Students' Difficulties in Understanding the Concepts of Magnetic Field Strength, Magnetic Flux Density and Magnetization

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(Received 13 August 2008; accepted 20 September 2008)

Abstract
The concepts of magnetic field strength, magnetic flux density and magnetization are important fundamental concepts in magnetism. However, these concepts are often confused by students due mostly to different notations and interpretations. This confusion inhibits learning by students about magnetic properties of magnets and of paramagnetic, ferromagnetic and diamagnetic materials. It is therefore very crucial to determine some students' difficulties on these specific concepts. Hence, we prepared seven multiple-choice conceptual questions in accordance with our specific goals and administered to one hundred and sixty-nine undergraduate students (40 first year, 34 second year, 43 third year, 28 fourth year and 24 fifth year) attending the Physics Education Department of Buca Education Faculty at Dokuz Eylül University. Also we interviewed with 11 fifth grade students about their answers. Results of our study show that students have important understanding problems and confusions about related concepts. Otherwise it is stated that this situation causes learning deficiency of magnetic properties of matters.

Keywords: Magnetic field strength, Magnetic flux density, Magnetization, Understanding magnetism concepts.

Resumen
Los conceptos de campo magnético, inducción magnética y magnetización son importantes conceptos fundamentales en el magnetismo. Sin embargo, a menudo estos conceptos se confunden por los estudiantes debido principalmente a las diferentes notaciones y a la interpretación. Esta confusión impide el aprendizaje de los estudiantes acerca de las propiedades magnéticas de imanes y de materiales paramagnéticos, ferromagnéticos y diamagnéticos. Por lo tanto, es crucial determinar algunas de las dificultades de los estudiantes en estos conceptos específicos. Por lo tanto, hemos preparado siete preguntas conceptuales de elección múltiple, de conformidad con nuestros objetivos específicos y administrados a ciento sesenta y nueve estudiantes (40 de primer año, 34 de segundo año, 43 de tercer año, 28 de cuarto año y 24 de quinto año) que asisten al Departamento de Educación en Física de la Facultad de Educación en la universidad Buca Dokuz Eylül. También se entrevistó a 11 estudiantes de quinto grado acerca de sus respuestas. Los resultados de nuestro estudio muestran que los estudiantes tienen problemas importantes de comprensión y confusiones sobre conceptos relacionados. De otra manera se afirma que esta situación provoca deficiencia de aprendizaje de propiedades magnéticas de la materia.

Palabras clave: Campo magnético, la densidad de flujo magnético, magnetización, Comprensión de conceptos de magnetismo.

PACS: 01.40.Fk, 01.40.gb, 01.40.Ha, 01.40.Di **ISSN 1870-9095**

I. INTRODUCTION

Magnetism topics are considered to be quite difficult to learn by students [1]. The concepts, such as magnetic field strength ($\mathbf{H}$), magnetic flux density ($\mathbf{B}$) and magnetization ($\mathbf{M}$), are considered to be essential within the fundamental concepts of magnetism topics in general physics at tertiary level. Hence, it is quite important that these concepts about magnetism have to be learned on the basis of the commonly accepted scientific knowledge. But, although the physical meanings of these are well understood, an agreed interpretation has never been found and controversy about these has obtained for more than a century [2]. The main reason of this problem is that there is a disagreement about which one of these concepts is the primary field and which one is the derived field. There are three fundamental ideas of interpretation of $\mathbf{B}$ and $\mathbf{H}$; one of them is William Thomson's which gives $\mathbf{B}$ and $\mathbf{H}$ equal status as field intensities acting on different elements of the medium, second one is Faraday's and Maxwell's which defines $\mathbf{H}$ as the primary magnetic field that causes the field $\mathbf{B}$ in magnetizable matter [2] and the last one is Lorentz's which interprets $\mathbf{B}$ as the average of microfields and primary magnetic field and $\mathbf{H}$ as derived field [2, 3]. In general, the physicists choice last one [3, 4, 5] and engineers prefer second one [3, 4, 6, 7] while teaching electromagnetism. The disagreement about interpretation of these concepts has also been reflected in the main text books [8].

