Problem 1

(a) 
\[
\begin{align*}
\langle V_n \rangle_{\text{rms}} &= \sqrt{4kTB} \\
R (\text{noiseless}) 
\end{align*}
\]

For resistors in series, the voltage fluctuations are independent so for the sum, we get another Gaussian with 
\[
\langle V_{\text{ab}}\rangle_{\text{rms}} = \sqrt{\langle V_n \rangle_{\text{rms}}^2 + \langle V_{n2} \rangle_{\text{rms}}^2} \\
= \sqrt{4kTR_1B + 4kTR_2B} \\
= \sqrt{4kTR_1R_2B} \\
\text{(agrees with what we expect for a single } R = R_1 + R_2) 
\]

(b) The carbon composite resistor would be expected to exhibit more 1/f noise than the metal film resistor (in addition to the expected Johnson noise). See Horowitz and Hill, p. 432.
2. NSE is sensitive to ground loops:

For example, a changing \( \Phi \) within the path shown can produce an e.m.f. and a voltage difference between a and b (for example, by the voltage drop \( V_{ab} \) due to a current due to the e.m.f. \( V_{ab} \) gets added to \( V_i \) at the op-amp input and appears as unwanted interference.

Also, ground currents between the two circuits can flow between a and b, causing a voltage drop, again contributing interference at the op-amp input.

The NSE connection only presents the voltage \( V_i \) across the op-amp inputs.

3. (a) \( \langle V_n \rangle_{rms} = \sqrt{4kT \Phi B} \)
   \[ = \sqrt{4 \times 1.38 \times 10^{-23} \times 300 \times 8000 \times 2 \times 10^{12}} \text{ K} \]
   \[ = 1.29 \text{ mV} \]

(b) \( \langle I_n \rangle_{rms} = \sqrt{2q \Phi B} \)
   \[ = \sqrt{2 \times 1.6 \times 10^{-19} \times 0.001 \times 2000 \text{ Hz}} \]

(c) \( \langle V_T \rangle_{rms} = \sqrt{\langle V_n \rangle_{rms}^2 + \langle I_n \rangle_{rms}^2 R} = \sqrt{(1.29 \text{ mV})^2 + (12.6 \text{ mV})^2} = 12.7 \text{ mV} \)

   \( \text{current noise is dominant.} \)

4. (a) \( V_L = \frac{R_T - Z_0}{R_T + Z_0} \) \( V_R = \frac{50 \Omega - 75 \Omega}{50 \Omega + 75 \Omega} \) \( V_R = -0.2 \times 1V = -0.2V \)

(b) \( V_{out (across resistor)} = V_L + V_R + (-0.2) = 0.8\text{V} \).