Physics 321: HW 9

Problems 9.6, 9.7, 9.11, 9.13, and 9.15 in Sprott.

Hints:

9.11: A subtle point: If you assume the golden rules, the answer in the back of the book appears correct. However, with a voltage source on the negative input as shown, the circuit will sit saturated + or –. The circuit will work correctly and give the calculated value for V_{in}/I_{in} if you put a current source I on the input and measure V. (Test both cases, doing our thought experiment of starting with source set to zero then giving it a small positive increment to see if the circuit responds correctly.) What do you need to do to make it work with a voltage source?

9.15: This sort of 'analog computer' is the way many computations were done before digital computers became available and got fast enough. For example, circuits like this could be put together to solve the equations of motion for an airplane, with the control surface settings as inputs and the outputs driving motors to orient a model of the cockpit in real time to make early flight simulators for training pilots.

To generate your circuit, start by solving the differential equation for its highest derivative ($\ddot{x} =$ . . .), then start with a dot at the left side of your schematic where you *assume* the voltage represents $\ddot{x}$ with a scale where x is in volts and 1 V at this point is 1 V/s^2. Now you can put this into an op-amp integrator, and its output will be $-\dot{x}$ (assume RC = 1). Putting this as the input into another integrator will give you $+x$. Now use amplifiers to scale the numbers, power supplies for constants, and an adder to generate the right hand side of your equation. Connecting this point back to your starting point completes the "=" part of the equation. (We started with the highest derivative because as a practical point differentiators amplify any stray high frequency noise too much, while integrators are better-behaved.)