{(E_c-E_F)/kT}}$

For an undoped semiconductor, $E_F = \frac{1}{2}(E_c+E_v)$

$\hookrightarrow E_c - E_F = \frac{1}{2}(E_c - E_v)$

$= \frac{1}{2}E_g$

$f(E_c) = \dfrac{1}{1+e^{\frac{1}{2}E_g/kT}}$, $kT = .026eV$

Ge : $E_g = .67\,eV \rightarrow f(E_c) = \boxed{2.54\times10^{-6}}$

Si : $E_g = 1.11\,eV \rightarrow f(E_c) = \boxed{5.36\times10^{-10}}$

Diamond : $E_g = 5eV \rightarrow f(E_c) = \boxed{1.74\times10^{-42}}$

$\boxed{11.3}$ a) Arsenic = n-type

$n \approx 10^{17}\ cm^{-3}$

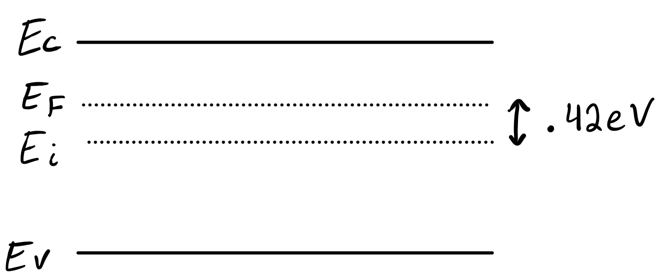
$n_i^2 = np \rightarrow p = \dfrac{n_i^2}{n} = \dfrac{(10^{10})^2}{10^{17}} = \boxed{10^3\ cm^{-3}}$

b) $p = n_i\, e^{(E_i-E_F)/kT}$

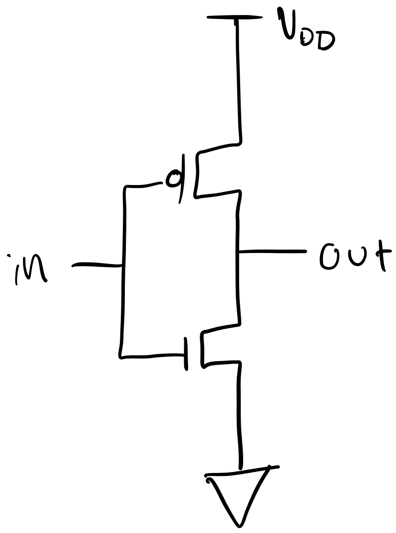
$e^{(E_i-E_F)/kT} = \dfrac{10^3}{10^{10}} = 10^{-7}$

$\dfrac{E_i-E_F}{kT} = \ln(10^{-7})$

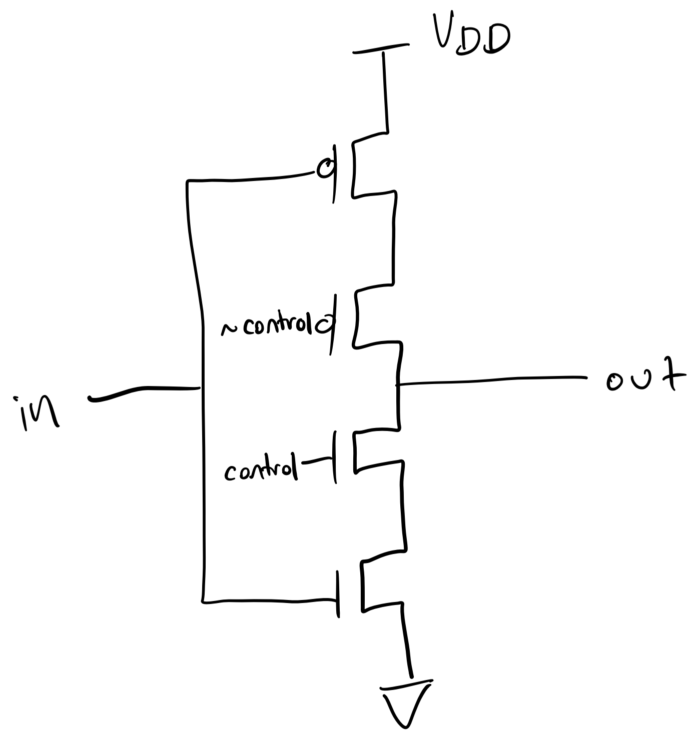
$E_i - E_F = -0.42eV$



$\boxed{11.4}$ Regular inverter:



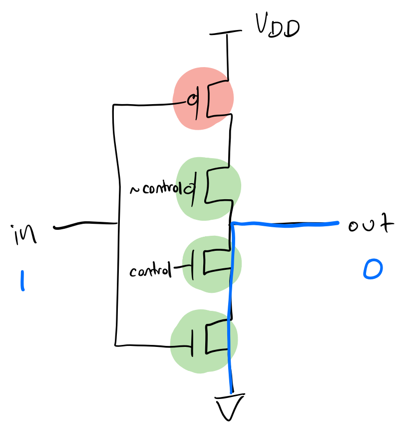
Tristate:

