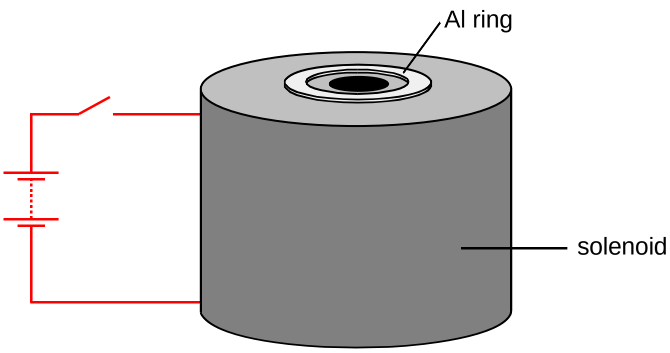
TAP 414-11: Eddy currents and Lenz's law

These questions are all about induced currents. In some circumstances, these are called 'eddy currents'.

Here is a diagram of the well-known 'jumping ring' experiment. If you have not yet seen it done 'live', ask your physics teacher to show it to you.



1. When the circuit is closed, the aluminium ring jumps and falls back down again. Explain why this happens.

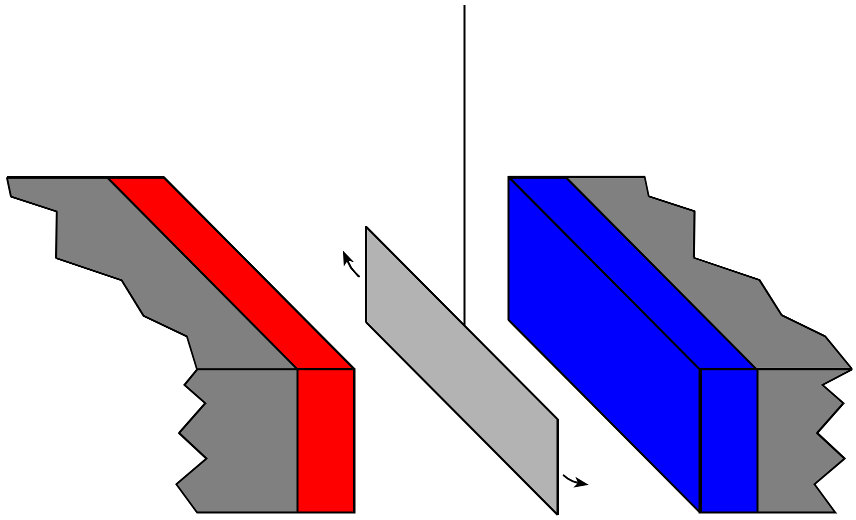
2. What happens when the circuit is broken? Explain your answer.

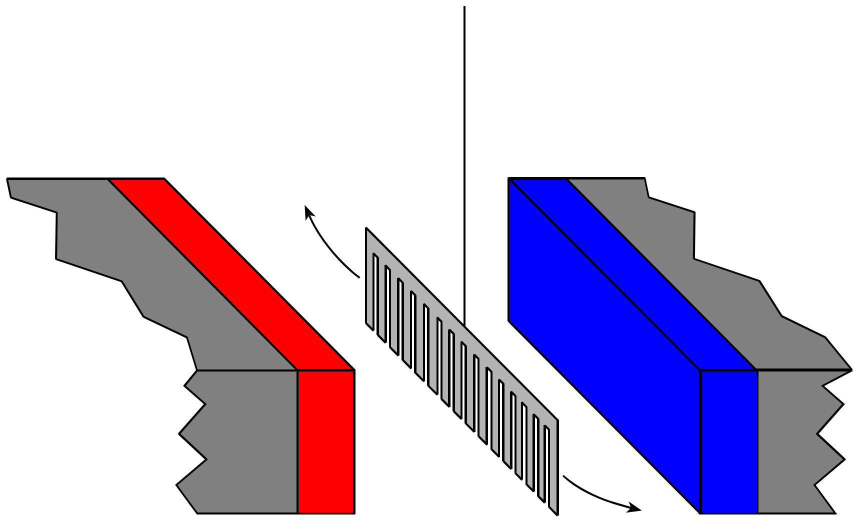
3. The demonstration is a lot more effective if the coil has an iron core that extends some way above the end of the coil. Why is this?

