Subject:
In the scientific and technical literature as well as in physics textbooks for the school, the concept of *eddy currents* is introduced. The following definitions which are taken from the literature, try to explain what is meant by an eddy current:

1. “An induced emf not only appears in a conductor loop and a coil. Electromagnetic induction also takes place when the magnetic field changes within a massive metallic body. Due to the extension of the body circular currents appear, which are called eddy currents.”

2. “Such induced currents within metals do not follow a well-defined pathway as would be the case in a wire or a coil. We call them eddy currents.”

3. “Among the induction phenomena there are emf’s and thus also currents whose path is seemingly disordered. These currents generate magnetic fields, that act against the direction of movement and thus hinder the movement. These currents are called eddy currents.”

4. “If a transformer has a core of massive iron, such currents also appear within this core and heat it up […]. These currents are called eddy currents.”

5. “If the disk moves within the homogeneous \( B \) field, the field that crosses each piece of metal is changing. At its circumference a circular emf is induced. The corresponding circular currents or *eddy currents*, that flow everywhere within the metal, experience Lorentz forces.”

6. “…They are called eddy currents because the stream-lines of the induced currents are closed like an eddy. Eddy currents create a magnetic field that is opposed to its cause, i.e. the original magnetic field, according to Lenz’s law.”

7. “Eddy current: The alternating current that is induced within an electric conductor by an alternating magnetic field or by the movement in an inhomogeneous magnetic field. The heat produced thereby (Joule effect) can be used to melt metals (induction furnace). In general it appears as an unwanted power loss (eddy current losses), which is diminished in transformers by making the core of a stack of plates that are insulated from each other. Application: in eddy current brakes, for the damping of electric measuring instruments and for the creation of a couple of forces in the AC electricity meter.”

Two more quotations in the context of superconductivity in which the term eddy current is not applied:

8. “An external magnetic field induces a circular current, that causes an opposing magnetic field inside the superconductor, that compensates the external field.”

9. “The same is true for external magnetic fields. These induce a circular current, which completely squeezes the magnetic field out. Kamerlingh Onnes started a circular current in a coil and switched the battery off.”
Deficiencies:

It is not easy to understand what is actually the characteristic of an eddy current.

Most definitions emphasize that they are closed or circular currents. This, however, is also true for other currents, even those in a circuit with a battery. It is not the case only if \( \frac{dp}{dt} \) (the time rate of change of the charge density) is unequal from zero somewhere in the circuit.

Definition 2 stresses that for an eddy current the pathway is not well-defined. Should that mean that the current could take another path without any reason or cause? Any current flows (in an isotropic conductor) in the direction of the electric field vector. The electric field lines define the path of the electric current. This is true for a current in a wire just as much as for the “eddy” current in the core of a transformer or an eddy current brake.

Quotation 3 says that an eddy current is seemingly disordered. What is meant by that? Is it meant that we cannot know the path of the current or is it meant that we simply did not make the effort to calculate the current distribution?

Quotation 1 and 4 emphasize that the body in which the eddy current is flowing is a massive body. What is meant by massive? Simply a great extension? But sometimes wires are rather massive and eddy current brakes tiny.

In some of the definitions reference is made to the effect of an eddy current. In references 4 and 7 heat production is mentioned, and in 3 and 7 the braking property that is due to Lenz’s rule. However, currents that are not called eddy currents also produce heat and they also have the braking effect. Each generator suffers this braking effect.

Quotation 7 shows best, that the definition is the same as that of any induced electric current.

Finally a comment regarding the term circular current in quotations 8 and 9. What is meant is that the stream lines of the current have no ends. However, this is true for any circuit which is not interrupted by a capacitor. We normally do not emphasize that the current in a circuit is circular. This is evident already from the fact that we use the word “circuit”.

We can state that one and the same phenomenon, is given another name, according to the circumstances in which it appears. In the brake we have an eddy current, in a superconductor a circular current and in the pressing iron or the light bulb we have a common current without a name.

It is useful to differentiate by giving proper names to different phenomena if the names grasp an essential characteristic. Otherwise it is counterproductive. Then it is better to use a unique wording in order to point out the similarities.

The term eddy current and the statement that the current distribution is disordered or undefined may cause yet an additional problem. It strongly suggests a similarity with turbulent flows of liquids, i.e. a phenomenon where the terms disordered and undefined are appropriate. They are, however, in this respect fundamentally different from the eddy currents of electricity.

Origin:

In 1824 François Arago discovered that a magnetic needle that could freely rotate was dragged by a rotating copper disc. This observation led Faraday in 1832 to the discovery of electromagnetic induction.
A quickly rotating copper disc that is placed between two magnetic poles is slowed down. Foucault concluded in 1855 that the work that has been spent to set the disc into rotation must reappear as heat. He was able to show it in impressing experiments. In french language eddy currents are called courants de Foucault. Both the braking effect and the heat production are since then considered the essential characteristics of an eddy current, although both phenomena also arise in any other induced current.

Thus, the particular circumstances of the discovery have lead to the introduction of a new term or concept, in particular the fact that the dragging effect had been discovered before Faraday gave a more general explanation of the electromagnetic induction.

The situation is rather similar to that of Lenz’s rule, which also has survived its own generalization [1].

**Disposal:**

Do not use a particular name for currents that are induced in the iron cores of transformers and in eddy current brakes. In order to distinguish the “eddy current brake” from a mechanical brake you may call it induction brake. If there are doubts about if a current is closed, do not call it a circular current, but simply say that the circuit is closed.

[1] *F. Herrmann: Lenz’s law, no 36 of this series of articles*

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