Rotary motion by eddy currents - principle of the alternating current meter (Demo) (Item No.: P1434605)

Curricular Relevance

Area of Expertise: Physics → **Education Level:** Age 16-19 → **Topic:** Electricity → **Subtopic:** Electric generator, motor, transformer → **Experiment:** Rotary motion by eddy currents - principle of the alternating current meter (Demo)

Difficulty	Preparation Time	Execution Time	Recommended Group Size
Difficult	10 Minutes	10 Minutes	1 Student

Additional Requirements:

- Power Supply

Experiment Variations:

Keywords:

eddy currents, force, alternating field, electricity meter, energy meter

Information for teachers

Introduction

A metal disc rotates on a bearing-mounted shaft in the presence to two out-of-phase alternating magnetic fields. Eddy currents are induced in the disc and forces are imparted onto this current-carrying conductor. Out-of-phase alternating fields also cause the rotational movement in conventional, commercial AC electricity meter.

Note

Required voltage: 25 V AC

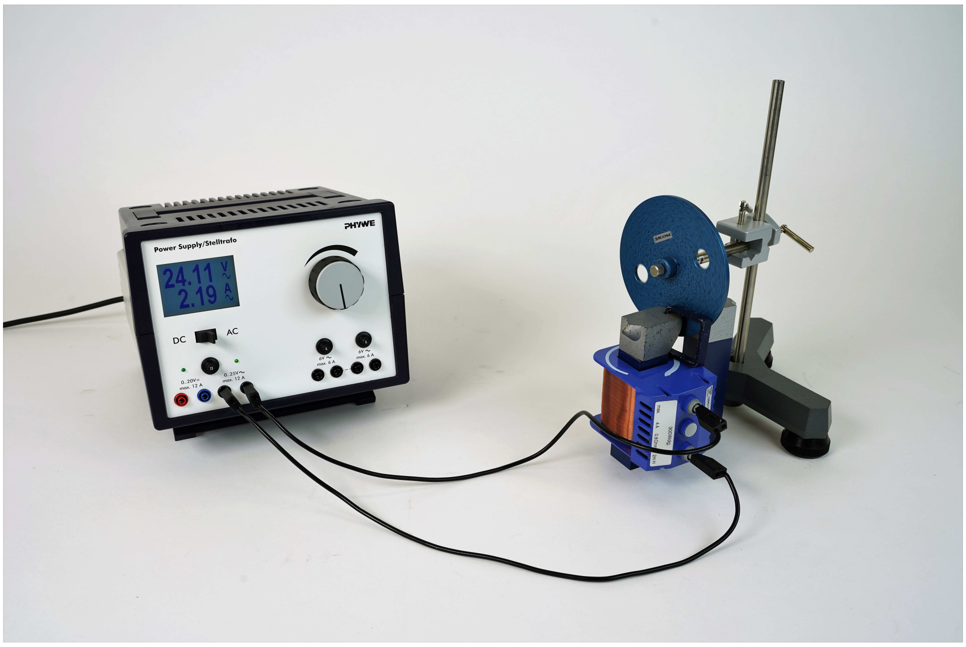

Fig. 1

Equipment

Position No.	Material	Order No.	Quantity
1	Aluminium disk	06564-00	1
2	Iron core, U-shaped, laminated	06501-00	1
3	Pole pieces for iron core, U-shaped	06493-00	1
4	Short-circuit ring	06565-00	1
5	Coil, 75 turns	06511-01	1
6	Bolt with pin	02052-00	1
7	Tripod base PHYWE	02002-55	1
8	Right angle clamp expert	02054-00	1
9	Support rod, stainless steel, l = 250 mm, d = 10 mm	02031-00	1
10	PHYWE variable transformer with digital display DC: 0...20 V, 12 A / AC: 0...25 V, 12 A	13542-93	1
11	Connecting cord, 32 A, 750 mm, black	07362-05	2

Safety information

For this experiment, the general instructions for safe experimentation in science teaching apply.