According to engineers' choice the equation concerning these concepts is defined as

$$\mathbf{B} = \mu_0 (\mathbf{H} + \mathbf{M}), \tag{1}$$

where $\mathbf{B}$ is the magnetic flux density inside the material, $\mathbf{M}$ is the magnetization induced by the applied external magnetic field strength $\mathbf{H}$ and μ_0 denotes the magnetic permeability of vacuum [8]. Direct relation between $\mathbf{B}$ and $\mathbf{H}$ is also given by equation

$$\mathbf{B} = \mu \mathbf{H}, \tag{2}$$

where μ is the magnetic permeability of medium.

According to physicists' choice the equation concerning these concepts is defined by equations [3]

$$\mathbf{H} = \mu_0^{-1} \mathbf{B} - \mathbf{M}, \tag{3}$$

or [2]

$$\mathbf{H} = \mathbf{B} - 4\pi \mathbf{M}. \tag{4}$$

Direct relation between $\mathbf{H}$ and $\mathbf{B}$ is also given by equation [3]

$$\mathbf{H} = \mu^{-1} \mathbf{B}. \tag{5}$$

In addition to this controversy, other reason of students' deficiencies is that there is a clear predominance of the magnetic induction $\mathbf{B}$ over the magnetic field strength $\mathbf{H}$ in majority of courses and textbooks. So, magnetic field strength $\mathbf{H}$ is almost absent in electromagnetism course [9].

Hence, we believe that, these confusions may easily mislead students causing severe internalizing problems. In this research, we aim to determine student difficulties especially about these three fundamental concepts and related topics such as magnetic properties of magnets and diamagnetic, paramagnetic and ferromagnetic materials.

II. METHOD

In order to determine the present situation, we employed seven conceptual multiple-choice questions as a quantitative measuring instrument (see Appendix). These questions are prepared based on the previous bibliographic review and the opinions of experienced physics professors in our department. One hundred and sixty-nine undergraduate students (40 first year, 34 second year, 43 third year, 28 fourth year and 24 fifth year) attending the Physics Education Department of Buca Education Faculty at Dokuz Eylül University answered the questions. First and second grade of these students completed general physics course, third and forth grade students fulfilled general physics and theory of electromagnetism courses and fifth grade students finished solid state physics course beside these courses before answered these questions.

We also interviewed with eleven students about their answers. Generally we asked them about what they think while answering questions. These students are selected form fifth grade students according to their general success from low to high. The selection reason of these students is think of they can explain their answers more scientifically because of finishing all related courses.

III. RESULTS and DISCUSSION

In this section, answers of the students were analyzed and some important outcomes of the investigation are briefly reported.

TABLE I. Answering Percentages for the Question 1.

Choice	Frequency	Percentage
None	1	0,6
A	17	10,1
B	38	22,5
C*	89	52,7
D	24	14,2
Total	169	100,0
*Correct Answer		

The aim of the question 1 was to determine students' difficulties on understanding the factors affecting magnetic properties of a magnet.

The majority of the students (89) in fact know the magnetic properties of a magnet depend up on the number of atoms having net magnetic moments in the same direction. However, 17 students think that the bigger the magnet, the stronger the attracting force must be. The number of magnetic dipoles in the same direction for each magnet was not given in the question. For this reason, there is no certainty about which magnet has more net magnetic moment per unit volume. Therefore, these students without considering the magnetization think that bigger magnet always attracts stronger than the smaller one. As Stephans [10] pointed out, one of the students' misconceptions about magnetism is that strength of a magnet determined by its size. So, we see that these students still remain their misconceptions about magnets. A number of students (38) believe that the effects of the magnets on the iron marble do not depend on their physical shapes of their poles. But we know that, distribution of the magnetic field lines is strongly related to the shape of the magnetic poles. Consequently, the shapes of the poles affect the density of field lines and so magnitude of the magnetic flux density can be changed with the shapes of the poles were the marbles exist. This shows us, these students have deficiency about physical meaning of magnetic flux density. Also, 24 students think that both magnets attract with the identical forces. We can say that, these students do not take into account which magnet has more net magnetic moment per unit volume.

