Quiz problems for Founder's Day 2019.

Quiz open to all staff members and graduate students.
The deadline for submissions is 11am, the 24th of October, 2019.
Top three prizes are \$ 250, \$150 and \$100.

Please submit solutions in pdf or Word format to: hdr.physics@anu.edu.au

Problem 1

A bus and a cyclist are moving on a straight road with speeds of 63 km per hour and 33 km per hour respectively. A truck is moving on a different straight road (not parallel to the first one) with a speed of 52 km per hour. The distance from the truck to the bus is always equal to the distance from the truck to the cyclist. Find the speed of the truck relative to the bus.

Problem 2

A spaceship is moving in outer space along a straight line with a constant speed v. The captain gives the order to turn by 90 degrees and continue to move straight with the same speed v. Find the minimal time required for this manoeuvre if the spaceship can accelerate in any direction with acceleration not exceeding a maximal value a. What will be the optimal trajectory of the spaceship ?

Problem 3

Sherlock Holmes and Dr. Watson were crossing Baker Street. Then Professor Moriarty drove out of the side street in his cabriolet nearly running them over. "Holmes", Dr. Watson exclaimed, "this maniac is driving around London at a frantic speed!"

"Not true, Watson, he could not be driving faster than 30 km an hour!"

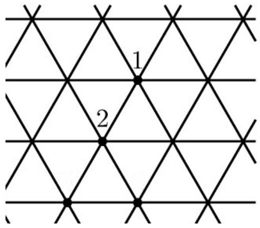
"Can you explain, Holmes ?!"

"Elementary, my dear Watson. I noticed that the light from the setting sun that was reflected by his side window remained for some time on that lamppost, 3 metres from the car."

Can you explain the logic of Sherlock Holmes ?

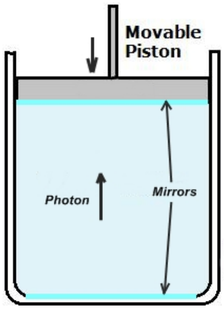
Problem 4

Consider a 2-dim triangular lattice infinite in both directions as shown in the picture below. Every edge of every triangle in the picture is made of a piece of a conducting wire with resistance r. What will be the resistance R measured between the points 1 and 2 ?



Problem 5

Consider a cylinder with a movable piston shown in the picture below. The bottom of the cylinder and the piston are ideal mirrors. A photon of a frequency ω inside the cylinder is moving parallel to the axis of the cylinder. Now we start to slowly move the piston down and stop when the volume inside the cylinder decreases by a factor of k. What will be the photon frequency ? Assume that the photon wavelength is much less than the size of the cylinder and the momentum of the photon is much less than the momentum of the piston.



Problem 6

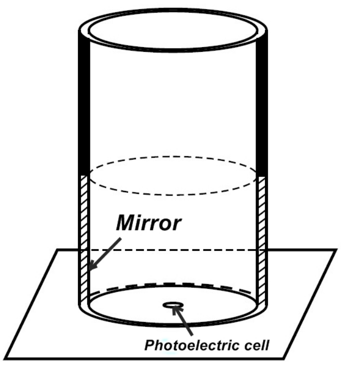
An empty cylinder of radius R and height H is filled with electrons of concentration n. Let us assume that all electrons have the same speed v, their velocities are perpendicular to the cylinder axis and collisions with walls of the cylinder are absolutely elastic. This implies that trajectories of electrons are always 2-dimensional and lie in planes perpendicular to the cylinder axis. Now we apply a strong constant magnetic field parallel to the cylinder axis such that

$$\frac{mv}{eB} \ll R,$$

where e is the electron charge and m is the electron mass. Calculate the pressure on the wall of the cylinder of such a 2-dim "electronic gas" in the presence of the magnetic field. Assume that the Coulomb repulsion of electrons is very small.

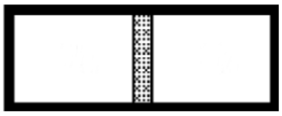
Problem 7

A long round pipe with its height much larger than its diameter is painted on the inside. The top half is painted with a black paint which absorbs light and the bottom half is painted with a 100% reflective paint. The pipe is placed on a black table such that a photoelectric cell on the table surface is located exactly at the pipe axis, see the picture below. The light power registered by the cell is P_0. Now we turn the pipe over and place it with the black side down. What will be the power P registered by the cell ? Assume that the source of light above the pipe is scattered with the same intensity in all directions.

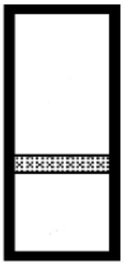


Problem 8

A thermally insulated horizontal cylinder is divided into two equal parts by a freely movable thin massive piston. There is an ideal monatomic gas of temperature T and pressure p in both parts of the cylinder.



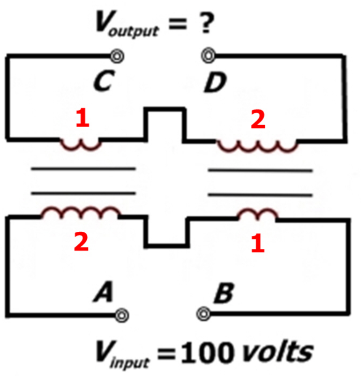
Now we slowly turn the cylinder clockwise by 90 degrees as shown in the picture below



The piston will move down and find its new equilibrium. Assuming that the difference of pressure in the bottom and top parts of the cylinder is now $\Delta p \ll p$, find the change ΔT of the gas temperature. You can assume that the heat capacity of the cylinder walls and the piston are very small.

Problem 9

Two identical transformers with winding turns ratios 2 : 1 are connected as shown in Figure 2. Namely, the long coil of the first transformer is connected in series with the short coil of the second transformer to form an "input circuit" marked by the letters A and B in the diagram. In addition, the short coil of the first transformer is connected in series with the long coil of the second transformer to form an "output circuit" marked by C and D. The input circuit is connected to a source of AC current with a voltage $V_{\text{input}} = 100\ Volts$. Find the voltage V_{output} between the points C and D of the output circuit.



Assume that the transformers are ideal. An ideal transformer has perfectly conducting coils with a common magnetic flux, which is closed and completely confined inside the transformer. It implies that magnetic fluxes of the two transformers are completely independent. The winding turns ratio 2 : 1 means that one coil of the transformer has two times more turns than the other. These coils are marked by the numbers 2 and 1 and referred to in the text as the "long" and "short" coils, respectively.