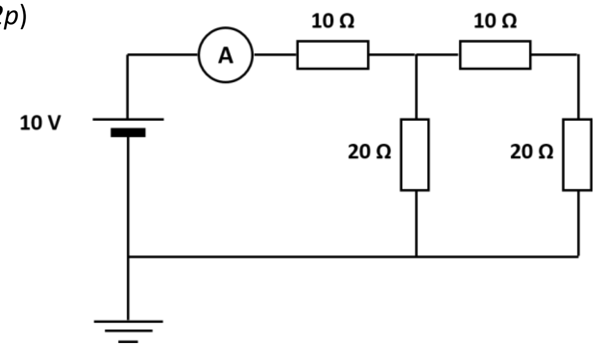
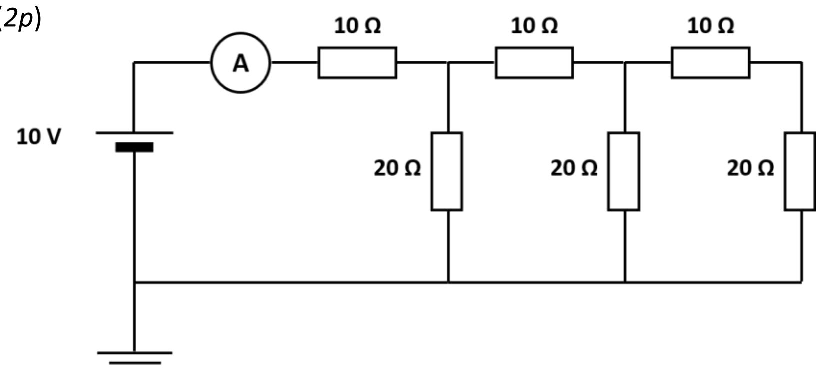
Physics – Grade 10

1. Determine the reading on the ammeter in the following circuits.

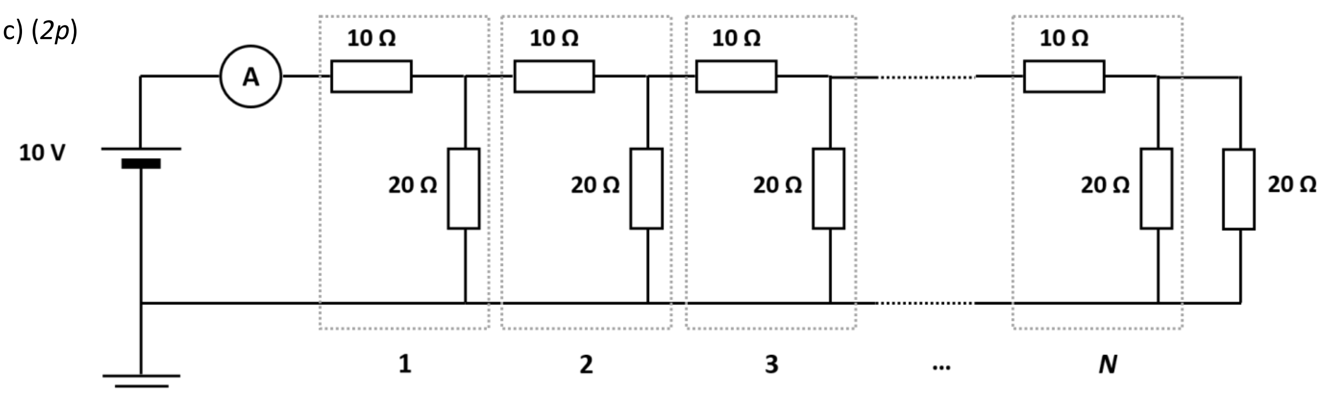
a) (*2p*)



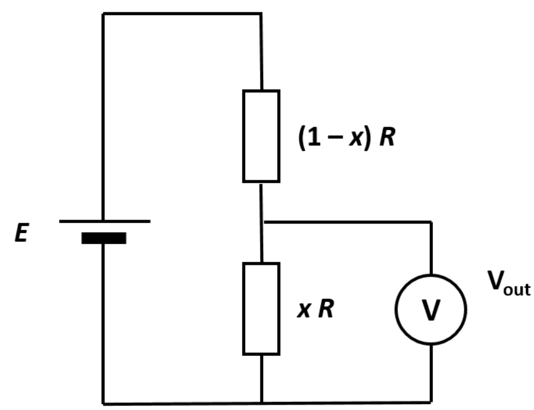
b) (*2p*)



c) (*2p*)