Eight students that we interviewed answered this question correctly and their explanations were consistent with scientific knowledge. Two (Yelda and Hidayet) of the students was answered as "D". When we asked about their preference;

Yelda said, "*Attraction force does not depend size of the magnets and magnetization of magnets does not depend kind of the material that magnets were made. So both attraction forces are equal*"

Hidayet said: "*Distances of the marbles to the magnets are equal. The numbers of the field lines at same distances (on marbles) are equal in both situations. So attracting forces must be equal too. Attracting force does not depend sizes of the magnets. Also, I have not well knowledge about formation of magnetic field of a magnet.*"

One (Serkan) of the students answered this question as "B". Serkan explained his answer as "*Shape of the poles of magnets does not affect the attracting forces on marbles.*"

The outcomes of this question clearly indicate that, many students have some difficulty on understanding the factors on which magnetic properties of a magnet depend.

TABLE II. Answering Percentages for the Question 2.

Choice	Frequency	Percentage
None	31	18,3
A	51	30,2
B *	24	14,2
C	11	6,5
D	2	1,2
E	6	3,6
F	2	1,2
G	21	12,4
H	21	12,4
Total	169	100,0
*Correct Answer		

The direction of magnetization vector ($\mathbf{M}$), in a strong and constant external magnetic field was asked in the question 2 for a diamagnetic material. Only limited number of students (24) seem to have the correct answer, B. The majority of the students can not decide the direction of the magnetization vector in a diamagnetic material when an external magnetic field is applied.

TABLE III. Answering Percentages for the Question 3.

Choice	Frequency	Percentage
None	34	20,1
A*	52	30,8
B	20	11,8
C	10	5,9
D	7	4,1
E	7	4,1
F	7	4,1
G	15	8,9
H	17	10,1
Total	169	100,0
*Correct Answer		

In the question 3, we investigated the direction of the magnetization vector in a paramagnetic material which lies in a strong and constant external magnetic field. As we see from the table III, only 52 students have the correct answer, A, to this question. Therefore, in accordance with the previous case, we can say that majority of the students could not decide about the direction of the magnetization vector in a paramagnetic material when an external magnetic field is applied.

TABLE IV. Answering Percentages for the Question 4

Choice	Frequency	Percentage
None	41	24,3
A*	55	32,5
B	22	13,0
C	6	3,6
D	3	1,8
E	9	5,3
F	5	3,0
G	18	10,7
H	10	5,9
Total	169	100,0
*Correct Answer		

The direction of the magnetization vector, this time in a ferromagnetic material and in a homogeneous external magnetic field, was questioned in the item 4. Only 55 students give the correct answer, A. Most of the students are not able to decide about the direction of the magnetization vector in a ferromagnetic material.

Six of the interviewed students gave the correct answer for question 2, eight of them answered correctly question 3 and for question 4 there are 10 students who have true answers. These three questions were evaluated together during the interview. Explanations of students who have difficulties about these questions are so;

Batuhan said: *"Concept of magnetization reminds me magnetic properties of materials. I do not have an idea anymore about this concept. So I could not answer these questions. I know theoretical means of paramagnetic, diamagnetic and ferromagnetic. I classify these materials according to their relative permeabilities. If μ_r>>1 then material is ferromagnetic, if μ_r≈1 then material is paramagnetic and if μ_r<1 then material is diamagnetic. But I do not know how magnetization occurs in these materials when they are in an external magnetic field"*

Harun said: "I always confuse properties of these materials. I think diamagnetic material is affected by external field at the very least within these materials. But magnetization occurs in the same direction with external magnetic field for all these materials."

Hidayet said: "The magnetization always tends to encourage the external field in these materials. At least in diamagnetic materials, thereafter paramagnetic materials and at most in ferromagnetic materials."

Nur said: "Diamagnetic and paramagnetic materials do not have permanent magnetization. So magnetization vector tends opposite to the external field in these. Only ferromagnetic materials have permanent magnetization *and magnetization vector tends to same direction with applied field."*

Serkan said: "If we put in order these according to their magnetic properties, we can say that the best magnetics are ferromagnetic materials, thereafter paramagnetic materials and the worst magnetics are diamagnetic materials. Magnetization occurs in the same direction with external field in all these materials and magnitude of this is in order as I mentioned above".

