1)

(1) $Q_{det} = 2 \times 10^{-13}$ coul

$V_{leak} = I_{leak} R \rightarrow I_{leak} = \frac{V}{R}$

$I_{leak} = 600 V / 10^{12} \Omega = 6 \times 10^{-10}$ Amp

$$\text{Ratio} = \frac{Q/\Delta t}{I_{leak}} = \frac{2 \times 10^{-13} \text{ coul}}{\Delta t \times 6 \times 10^{-10} \text{ Amp}}$$

$$\text{Ratio} = \frac{3.3 \times 10^{-4} \text{ s}}{\Delta t}$$

thus the signal will only be large relative to the leakage current when the Δt of the signal is less than 330 μsec

N.B. an estimate of Δt can be obtained from Eq 6.33 in the text if you know anode diameter

(2) $Q_{det} = 2 \times 10^{-13}$ coul $=$ Gain * (Q in gas)

Reaction is $n + {}^{10}B \rightarrow {}^{7}Li^{*} + {}^{4}He$ 94%
$\hookrightarrow {}^{7}Li + {}^{4}He$ 6%

Energy is 94% 2.31 MeV, 6% 2.79 MeV } 2.34 MeV average energy

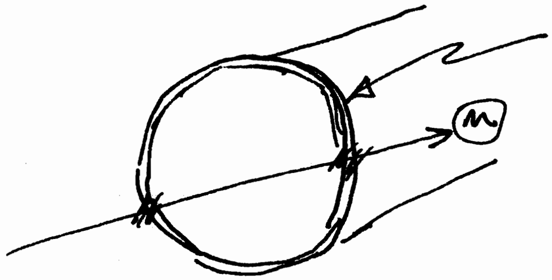
- Boron coated wall ... only ½ of energy goes into gas because the two-body decay sends other fragment into wall

$$\text{Gain} = Q_{det} / Q_{in\,gas} = \frac{2 \times 10^{-13} \text{ coul} / 1.602 \times 10^{-19} \text{ coul}/e^-}{\left(\frac{1}{2}\right) 2.34 \text{ MeV} \times 10^{6} \frac{eV}{MeV} \Big/ W \frac{eV}{IP}} = 1.07\, W$$

- note that W for gas was not specified in original problem use a "typical" value of 30 eV/IP

$$\text{Gain} = \frac{Q_{det}}{Q_{in\,gas}} = 1.07\, W = 32.$$

2)



Boron coating on wall

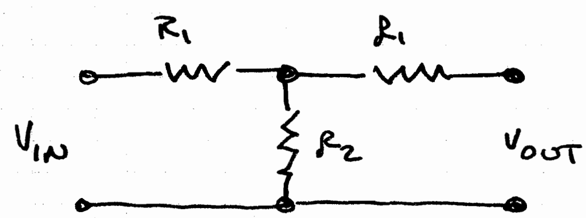
note that because the neutron ~~easy~~ capture efficiency is low the neutron is likely to go through the detector and can react with the coating on entering and exiting

$$\epsilon = N_0 \sigma_{th} = \frac{0.92 \times 0.9 \ \frac{mg}{cm^2}}{10.\ g/mol} \times \frac{2 \times 6 \times 10^{23}/mol}{\times 10^{+3} \frac{mg}{g}} \times 3840.6 \times 10^{-24} \frac{cm^2}{b}$$

$$\epsilon = \left(9.94 \times 10^{19} \frac{atoms}{cm^2}\right) 3.84 \times 10^{-21}\ cm^2 = 0.38$$

e.g. cross section on p507 in text

3) $-3\ db = 20 \log_{10} V_{out}/V_{in} \rightarrow \frac{V_{out}}{V_{in}} = 10^{-3/20} = 0.708$



$\alpha = V_{in}/V_{out} = 1/0.708 = 1.413$

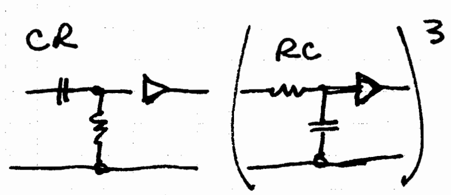
$$R_1 = R_0 \frac{\alpha - 1}{\alpha + 1} = R_0 \frac{0.413}{2.413} = 0.171\ R_0$$

$R_1 = 8.55\ \Omega$

$$R_2 = R_0 \frac{2\alpha}{\alpha^2 - 1} = R_0 \frac{2.826}{0.995} = 2.84\ R_0$$

$R_2 = 142.\ \Omega$

4)



