

1994-1995 Physics Olympiad Preparation Program

– University of Toronto –

Problem Set 1: General Physics

Due October 24, 1994

1. Your physics professor (you're in university now) has babbled all year long in lectures and you couldn't understand a word he said. It's now exam time and, since you didn't bring a cheat sheet (good for you), you decide to derive the formulas for various physical quantities using dimensional analysis in the hopes of partial marks. Your babbling professor may give you partial marks but we'll give you full ones if you get all these (as long as you show your assumptions and your work!).
 - (a) You remember a 2π but can't remember the rest of the expression for the period of a simple pendulum. What is the full expression?
 - (b) A particle of mass m rotates in a circle of radius r with speed v . The particle has an acceleration a_c called centripetal (centre seeking) acceleration. What is the form of a_c ?
 - (c) A gas bubble from a deep explosion under water oscillates with a period T . Known variables are p , the static pressure, ρ , the water density, and e , the total energy of the explosion. Find the dependence of the period on the other variables.
2. Being the hip physics-dude/dudette you are, you often go to parties with your non-physics friends. You like to be the centre of attention, telling them about the physics of quarks and gluons, but that usually ends up killing the party. You decide, then to pull a different beast out of your physics hat: *rapid estimation*. You know that sometimes we don't need exact answers but only order-of-magnitude estimations. At a recent party, your friends asked you the following:
 - (a) Jake asked: if I beat everyone on the planet into a pulpy liquid, roughly how deep would the liquid be on the Earth's surface? Would I need Doc's, rubber boots, hip waders, or a boat to avoid getting my new socks dirty? What if I wanted to fill up containers the size of the Skydome™ in downtown Toronto with this vile mess; how many containers would I need?
 - (b) Jane asked: if the entire debt of the Government of Canada were paid off in loonies, how much would it weigh? If I stacked them, how high would it reach? If each loonie was turned into a pound of flesh, how would that affect the answer to Jakes question?

Remember to justify any non-obvious estimations you make; your physics teacher's daughter is at the party and she'll call your bluff on bad estimations, making you look like a fool in front of your friends.
3. Your Great-Aunt Edna is in town visiting. She's really rich and is about to kick the bucket, so she will be drawing up her will soon. You want to be in it, you materialistic !@?\$\$%#!, you. Now, Auntie Edna, as you like to call her, made her fortune as a high-school physics and english teacher, so she really gets P-O'd when people use poor grammar and physically incorrect phrases. You decide to impress her with the following:
 - (a) Metro Toronto Police as well as local newscasters on TV often describe the latest traffic fatality using the phrase "the car was traveling at a high rate of speed." What is wrong with this?
 - (b) People describe their watch as being "five minutes fast" or "two minutes slow". What is wrong with this? What do they really mean (or what should they really say)? Is there a correct way of describing a watch's inaccuracy using the words "fast" or "slow"?
 - (c) Weather announcers and even meteorologists use the phrase "normal high" and "normal low". What do they mean by "normal"? Is that normal? What might be a better word? Discuss.

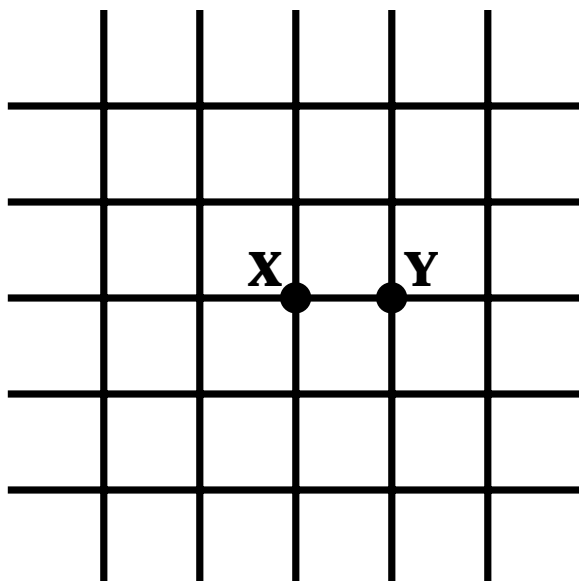


Figure 1: Rectangular wire mesh of infinite extent.

4. Your Uncle Sal from Italy was in North America for the World Cup. He was terribly disappointed with their loss, and is in a blue funk (the blue that is found on the Brazilian flag, as a matter of fact). You want to make him a pesto pizza to cheer him up. While pouring the olive oil, you accidentally spill some into a glass of water, and it spreads out on the surface. Sal, who is watching, is a physics teacher in Italy and he is reminded of an experiment done by Lord Rayleigh. He tells you that he would be happy if only you would solve the following.

Rayleigh¹ found that 0.81 mg of olive oil on a water surface produced a mono-molecular layer 84 cm in diameter. What value of Avogadro's Number results?

Note: The approximate composition of olive oil is $H(CH_2)_{18}COOH$, in a linear chain with one end (which?) hydrophilic and the other hydrophobic. Its density is 0.8 g/cm^3

5. Ever the consummate student, you are at Woodbine doing some betting studying. Of course, you brought your \$500 camera with a telephoto lens. Watching the thoroughbred racers Eric's Idle and Paul's Bunyon thunder down the home straight, you decide to take a picture. You are looking head on through the telephoto lens and you notice that the horses seem strangely foreshortened (not as long from front to back) as they gallop towards the camera. Explain this observation.
6. Your little brother has been playing with the wire screens and batteries again. Will he ever learn? He asks you the following.
- A rectangular wire mesh of infinite extent in a plane has 1 A of current fed into it at point X, as in the diagram (Figure 1), and 1 A of current taken from it at point Y. Find the current in the wire XY.
 - Suppose the wire mesh was made of equilateral triangles joined in the obvious way. What is the current where X and Y are separated by one wire?

¹Rayleigh, Proc. Roy. Soc., 47, 364 (1890); Holy smokes, that's 104 years ago! And you're only learning about it now? Bonus points to anyone who can get me a photocopy of the article.

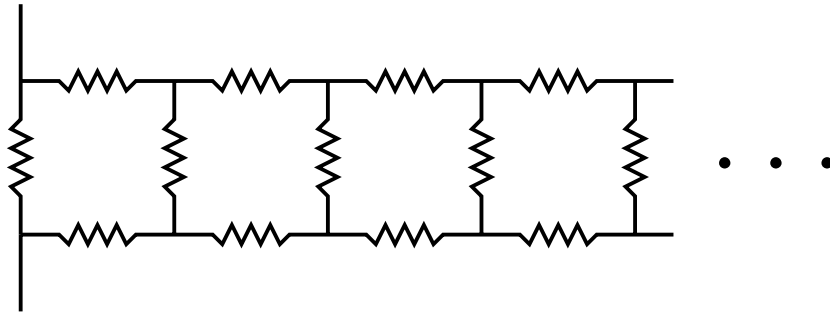


Figure 2: Infinite resistor ladder.

- (c) The screen has been cut up and now resembles the circuit in the diagram. What is the resistance of the circuit shown, an *infinite* ladder.