BPhO Taster Problems

1. On a clear day in summer the normal incident radiation on the surface of the Earth from the Sun is about 1000 W m^{-2}. By making suitable simplifying assumptions, determine:

   i) the power per square metre of radiation emitted from the surface of the Sun

   ii) the pressure on the surface of the Sun due to this radiation.

   Calculate how many photons of wavelength 590 nm would be needed to accelerate a proton to a speed equivalent to a temperature of 10^6 K.

2. A pole sits vertically in a sheet of ice (say, on a pond), and a string is attached to the pole and laid outwards (see figure below). A hockey puck slides along the ice (no friction of course) and hooks onto the string. Initially the puck is moving with velocity v (all tangential). When the rope is half wound around the pole (so the rope is half its original length), how fast is the puck moving? There are at least two plausible answers, but at most one is right!

3. a) Why is there a force of net attraction between a charged sphere and an uncharged isolated copper sphere some distance away?

   Why does this force increase if the sphere is earthed?

   b) Why can a ladder be leaned at an angle on a rough floor against a smooth wall, but not on a smooth floor against a rough wall?

   c) Why must a hole in a pinhole camera be neither too small nor too large?

   d) Why does a blue cloth look dark when viewed in sodium light?

4. Here you will study the well-known formula for the horizontal range of a rock. You throw a rock with velocity v at an angle θ with respect to the ground. Its range is

$$R = \frac{2v^2}{g} \sin\theta \cos\theta.$$

   You can increase your confidence in this result in a number of ways (parts a–e). (It may help for many of the parts to draw a diagram.)

   a) Dimensional analysis: Check whether the dimensions are correct.

   b) Consider limiting cases (for example, $\theta = 0$). Does the range formula work in these cases?

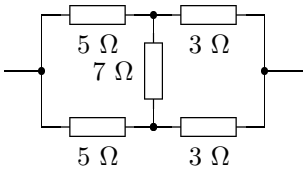
   c) Give a physical argument for why the range contains a factor of v^2 (instead of, say, simply v or $1/v$ or no v at all). (Dimensional analysis, which you did in part a, is a mathematical argument; in this part, you are asked to reinforce the mathematics with a physical argument.)

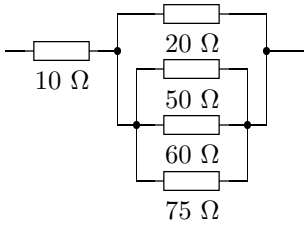
   d) Give a physical argument for the factor of 2.

   e) Give a physical argument for the $1/g$ factor.

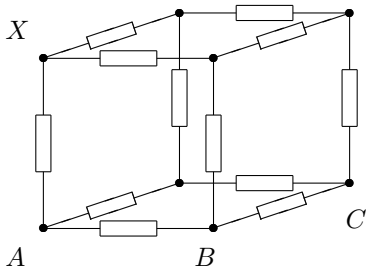
f) To derive the equation, you have to neglect many effects (for example air resistance). List as many of these effects as you can. Let your imagination run; no effect is too small to mention here.

5. Calculate the resistance of the following networks of resistors.





6. Work out the resistances between X and each of the points A, B and C in the resistance cube shown below.



7. Make brief notes on the dependence of resistance on temperature in metals.

8. Without a calculator, estimate

   a) $\sqrt{1.3}$

   b) $\sqrt[3]{1.6}$

   c) $\sin 7$

   d) 1.01^{100} (Hint: What is $\ln 1.01$?)

9. Explain why light can be polarized but sound cannot. How would you distinguish, experimentally, between partially and fully polarized light?

10. A bullet leaves the 1.20 m barrel of a rifle at a horizontal speed of 310 m s^{-1}.

    i) Calculate the acceleration of the bullet in the barrel, assuming it to be constant.

    ii) If the bullet emerges from the barrel after two complete revolutions, estimate its final rotational speed in radians per second.

    iii) What advantage has a barrel that causes the bullet to rotate?

    iv) In practice the acceleration of the bullet is not constant. Sketch a graph of the expected variation, with distance, and explain the variation.

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