Combining the questions 2, 3 and 4 shows us that, the majority of the students do not know how an external magnetic field and matter interact. Hence, they have some fundamental difficulties in explaining the magnetic properties of diamagnetic, paramagnetic and ferromagnetic materials.

TABLE V. Answering Percentages for the Question 5.

Choice	Frequency	Percentage
None	6	3,5
A	59	34,9
B*	90	53,3
C	14	8,3
Total	169	100,0
*Correct Answer		

In question 5, we aimed to determine the level of the students' knowledge on the effects of an external field to the reorientation of the magnetic dipoles in a ferromagnetic material. According to the given answers, 59 students think that the iron rod could be magnetized if we touch it to the magnet for a short time. In this case, the point A of the rod behaves as the N pole of the magnet and the point B behaves as the S pole of the magnet. However, after the rod was removed from the magnet and the other pole of the magnet was drawn nearer to the rod, these students think that both poles of the magnet and rod are the same and they repel each other. Also, eight of the interviewed students explained their answers according to this idea. For example:

Harun said: "*When we touch the magnet to the iron rod, iron rod becomes a magnet and it has the same polar properties with touched magnet. Because it is a ferromagnetic material. So A point becomes N pole and B point becomes S pole. In second situation same poles repel each other."*

Also, in addition to Harun's like explanations, three of the students (Duygu, Özgür and İsmail) indicated that magnetization occurs with physical contact. So, when magnet is drawn nearer to the rod in second situation, magnetization of the iron rod does not change. Because, magnet did not touch to the rod.

The results show that, these students do not take into account that the magnetic dipoles were inclined to the opposite direction in iron rod due to the new external magnetic field at second situation. We can now draw a conclusion that, students could not learn or remember the magnetic properties of a ferromagnetic material and the characteristics of the hysteresis curve.

Surprisingly, our interview exposed that, two of the students (Aysun and Yelda) who seem gave correct answer used a wrong way while answering. For example:

Aysun said: *"If we think that, N pole of the magnet charged (+) and S pole (-). When we touch the magnet to the rod, A point becomes (-). So in the second situation, magnet attracts the iron rod. Because opposite charges attract each other."*

This result shows that some of the students use electrical model to explain the magnetic phenomena as indicated in related literature [11, 12]. According to us, the cause of this problem is that students have important deficiencies on explaining how a magnet creates its magnetic field.

TABLE VI. Answering Percentages for the Question 6.

Choice	Frequency	Percentage
None	19	11,2
A	15	8,9
B	37	21,9
C	25	14,8
D*	57	33,7
E	16	9,5
Total	169	100,0
*Correct Answer		

In question 6, we propose to measure student understandings about the relationship between the concepts of magnetic field strength, magnetic flux density and magnetization. It is fairly well known that, iron is a ferromagnetic and gold is a diamagnetic material. These properties are strongly linked with the magnetic permeability of the materials. When the iron sphere is placed in an external magnetic field, the magnetic dipoles tend to orient themselves parallel to the applied magnetic field strength ($\mathbf{H}$). In this situation, a net magnetization ($\mathbf{M}$) occurs which is parallel to the external field. So the number of the field lines increase at the point "1" in the figure. This means the magnitude of the magnetic flux density ($\mathbf{B}$) at the point 1 increases too. When the gold sphere is placed in an external magnetic field, atomic dipoles tend to orient themselves opposite to the applied field depending on the magnetic field strength ($\mathbf{H}$). In this situation, a net magnetization ($\mathbf{M}$) occurs which is opposite to the external field. The number of field lines this time goes down at the point "2". One can say that the magnitude of the magnetic flux density ($\mathbf{B}$) also decreases. There is a vacuum at the point "3", so there is no change at the number of the field lines at that point.