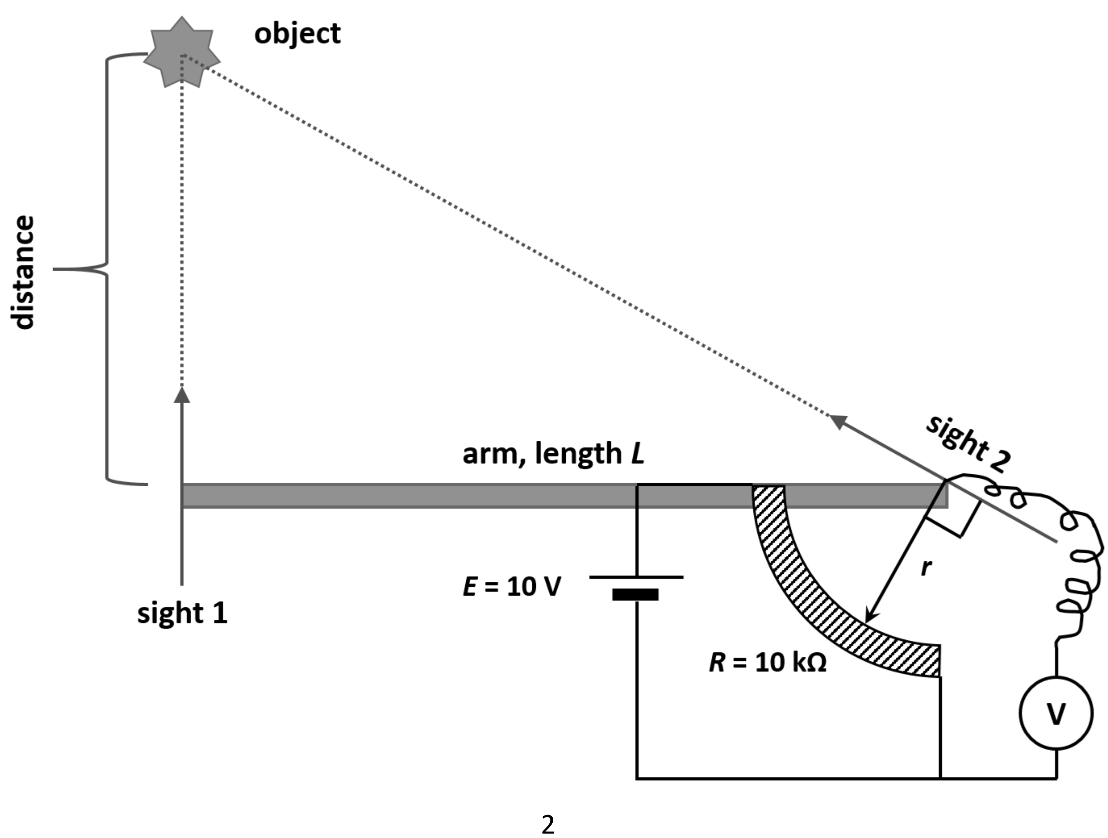


2. A potentiometer is a three-terminal resistor with a sliding or rotating contact that forms an adjustable voltage divider (or potential divider). If only two terminals are used, one end and the adjustable contact, it acts as a variable resistor. The equivalent circuit of a potentiometer is shown below, with $x \in [0, 1]$ describing the sliding or rotating contact's position as a fraction of the full reading.



a) Express the reading V_{out} of the voltmeter as a function of the operating voltage E. (*1p*)

Distance is measured with a system described in the figure below. The apparatus has two sights, one of which is connected to an arc-like wire resistor (a potentiometer). The radius of the glide of the potentiometer is r = 3.0 cm, and the wire has 500 turns/cm (we can assume that the potentiometer behaves ideally, and the resistance on the wire is uniform). The potentiometer is set up in a way that a distance of 0 m corresponds to 0 Ω and infinite distance corresponds to 10 kΩ. The operating voltage is E = 10 V. The length of the system is L = 2.0 m.



b) Derive and sketch the calibration curve (distance as a function of voltmeter reading V_{out}). (*1p*)

c) What are the accuracy, sensitivity and resolution of the setup? (*3p*)

accuracy = measured value – true value

resolution = the largest change in the input (distance) that doesn't affect the output (V_{out})

sensitivity = f′(x), where the calibration curve in (a) is y = f(x) (y = distance, x = V_{out}) – i.e., how much the output changes relative to the input when the input changes just a little.

d) What distances can be measured with an accuracy better than 10 m? (*1p*)

3. You have a thermally well insulated calorimeter: a liquid-fillable container that doesn't exchange heat with its surroundings even when you stir the liquid and measure its temperature. You are about to measure the heat capacity of a small handful of copper pellets. In order to get started, you weigh the bunch of pellets and obtain a result of 83 g. Your friend also weighs them, and obtains 78 g. The calorimeter can hold up to 1 litre of liquid.

In order to start your project, you need to determine the effect of your calorimeter on your measurements. You do this by pouring 4.0 dl of cold tap water into the calorimeter (you measure the temperature after stirring and settling down to be 12 °C). You then pour 4.0 dl of boiling water into your calorimeter, and after stirring and settling down you measure the temperature to be 44 °C.

Now you can measure the heat capacity of your copper pellets. You again start with cold tap water, now taking 8.0 dl, and after stirring and settling down the temperature is 14 °C. You heat the copper pellets in boiling water, and then pick them up with a sieve and quickly place them in your calorimeter. After stirring and settling down you measure the temperature to be 15 °C.

a) What is the heat capacity of your copper pellets? (*3p*)

b) As you know the mass of your copper pellets, you can also determine the specific heat capacity and compare it to that of copper. Discuss the result of your comparison. Is the result of your experiment OK? If yes, why? If not, why? (*2p*)

c) What changes if you decide to do the same measurement for a substance that transforms when in touch with water at these temperatures (for example, melts or dissolves)? (*1p*)

4. You have been assigned the task of measuring the speed of light. You have a laser, a power drill (up to 30000 rpm speed, with a speed display), mirrors, pieces of (transparent) glass, benches, stands, a selection of tools and appliances with which you can fasten things with relative ease to one another (or on the drill, wall, bench, stand, etc.), and means to measure distances from fractions of millimeters to meters (micrometer scew, ruler, measuring tape), but no means to measure time (other than a regular wristwatch). You are in a large hall with 30 m wall-to-wall-distance.

Design the experiment and prove (also by calculating) that it is feasible. (*6p*)

Useful values and formulas:

Water specific heat capacity: 4.184 kJ / (kg · K)

Copper specific heat capacity: 385 J / (kg · K)

Electron mass: 9.11×10^{-31} kg

Elementary charge: 1.602×10^{-19} C

Speed of light in vacuum: 2.998×10^{8} m/s

D arctan $x = (1 + x^2)^{-1}$

D tan $x = (\cos^2 x)^{-1}$