The Open University

Science Supplementary Material
**S271 Discovering Physics**

arm – vel
thumb – mot
fingers – field.

Course and assignment number:
**S271 03**

# Tutor Marked Assignment

Make sure you know how to complete and send in your TMA and PT3 form: detailed instructions are given in your student handbook (or supplement).

Covering: **Units 10–12**
Cut-off date:
**Friday 16 August 1996**

*This assignment consists of* **three** *questions, which relate to the material covered in Units 10 to 12.*

## Question 1

*This question relates mainly to Unit 10 and carries 30% of the marks for this assignment.*

*In this question, extra marks can be gained for 'good problem-solving technique'. This means that you should structure your answer into stages of preparation, working and checking. (The dividing line between the preparation and working stages is rather vague and you need not worry about its exact position.) The preparation stage should outline your understanding of the question, including suitable diagrams and standard equations that might help in the solution. The working stage will probably be the bulk of your answer and will include algebra and/or numerical calculations. Finally, don't forget to include an argument that supports your answer in the checking stage.*

An inventor designs a speed selector — an apparatus designed to select particles with a narrow range of speeds from a beam that contains charged particles with a wide spread of different speeds. The design is based on the idea of passing the beam of particles through perpendicular electric and magnetic fields. The beam is aligned along the $x$-axis, the electric field along the $y$-axis and the magnetic field along the $z$-axis. The electric and magnetic fields are zero outside the selector and uniform within it. The beam enters the apparatus at point A on the $x$-axis. Some of its particles are deflected by the electric and magnetic fields, but particles with a certain speed $v_0$ pass through undeflected. These undeflected particles pass through a narrow slit centred on a point B further along the $x$-axis, at the far end of the selector. The particles that pass through this slit form the speed-selected beam.

Hearing that you are studying physics, the inventor asks for your help in perfecting the apparatus. She would like to select charged particles with speeds in a narrow range centred on $1.00 \times 10^5\,\mathrm{m\,s^{-1}}$. Each particle in the beam has a charge of $1.602 \times 10^{-19}\,\mathrm{C}$ and a mass of $1.67 \times 10^{-27}\,\mathrm{kg}$. The electric field is created by placing the apparatus between two large charged plates, separated by a distance of 10 cm, with a voltage difference 300 V across them and the magnetic field is created by placing the entire apparatus inside an effectively infinitely long solenoid with 20 000 turns per metre. The inventor would like to know what current to pass through the solenoid. What advice would you give? (You may assume that the effects of gravity on the beam of particles are negligible.)

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|---|---|
| *Preparation* | *10 marks* |
| *Working* | *16 marks* |
| *Checking* | *4 marks* |

## Question 2

*This question relates mainly to Unit 11 and carries 35% of the marks for this assignment.*

A magnet, just above the ground, produces a strong magnetic field which acts vertically downwards. This magnetic field is approximately uniform inside a 20 cm by 20 cm square region ABCD at ground level; the magnetic field is relatively small outside ABCD. This situation can be modelled by taking the magnetic field to be of constant magnitude, 0.3 T, within the region ABCD and zero outside.

A small 4 cm by 4 cm square horizontal loop EFGH slides along the ground with the same orientation as the square ABCD. This loop obeys Ohm's law and has a resistance of 6 Ω. Initially, the loop is wholly outside the region ABCD, but it is displaced (without rotation) along a straight line; it enters the region ABCD, becomes wholly contained within it, and then emerges from ABCD so that it is wholly outside it again (see Figure 1 *overleaf*). Throughout this displacement, the loop EFGH is moved at constant speed $v = 2\,\mathrm{m\,s^{-1}}$.

(a) Sketch a graph of the downward flux through EFGH against time, taking $t = 0$ to be the instant when EFGH first overlaps ABCD. Your graph should include a scale and units for both axes. *(9 marks)*

(b) Use your answer to part (a) to calculate the magnitude of the rate of change of flux through EFGH as it enters and leaves the region ABCD of the magnetic field. *(6 marks)*

(c) Sketch a graph of the current through EFGH against time, including a scale and units for both axes, and using the convention that, looking down from above, anticlockwise currents are taken to be positive. Show your working for any numerical values given and indicate your reasoning for the signs assigned to the current. *(12 marks)*