

TAP 413-5: The Hall effect

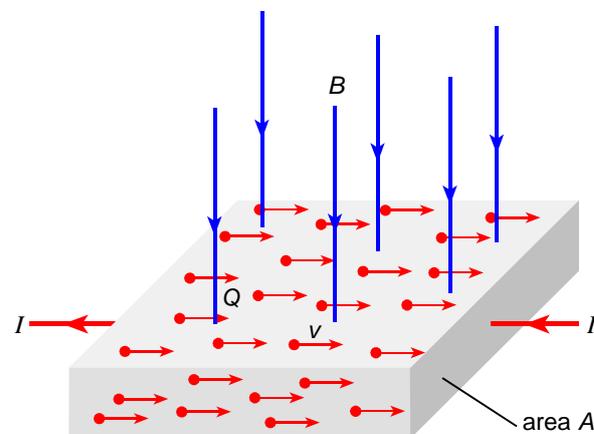
Background

In 1879 the American physicist E H Hall found that when a current was flowing in a conductor, a magnetic field at right angles to the current caused a very small potential difference across the conductor. If semiconductors are used instead of ordinary conductors, there is a much larger pd. The Hall effect is widely used in industry for measuring magnetic fields.

Questions

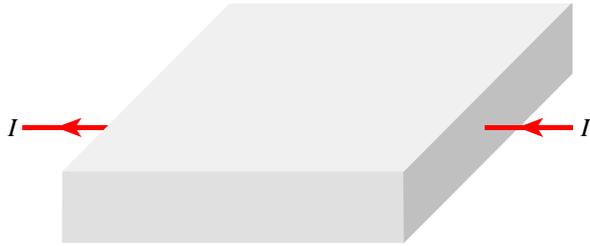
If I is the current when there are n charge carriers per unit volume, each with negative charge Q passing through an area A with a velocity v , then $I = nAQv$.

1. When the magnetic field B is switched on, what force will be exerted on one moving charge carrier?
2. What is the direction of the force? Mark it on the diagram.

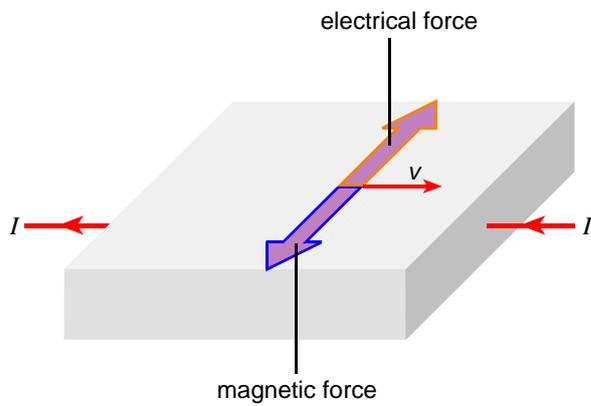


negative charge carriers going from left to right;
there are n of them per cubic metre

3. After a time there will be higher density of negative charge near the front edge than near the rear edge. Why?



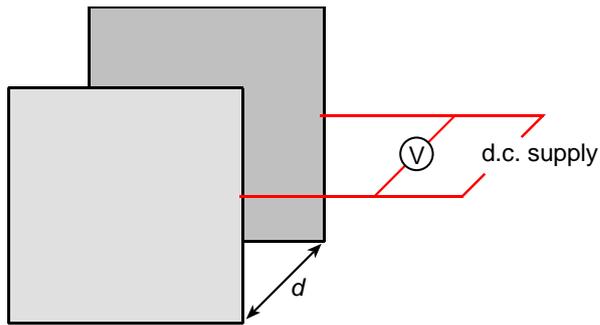
4. A charge carrier in the middle will still experience a force due to the magnetic field, but it will also be repelled by the extra charge carriers near the 'front edge'.



How big must the electrical force be so that there is no further change in the number of negatively charged particles near the edge?

5. Which edge of the strip will be positively, and which negatively, charged?

If, in another experiment, there were two parallel plates separated by a distance, d , and one plate was kept positively charged and the other negatively charged, then there would be an electric field, E , present between the plates, given by $E = V/d$ where V is the pd. between the plates.



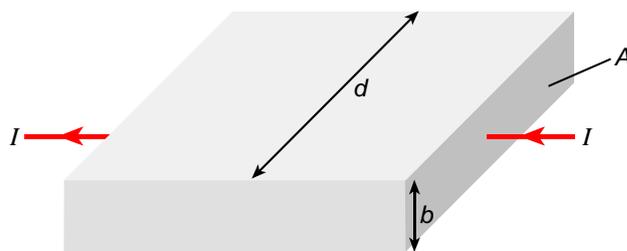
A charge, Q , placed between the plates would experience a force due to this electric field:
force = EQ .

The electric force acting on a charge moving in the metal strip has been given by your answer to question 4.

6. What is the potential difference that has been produced between the front and rear edges of the strip?

7. But $I = nAQv$. What is A if the strip has thickness b ?

You need a relationship for the number of charge carriers that does not contain the velocity of the charge carriers.



8. Use $I = nAQv$ to eliminate v from your equation for the potential difference and obtain an equation relating the number of charge carriers per unit volume to the potential difference. (Check that your expression has the units m^{-3} .)

Practical advice

Because it builds on an optional equation ($I = nAQv$), this question set must be regarded as an extension for more able student.

Answers and worked solutions

1. QvB
2. Towards the front edge.
3. The moving charge carriers are pushed towards the front edge, so the density there will build up. It will continue to increase until there is an equally strong electrical force in the opposite direction to the magnetic field, i.e. from the front to the back.
4. The electric force (EQ) must be equal in magnitude to the magnetic force (BQv). So the electric field $E = Bv$.
5. Front edge negative, rear edge positive.
6. $V = Ed = Bvd$
7. Bd
8. $N = BI / V b Q$

External reference

This activity is taken from Advancing Physics chapter 16, 140S