4. It is possible to make the ring hover dramatically above the coil if an alternating current is passed through the coil. How can this happen?

5. Discuss the probable effect on the demonstration of using rings of different materials and dimensions.

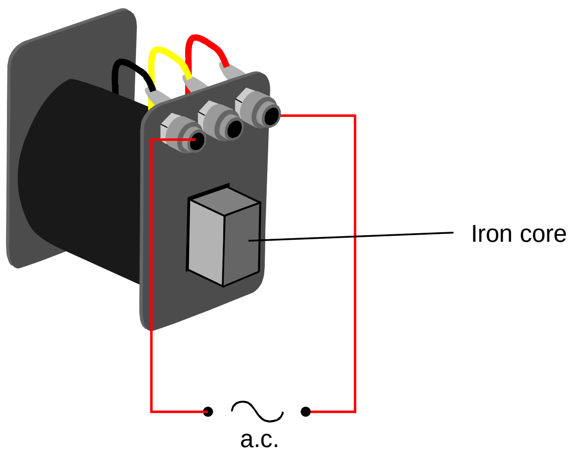
Here is an aluminium vane that swings between the poles of a powerful magnet. When pulled back and released, it comes to rest very quickly. When slots are cut into the vane, it swings for a long time in the same magnetic field.





6. Explain the difference between the two results.

A solenoid is connected to a source of alternating current. Two pieces of iron, A and B, of identical dimensions are treated to look the same. When iron core A is inserted into the solenoid and the current switched on, the iron heats up rapidly and quickly reaches a temperature of 50°C. When iron core B is inserted into the solenoid and the same current passed, there is no detectable heating effect.



7. Suggest and explain how the two pieces of iron differ.

Practical advice

These are good practice questions. The initial ones concern what happens in the 'jumping ring' experiment, and would form a useful follow-up to that demonstration. Another question looks at eddy currents used for braking. A final question requires students to remember and understand why laminations are so helpful in magnetic cores.

Question 5 may be most suitable for a class discussion.

Answers and worked solutions

1. The current is switched on and produces a magnetic flux in the solenoid. Flux lines near the end of the solenoid cut the aluminium ring as the field grows. Change in flux linkage induces an emf in the ring and current flows. The direction of the induced current is such as to oppose the change inducing it (Lenz's law) and the force on the ring due to current in the field acts to drive the ring out of the field, i.e. upwards. When the current, and therefore the flux, reaches a steady value, the induced current falls to zero and the ring falls.
2. The current is switched off and the flux collapses; induced current and the force are in the opposite direction.
3. Presence of iron increases the permeance and more flux is generated for the same current. Assuming that the flux changes at the same rate as without the iron, a greater emf will be produced. (Note: there is a potential problem here with self inductance – if it is very large, the current will collapse slowly.)
4. Alternating current generates an alternating force. Although the current direction changes, the force is always such as to push the ring out of the field – an effect which is counteracted by the weight of the ring. The ring hovers when these forces are (more or less) balanced.
5. Points for discussion include the effect of dimensions on resistance and therefore the size of the induced current; also different materials will have different resistivities. Changing dimensions will also affect the weight of the ring and therefore the balance between gravitational and electromagnetic forces.
6. The solid vane swings in the field, and the conductor cutting the flux lines induces eddy currents in the plane of the vane. Currents flow in such a direction as to minimise change – forces act so as to slow the motion of the vane, i.e. always act in the opposite direction to the motion. In the case of the slotted vane the presence of slots limits eddy currents and therefore the magnetic braking forces.
7. The bar which heats up is completely solid – the heating effect is due to induced currents in the core produced by the flux changing at 50 Hz. The bar remaining cool has been laminated, i.e. made up of thin strips of iron insulated from each other by a non-conducting coating.

External reference

This activity is taken from Advancing Physics chapter 15, 120S