Instrumentation Problem Sheet 1

(1) (i) Find the Thevenin equivalent circuit for a voltage divider made of two resistors R_1 and R_2 driven by a voltage V, with the output voltage taken across R_1.

(ii) Find the Norton equivalent of the same circuit.

(2) (i) Verify that when a load impedance R_{load} is connected to a voltage source with impedance R_{source}, the power in the load is maximised when $R_{source} = R_{load}$,

(ii) Show that the matching condition that $R_{source} = R_{load}$ holds also for a current source when maximum power is to be transferred to the load.

(3) What is the Thevenin equivalent of (i) a high pass filter and, (ii) a low pass filter?

(4) What is the 3dB frequency of (i) a high pass filter with $RC = \tau$, (ii) a low pass filter with the same time constant? What are the numerical values for $\tau = 1\mu s$, $\tau = 20ms$?

(5) A student decides to construct a band-pass filter by connecting the output of a low pass filter to the input of a high pass filter. Why would this not work as intended?

(6) A step pulse of amplitude 1V is passed through a low pass filter with a time constant of 50ns. Sketch the pulse shape for a step pulse duration is 100ns, 200ns, 500ns.

(7) What is the 10-90% rise time of a step pulse passed through a low pass filter with time constant τ?

(8) An optical fibre telephone cable has an attenuation of 2.5dB/km at $\lambda = 850nm$ and 0.8dB/km at $\lambda = 1300nm$. Signals of both wavelengths with equal initial power are launched into the fibre. What is the relative power of the two signals in dB after 100km?

(9) The precision of an energy measurement is often quoted in terms of ΔE, where ΔE is the Full Width at Half Maximum (FWHM) of the resolution function, which is usually assumed, or measured, to be a gaussian distribution. Show that in this case ΔE is related to the standard deviation by $\Delta E = 2.35\,\sigma$.

As a reminder: the gaussian probability distribution whose mean is E_0 and variance is σ^2 is given by

$$p(E) = (1/2\pi\sigma)^{1/2}.\exp[-(E-E_0)^2/2\sigma^2]$$

(10) The splitter in the figure is designed to connect a radio aerial to two cables connected to radios. All the cables and loads are transmission lines with $R = 75\Omega$. What value should be chosen for r so that no matter what direction the system is viewed from, a load of 75Ω is seen?