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Introduction

Application and Task

An electricity meter is mostly well-known from the private household. The electricity meter shows the power consumption and gives the electricity supplier the basis for the bill. In this experiment, the principle of the electricity meter will be developed qualitatively.

Task: Observation of the disc after switching on the current.

Theory

Eddy currents are formed in the disk by the external alternating magnetic field according to the law of induction.

$$rot\vec{E} = -\frac{\partial\vec{B}}{\partial t}$$

Due to the Thomson short-circuit ring placed in one of the pole shoes, the two external magnetic fields are spatially and phasically shifted.

Electricity meters based on this functional principle are so-called Ferraris meters (named after the Italian Galileo Ferraris) and the aluminium disc is also referred to as Ferraris rotor in this context.

Due to the induced eddy currents and their spatial and temporal shift, a mechanical torque is generated, causing the disc to rotate.

Note: In regular Ferraris meters, the rotatably mounted aluminum disc is penetrated by the alternating fields of two excitation coils. One coil is designed as a current path with very few turns, the other as a voltage path with many turns and high impedance. The electric current flowing through the loads also flows through the coil in the current path, while the mains voltage is applied to the coil in the voltage path. The torque exerted on the disc by the magnetic fields is proportional to the product of current and voltage at any given moment. In multi-phase systems, a separate coil in the current and voltage path is required for each phase conductor, whose fields add up.

The cores of the coils in the current and voltage path are arranged on the aluminium disc in such a way that together they generate a rotating magnetic field, which drives the disc via eddy currents induced in it, as in an asynchronous motor. Due to the geometric arrangement of the coils and the fact that the phase angle in the voltage path is shifted by 90° due to the inductance, the torque is proportional to the product of current and voltage, i.e. to the active electrical power, at any given time. For adjustment, the correct phase shift in the voltage path can be set during calibration at the meter. The reactive power then leads to no torque on a time average and is not counted. In addition, there are often short circuit brackets made of resistance wire with which the torque can be adjusted for different power levels.

Setup and procedure

Setup

Fig. 2

Set up the experiment as shown in Fig. 2:

Mount the aluminum disc rotatable onto the bolt with pin. Take care that no clamping friction will occur.

The lower part of the disc has to be located between the pole pieces of the electromagnet. Put the short-circuit ring on the pole piece with slit.

Procedure

When switching on the current, the disc will be penetrated by two phase-shifted magetic alternating fields: On one hand by the field of the electromagnet itself and on the other hand by the field induced by the alternating current in the short-circuit ring.

After switching on the power supply, the disc begins to rotate (approximately 25V~).

Note: If the disc does not turn, move the U-shaped iron core slightly to the side. (The projection of the area of the short-circuit ring should be about halfway free and half on the disk.)

To clarify the importance of the phase shift of the second field, you can remove the short-circuit ring and show that the disc is not rotating anymore.

To change the direction of rotation, the short-circuit ring in the pole piece with slit can be repositioned such that it is on the other side of the pole piece. To do this, switch off the power supply, remove the pole shoe with the short-circuit ring and move the latter from right to left.

Evaluation

Observation

The disc starts to rotate. Without the short-circuit ring, the disc does not move.

When the short-circuit ring is moved to the other side, the direction of rotation changes. The aluminium disc always rotates in the lower area towards the side, to which the short-circuit ring is shifted.

Result

A metal disc, penetrated by two phase-shifted alternating magnetic fields, experiences a force. This way, a revolving disc can be forced to rotation.

The rotation of the disc is caused by the eddy currents induced in the disc. Thereby the disc becomes a conductor through which current flows and on which a force acts in the magnetic field - the Lorentz force.

Since the two magnetic fields are spatially shifted and out-of-phase due to the inductance, the induced eddy currents result in an overall mechanical movement similar to that of an asynchronous motor.