When we look at the given answers, we can see that students could not think about the magnetic properties of matter while answering the question. For example, 15 students explain that the materials in the external field do not affect the field lines and magnitude of the magnetic flux density is equal at the points of 1, 2 and 3. One of the interviewed students (Harun) explained his answer so:

Harun said: "*Materials in-between the poles of magnets do not affect the magnetic field. Because distances of poles are equal.*"

Also, 37 students believe that all materials affect the external field because they prevent the field lines crossing the material.

Aysun said: "*I think that magnitude of the magnetic flux density reaches its highest value at the point 3 because there is no matter between poles. Matters prevent the field lines.*"

We think that these students may believe real existence of field lines as defined in Guisasola et als' the study [12] and think of magnetic field as a flow of something that was denoted by Saglam and Millar [13]. Because according to them, matters prevent the flowing of field lines.

25 students express that gold is a better conductor than the iron, so it allows the field lines penetrating the material better than iron. Two of the interviewed students (Duygu and Serkan) have this idea. For example;

Serkan said: "*Gold is better conductor than iron. So it conducts the magnetic field lines better than iron.*"

Thus, again we can say that these students confuse electrical and magnetic properties of matters.

16 students believe that, both the gold and iron are metals, so exactly same effects occur on the field lines for both of these cases. These students may think that magnetic field has same affect on all metals. As Stephans [10] indicated that, one of the students' misconceptions about magnetism is idea of magnets attract all metals. We see that these students still remain their misconceptions.

According to these outcomes, students have some difficulties about magnetic properties of materials and interaction of matter-magnetic field. Also they could not understand the relationship between the concepts of magnetic field strength, magnetic flux density and magnetization. In addition, they seem to be confusing the electrical permeability and the magnetic permeability of materials.

TABLE VII. Answering Percentages for the Question 7.

Choice	Frequency	Percentage
None	23	13,6
A	24	14,2
B	44	26,0
C	54	32,0
D*	24	14,2
Total	169	100,0
*Correct Answer		

At question 7, we want to underline students' understanding about the relationship between the concepts of magnetic field strength, magnetic flux density and magnetization. It is clear that when we insert the iron core inside the coil L, the magnetization in the iron core increases the magnitude of the magnetic flux density and compass needle turns towards the point "2". Only 24 students give the correct answer to this question. Other 24 students think that the iron core does not affect the magnitude of the magnetic flux density, because the value of the current on the coil is constant.

Aysun said: "*Direction of the compass needle does not change. Because value of the currents on the both coil are same and they create equal magnetic fields.*"

The students here can not assume that the reorientation of the magnetic moments inside the iron core actually causes an increase in the magnetic field strength outside the material.

According to 44 students, the magnetization in the iron core occurs opposite to the external magnetic field strength which is produced by the current in the coil. Hence, the value of the magnetic flux density decreases and the compass needle turns towards the point "1".

Also 54 students claim that when the iron core is placed in the coil, the magnitude of the magnetic field strength produced by the current also increases. Five of interviewed students (Nur, Serkan, Yelda, Özgür and İsmail) have this idea. We see that these students confuse Faraday's induction law and magnetic induction (magnetic flux density). As an example;

Özgür said: "*When we put the iron core inside the coil, it creates induction current and this current increases the magnitude of magnetic field*"

But as we all know, the current has a constant value and never changes in this situation.

Also four interviewed students denoted that they do not know the difference between magnetic field strength and magnetic flux density.

Therefore, it is quite clear that students are very much confused with the concepts of magnetic field strength ($\mathbf{H}$) and magnetic flux density ($\mathbf{B}$). And they could not decide the affect of magnetization on magnetic flux density.

IV. CONCLUSIONS

If we summarize the outcomes of this work; it is clear that, students have some certain difficulties on the following points.

According to results of question 1, students have important deficiency about explaining of magnetic properties of magnets. They can not decide how a magnet creates its magnetic field and what conditions affect this. As we know that there are two sources of magnetic field, one is that magnetic field created by magnets and second is that magnetic field created by electric currents. On the other hand, second one is predominant in electromagnetism courses generally. We suggest that at the beginning of the magnetism course, creation of magnetic field of magnets should be introduced. Because most of the students have experiences with magnets in their life. We think this will draw attention of students. So, firstly, a simple atomic model of magnets should be introduced. This will allow students to predict the magnetic dipole moment of a bar magnet [14]. Magnetic dipole moment that created by atomic currents per unit volume gives the magnetization and net magnetization in magnets generate magnetic field of magnets as shown in the figure 1.