① easy way, text equation 16.24

$$V_{out}/V_{in} = \left(\frac{t}{\tau}\right)^n e^{-t/\tau}$$

In[43]:=
```
(*  Nuclear Radiation Detector Course, djm
      Calculations for Homework Problem PS-4-#4
      on Shaping Amplifiers
      N.B. all times given in nanoseconds
 *)
(pulse[t_, t0_, a_] = 1/(e^(-(t-t0)/a) + 1)) ; (P1 = Plot[0.1 pulse[x, 50, 10], {x, 0, 4000},
   PlotStyle → RGBColor[0, 0, 0],
   PlotRange → {0, 0.1}])
```

In[24]:=
```
tau = 1000 ; (* ns *)
```

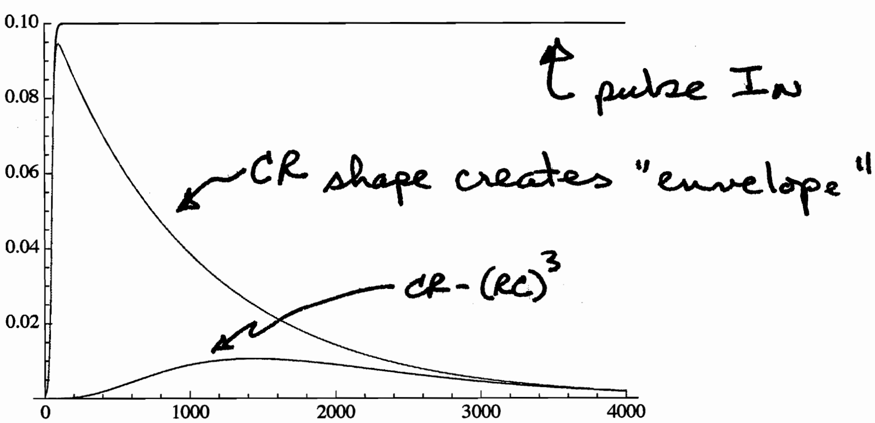
In[44]:=
```
(* CR part:  rise time = 10 ns << tau  *)
P2 = Plot[0.1 pulse[x, 50, 10] Exp[-(x - 50) / tau] ,
  {x, 0, 4000}, PlotStyle → RGBColor[1, 0, 0] ,
  PlotRange → {0, 0.1}]
```

In[45]:=
```
(* First RC part: rise time << tau *)
P3 = Plot[ 0.1 pulse[x, 50, 10] (1 - Exp[-(x - 50) / tau]), {x, 0, 4000},
  PlotStyle → RGBColor[0, 1, 0],
  PlotRange → {0, 0.1}]
```

In[46]:=
```
(* CR & RC^3 part: *)
P4 = Plot[ 0.1 pulse[x, 50, 10] Exp[-(x - 50) / tau] (1 - Exp[-(x - 50) / tau])
   * (1 - Exp[-(x - 50) / tau])
   * (1 - Exp[-(x - 50) / tau]), {x, 0, 4000}, PlotStyle → Hue[0.7],
  PlotRange → {0, 0.1}]
```

In[47]:=
```
(* Show[ P1,P2,P3,P4] *)
Show[ P1, P2, P4]
```

Out[47]=

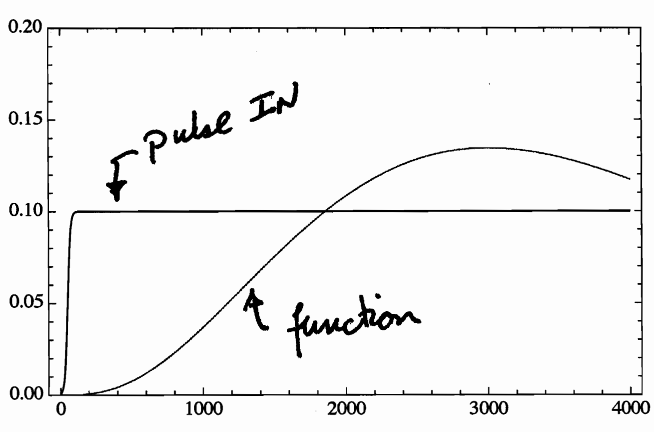


In[48]:=
```
(* CR-(RC)^n shaped signal, Eq.16.24 Knoll-3rd Ed. *)
Vn[t_, tau_, n_] = (t / tau) ^n Exp[ -t / tau]

P5 = Plot[{0.1 Vn[x, 1000, 3]}, {x, 0, 4000}, Frame → True,
  PlotStyle → RGBColor[0.5, 0.1, 1], PlotRange → {0, 0.2}]
```

In[50]:=
```
Show[ P5, P1]
```

Out[50]=



agreement is not very good!