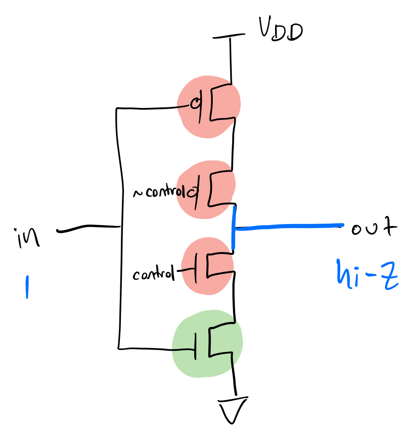


Control = 1:

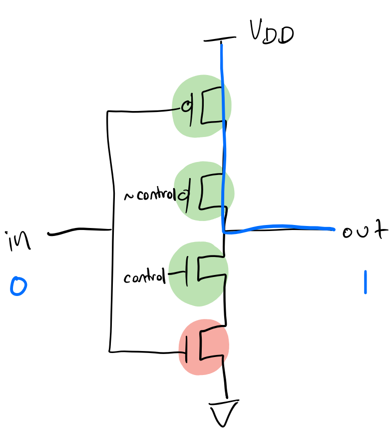
Control = 0:

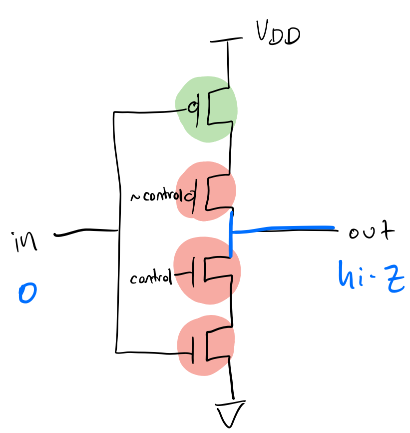
in = 1:



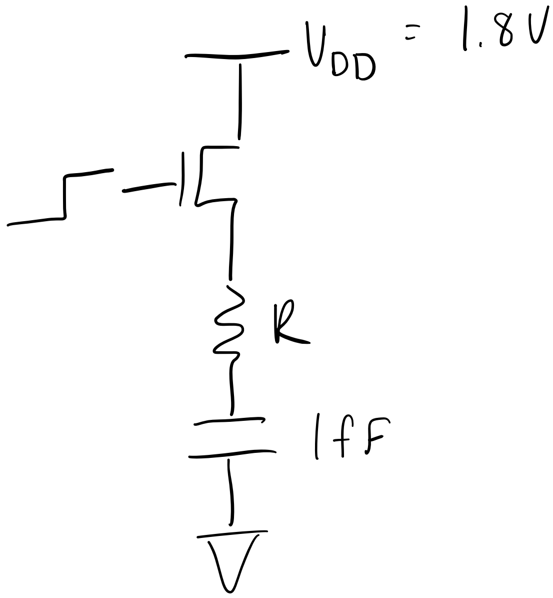


in = 0:





11.5



a) $E = \frac{1}{2} C V^2 = \frac{1}{2} \cdot 1fF \cdot (1.8V)^2 = \boxed{1.62 fJ}$

b) $I = \frac{V_{DD}}{R} e^{-t/\tau}$ where $\tau = RC$

$$E = \int_0^\infty \underbrace{I^2 R}_{P} \, dt = \int_0^\infty \left(\frac{V_{DD}}{R} e^{-t/RC} \right)^2 R \, dt$$

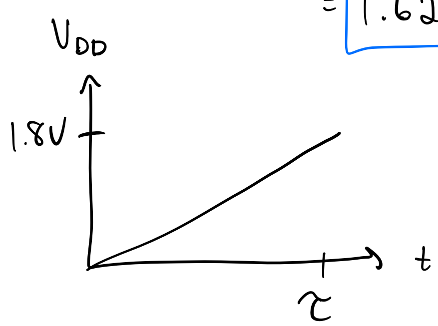
$$= \frac{V_{DD}^2}{R} \int_0^\infty e^{-2t/RC} \, dt$$

$$= \frac{V_{DD}^2}{R} \cdot \frac{1}{2} RC$$

$$= \frac{1}{2} C V_{DD}^2$$

$$= \boxed{1.62 fJ}$$

c)



Should be same, $\boxed{E = \frac{1}{2} C V_{DD}^2}$

$= 1.62 fJ$

d) $E_{tot} = CV_{DD}^2$

$1W = CV_{DD}^2 \cdot \frac{1}{t}$

$t = CV_{DD}^2 \approx 1.62 fs$

$\therefore$ $\boxed{\text{charge in } \frac{1}{2}CV_{DD}^2, \text{ discharge in } \frac{1}{2}CV_{DD}^2}$

Frequency: $\frac{1}{CV_{DD}^2} = 6.17 \times 10^{14}\ Hz = 614\ THz$

e) $P = CV_{DD}^2 \cdot \frac{1}{10^9}\ s$

$= 3.24 \times 10^{-24}\ W$ per transistor

$P_{total} = \boxed{3.24\ fW}$

f) $Q = CV_{DD} = 1.8\ fC$

$1.60 \times 10^{-19}\ C$ per e^-

$\hookrightarrow \frac{1.8\ fC}{1.60 \times 10^{-19}\ C} = \boxed{11{,}250\ e^-s}$