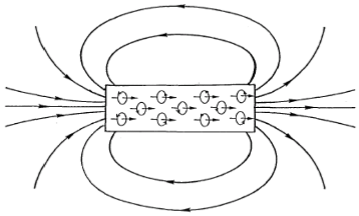

FIGURE 1. Micro-currents Circulating Create Elemental Magnets [11, p. 371].

This model will help students to understand how magnetic field of magnets occurs, may prevent students' electrical modeling about magnets and also introduce the concept of magnetization, $\mathbf{M}$. This content also will help students to understand magnetic properties of matters.

Results of questions 1, 2 and 3 show that students have deficient knowledge about paramagnetic, diamagnetic and ferromagnetic materials. And they confuse the properties of these materials. We think that, if the model, mentioned above for magnets, is used for these materials this should solve the students' problems. After the introduction of magnets and its properties, magnetic properties of matters should be given. Because, existences and behaviors of the magnetic dipole moments identify the properties of these materials. We also see that when students use comparing permeabilities of these materials (μ) with permeability of vacuum (μ_0) as $\mu >> \mu_0$, $\mu < \mu_0$, etc. or relative permeabilities of these (μ_r) with the number of 1 as $\mu_r >> 1$, $\mu_r < 1$, etc. to classify these materials, they may make mistake. They think that magnetization in the material occurs in the same direction with external field when the material is placed in an external magnetic field in all of these materials. Because there is no negativity in above comparisons and there seem to be graduation. We think that this situation causes confusion. So we suggest using magnetic susceptibilities (χ_m) of materials rather than permeabilities. Because, χ_m of diamagnetic materials have negative value and paramagnetic and ferromagnetic materials have positive value. Thus equation that gives relation between $\mathbf{H}$ and $\mathbf{M}$

$$\mathbf{M} = \chi_m \mathbf{H}, \qquad (6)$$

shows that magnetization occurs in opposite direction with external field in diamagnetic materials and in the same direction with external field in paramagnetic and ferromagnetic materials. This would solve students' confusion problems.

Also, using the χ_m in the equation that gives the relationship between $\mathbf{B}$ and $\mathbf{H}$ like

$$\mathbf{B} = \mu_0 (1 + \chi_m) \mathbf{H}, \qquad (7)$$

can solve the students' problems in question 6. If χ_m is negative, magnitude of magnetic flux density in the material will be lesser than magnitude of external magnetic field for diamagnetic materials. This means that magnetization inside the material tends to deflect the external field. If χ_m is positive magnitude of magnetic flux density in the material will be more than magnitude of external magnetic field for paramagnetic and ferromagnetic materials. It means that magnetization inside the material tends to encourage the external field. So, after this clear difference between diamagnetic materials and paramagnetic/ferromagnetic materials students only have to keep in their minds that paramagnetic materials does not have permanent magnetizable properties and ferromagnetic materials have permanent magnetizable properties.

But we see that definition of "permanent magnetizable" could be understood wrongly by students as in question 5. Students do not take into account that magnetization of magnetized ferromagnetic material can be changed or disrupted by external effects (new external magnetic field, hard stroke, temperature etc.). In this situation importance of hysteresis loop for ferromagnetic materials appears. Teaching the properties of ferromagnetic materials on hysteresis loop as detailed can solve this problem. Also designing some easy experiments can be more didactic. We realized our fifth question with a simple experiment and students that we interviewed and who gave the answer of magnet repels the iron rod were very surprised. Because, magnet attracted the rod. Then we explained the reason of this. Also we showed that a magnetized iron rod attracts the pin. After this demonstration we hit the rod hardly to the table and bring near the pin again. Students saw that rod did not attract the pin after this. Thus students were aware of magnetization of a ferromagnetic material can be changed.

