Achievement Award: Sample Paper

Physics & Astronomy
University of Southampton

Attempt as many questions as you can.

The questions are designed to be of varying length and level of difficulty.

The number in square brackets to the right of each question gives the number of marks available for that question.

For all questions give reasoning for your answers and show your working clearly.

Non-preprogrammed calculators may be used.

1. A lunar eclipse occurs when the moon passes into the shadow of the Earth.

(a) Explain why this occurs at full moon and not at new moon.

(b) Explain why we do not observe a full lunar eclipse every full moon. [4]

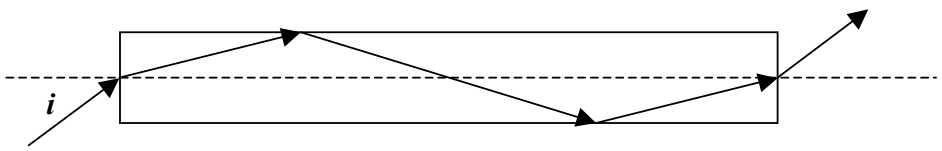
2. An ice-cold drink initially has some crushed ice in it. Draw a graph of the temperature of the drink as a function of time as it warms to room temperature. [4]

3. Explain how a boat made of steel floats.

A fisherman in a small boat on a lake throws the anchor made of steel overboard. The anchor sinks to the bottom of the lake. Does the level of the water in the lake rise or fall? [7]

4. I come across a group of training athletes who are running at a constant speed of $15\,\mathrm{km\,h^{-1}}$ around a 10 km track, such that they are evenly spaced with a separation of 500 m. If I run a single lap at a speed of $10\,\mathrm{km\,h^{-1}}$, how many athletes will pass me: (a) if I run in the same direction; (b) if I run in the opposite direction? [6]

5. A laser beam is incident at the midpoint of one side of a block of glass of length 12 cm and width 2 cm at an angle $i = 27°$. After undergoing total internal reflection from opposite sides, as shown in the diagram below, it emerges from the point opposite the point of entry. Calculate the refractive index of the glass.



Why does no light escape from the long sides of the block? [8]

6. A comet of mass m is travelling radially away from the Sun at speed v. The Sun has mass M. At distance r from the Sun the gravitational potential energy of the comet is

$$E_{\text{grav}} = -\frac{GmM}{r},$$

where G is the gravitational constant.

Explain the meaning of the minus sign in this formula.

The total energy of the comet, E_{tot}, is given by the sum of its potential and kinetic energies. What condition must E_{tot} meet so that the comet cannot leave the gravitational field of the Sun, that is to prevent $r \to \infty$? [5]

7. Estimate the number of grains of rice in a 1 kg bag of rice. [5]

8. A truck of mass M is travelling with a constant velocity v. A bag of sand of mass m is dropped from a small height (with no horizontal component of velocity) on to the back of the truck. What is the velocity of the truck after the bag has been dropped? Assume that the bag does not slide on the back of the truck.

Show that the kinetic energy of the truck plus the bag, after the bag has fallen on the truck, is smaller than the kinetic energy before the bag is dropped, and explain where the energy has gone. [5]

End of paper