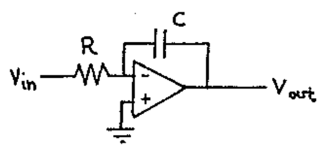
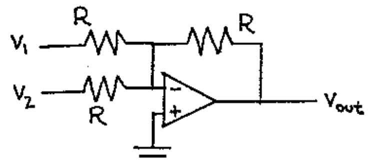
# Physics 623 — Problem Set 4

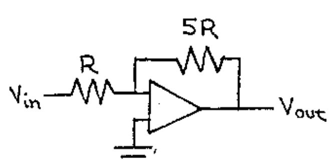
1. Calculate $V_{OUT}$ for the following circuits:



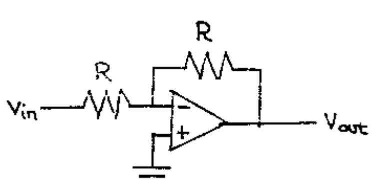

$V_{out}$ = ________




$V_{out}$ = ________




$V_{out}$ = ________




$V_{out}$ = ________

2. Use the circuits in problem 1 and a signal generator set to deliver 2 volts peak at frequency $\omega_0$ to construct an analog computer where the voltage at point x satisfies the following equation:

$$\frac{d^2x}{dt^2} = 5\frac{dx}{dt} + x + 2\sin(\omega_0 t)$$

Let RC = 1. Mark the point in your circuit where the voltage = x.

Hint: Start at a point where you define the voltage to be $d^2x/dt^2$. It is standard practice to start with the highest derivative present in the equation. This avoids the use of differentiator circuits, which have the practical problem of high gain for high frequency noise. Use the circuits from problem 1 to generate the right hand side of the equation from this starting point. Connect the resultant point back to your starting point to force the differential equation to be true.

3. The open loop gain of an op-amp is given as a function of frequency by $A_0 = A/(1 + j\omega/\omega_C)$, where $A$ and $\omega_C$ are constants. Note that this has the same phase and relative amplitude response as a single-pole low pass filter. Since the response goes down to zero frequency, bandwidth of the op-amp is $\omega_C$ and the gain-bandwidth product is $A\omega_C$. Find an expression for the gain vs. frequency of a circuit using this op-amp that has a feedback factor $\beta$ (assumed independent of frequency) and show that the gain-bandwidth product of the closed-loop amplifier is also $A\omega_C$.

4. Design a circuit where the output is the square root of $V_{in}$.

5. Calculate the magnitude and phase of $V_{out}/V_{in}$ for the circuit shown below. Use $1/j\omega C$ for the impedance of the capacitor and do the analysis using complex numbers until you have a final result for $V_{out}/V_{in}$. Then convert to magnitude and phase notation. $R$ can be adjusted from zero to infinity. This circuit is called a "phase shifter".