1. The output of a circuit is grounded locally and connected to a data acquisition system using a 6 ft coaxial cable. The center conductor and shield are connected to instrumentation amplifier differential inputs as shown below.

(a) Should the shield also connect to the instrumentation amplifier ground at the IA end?
(b) Explain why or why not.

![Diagram of circuit with instrumentation amplifier and ground connection through safety ground]

2. The following is a simple 3-point smoothing digital filter for a sampled waveform, using the notation developed in class (sampling period = 1, the $u_i$ are samples, etc.):

$$y_n = \frac{1}{3}(u_{n+1} + u_n + u_{n-1}).$$

(a) Find the transfer function, $H(\omega)$. Express your result in terms of $\cos(\omega)$ instead of complex exponentials.
(b) Find any zeros of $H(\omega)$ in the interval $0 \leq \omega \leq \pi$.

3. A long 75 $\Omega$ transmission line is connected to a pulse generator and is terminated at the far end by a 50 $\Omega$ resistor. The voltage on the cable is initially zero. A wave in the form of a 1 V boxcar function 20 ns wide is input and reaches the improperly terminated end.

(a) Find the amplitude and polarity of the reflected wave.
(b) Find the voltage across the 50 $\Omega$ resistor during the pulse.
4. The figure above shows a pulsed voltage source $V_s$ with source resistance $R_s = 50 \, \Omega$ coupled (at point a) to a 100 ns long coaxial cable (coax) with $Z_0 = 50 \, \Omega$. The other end of the cable is connected (at point b) to a 2.5 ns length of the same coax whose far end is shorted to the outer shield (point c). A high impedance oscilloscope connected at point b indicates $V_b(t)$ but does not significantly disturb the signals traveling on the cable. A single rectangular pulse $V_s(t)$ is generated starting at $t = 0$ which has a height of 2 V and width of 20 ns. The cables are initially uncharged ($V = i = 0$ everywhere on the cables for $t < 0$). Neglect any energy losses (attenuation) due to the cable.

(a) Let $i_s$ be the source current, $V_R$ the voltage drop across the 50 $\Omega$ source resistance, $i_r$ the current in a right-traveling wave on the cable at point a and $V_r$ be the voltage of the right traveling wave at point a.

i. What is the ratio $V_r/i_r$ on the cable? (Give a number with units.)

ii. At point a, find $i_s$, $i_r$ and $V_r$ for $0 < t < 20$ ns.

iii. Sketch $V(t)$ at point a for $0 < t < 30$ ns.

(b) (Extra Credit) What is the waveform observed on the oscilloscope? Explain your answer in terms of the superposition of right-going and left-going waves.

5. (Extra Credit) One method of obtaining a digital filter with characteristics similar to a given analog filter with transfer function $H_a(s)$ is through the substitution,

$$s = \frac{2(z - 1)}{z + 1},$$

to give

$$H(z) \equiv \frac{A_O}{A_I} = \frac{\sum_{k=0}^{N} c_k z^{-k}}{1 - \sum_{k=1}^{M} d_k z^{-k}}$$

(recursive digital filter). This is an approximation applicable for frequencies much less than the Nyquist frequency.

(a) An analog integrator circuit has $H_a(s) = \frac{1}{s}$. Make the substitution above to obtain $H(z)$.

(b) Multiply numerator and denominator of the resulting expression by appropriate factors of 2 and $z^n$ to put it in the form for $H(z)$ given above. (Hint: N=1 and M=1.)

(c) Find $c_0$, $c_1$ and $d_1$ by identifying coefficients in $H(z)$.

(d) Put this in the form we gave for the recursive filter

$$y_n = \sum_{k=0}^{N} c_k u_{n-k} + \sum_{k=1}^{M} d_k y_{n-k}$$

by substituting your values for the $c_i$ and $d_i$ coefficients into the expression. Does your result look reasonable for a network which is supposed to perform an integration? Explain briefly.