In addition to all these we suggest to use magnetic field strength $\mathbf{H}$ as primary (external) magnetic field, not the magnetic flux density $\mathbf{B}$ while teaching magnetostatics as pointed out in Herrmann's [9] study. Because, we think that physical meanings of these concepts can be learned easily by this way. According to equation (1), magnetization $\mathbf{M}$ inside the material which tends to encourage the external field $\mathbf{H}$, provides concentrating of the field lines in the material for paramagnetics and ferromagnetics. So, Magnetic flux density $\mathbf{B}$ inside the material increases. And magnetization $\mathbf{M}$ inside the material which tends to deflect the external field $\mathbf{H}$, provides scattering of the field lines in the material for diamagnetics. So, Magnetic flux density $\mathbf{B}$ inside the material decreases. We think that this kind of explanation helps to understanding of the meanings of these concepts and decreases students' difficulties as seen in questions 6 and 7.

We know that relationship between $\mathbf{B}$ and $\mathbf{H}$ for vacuum is given by equation

$$\mathbf{B} = \mu_0 \mathbf{H}, \qquad (8)$$

This equation suggests that the information content about the field provided by **H** in a vacuum is always exactly the same as that provided by **B** [2]. Hence, we think that use of **B** as a primary field when discussing problems of other magnetism topics (magnetic fields of current carrying cables and coils, magnetic forces, magnetic induction etc.) will not cause a conceptual confusion for students. Because, generally we operate in vacuum when dealing with these topics.

Thus, we hope that we can prevent the students' conceptual confusions about these concepts and provide better learning.

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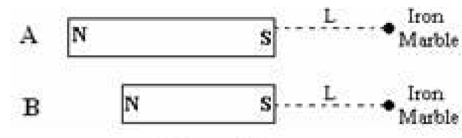
APPENDİX : Questions

Question 1



Two iron marbles having identical properties are placed at a distance of "L" from the bar magnets A and B having the same pole shapes as shown in the figure. Which of the following is <u>certainly correct</u> for the magnitudes of the attracting forces between the magnets and the marbles?

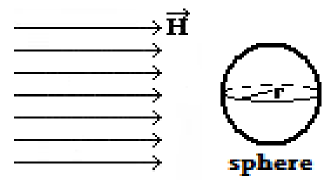
A) The magnet A always attracts stronger than the magnet B because it is physically bigger than the magnet B.

B) The magnitude of attracting force of the magnets does not depend on the shape of the poles.

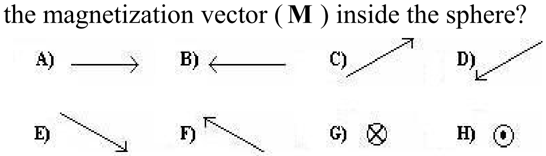
C) The magnet having more net magnetic moments in the same direction attracts more strongly than the other.

D) Both magnets attract with identical forces because magnitudes of the magnetic field strength are equal at the points where the marbles exist.

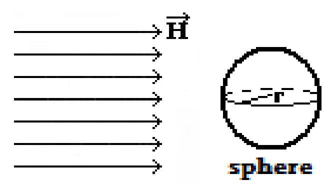
Question 2



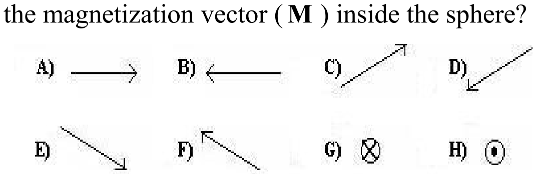
If a sphere, having a unit volume and made of a <u>diamagnetic</u> material, is placed into a strong and constant external magnetic field **H** that has a direction as shown in the figure, which of the following shows the direction of the magnetization vector (**M**) inside the sphere?



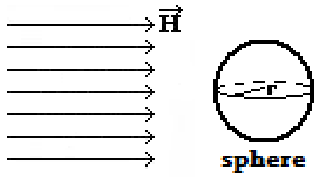
Question 3



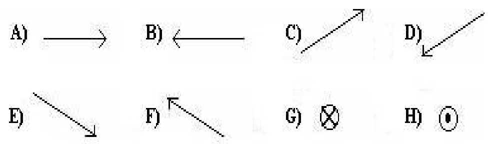
If a sphere, having a unit volume and made of a <u>paramagnetic</u> material, is placed into a strong and constant external magnetic field **H** that has a direction as shown in the figure, which of the following shows the direction of the magnetization vector (**M**) inside the sphere?



Question 4



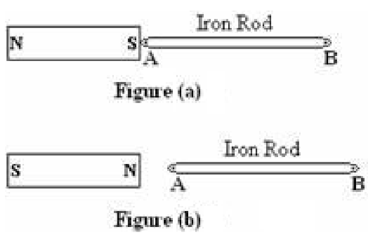
If a sphere, having a unit volume and made of a ferromagnetic material, is placed into a constant external magnetic field **H** that has a direction as shown in the figure, which of the following shows the direction of the magnetization vector (**M**) inside the sphere?



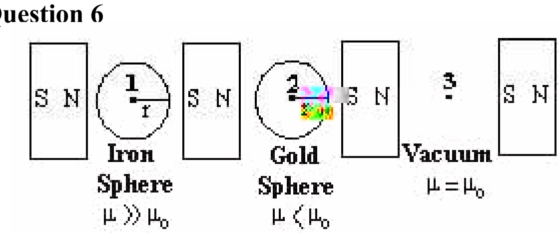
Question 5

Point A of an iron rod is touched to the S pole of a magnet as shown in the figure (a). The rod is then disconnected from the magnet and the other pole of the magnet is drawn nearer to the rod as shown in the figure (b). According to this information, which of the following is certainly true for the effect of the magnet on the rod in the figure (b)?

A) Magnet repels the iron rod.
B) Magnet attracts the iron rod.
C) No force exerts on the iron rod.



Question 6



A system consisting of four identical magnets and two different spheres is set as shown in the figure. Which of the following is correct for the magnitude of the magnetic flux densities at the points of 1, 2 and 3? (Here, μ is the magnetic permeability of the spheres and μ_0 is the magnetic permeability of the free-space. Suppose that magnetic field strength of the magnets are efficient to affect the magnetic properties of gold and iron.)

A) Magnitudes of the magnetic flux densities are equal at all three points because the magnets are identical.

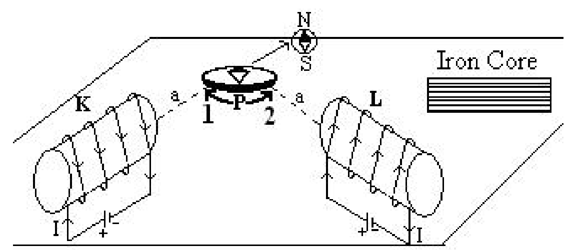
B) Magnitude of magnetic flux density reaches its highest value at the point 3 because there is no medium which would affect the magnetic flux density in any way.

C) Magnitude of magnetic flux density reaches its highest value at the point 2 because gold is a better conductor than iron and it allows the field lines to penetrate better than iron.

D) Magnitude of magnetic flux density has its highest value at the point 1 because magnetization inside the iron sphere increases the magnitude of the magnetic flux density in the region including the point 1.

E) Magnetic flux densities have the same values at the points 1 and 2, and also they are higher than the one at point 3. Because, gold and iron are metals and same effects occur on the field lines for each case.

Question 7



Two identical coils carrying the same constant current are placed on a table as shown in the figure. A compass needle is placed at the same distances from the coils. To start with, the S pole of the compass needle points to P. If we put an iron core inside the coil L, which of the following is certainly correct for the new direction of the compass needle?

A) Direction of the needle does not change because of the value of the current on the coil L is constant. Therefore, magnitude of the magnetic flux density remains at the same value.
B) The needle of the compass turns towards the direction of 1, because there is an induced magnetic field inside the iron core that opposes to the magnetic field of the coil L. So magnitude of the magnetic flux density decreases at the point where the compass is placed.
C) The needle of the compass turns towards the direction of 2, because when we put the iron core inside the coil L, the current dependant magnitude of the magnetic field strength increases.
D) The needle of the compass turns towards the direction of 2, because the magnetization in the iron core increases the value of the magnetic flux density at the point where the compass exists.