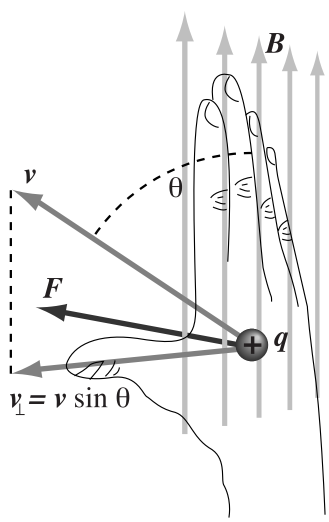
Magnetism

Answers and Explanations

1. C

A magnetic force is produced on a particle proportional to the charge, field strength and the component of its velocity perpendicular to a magnetic field. The force produced is perpendicular to both the particle velocity and to the field.

We have a right hand rule to determine the direction of the magnetic force on a positively charged particle. Align your thumb in the direction of the component of particle velocity perpendicular to the field. Align your fingers in the direction of the magnetic field. The direction of the magnetic force vector is pointing out of your palm.



If the charge moving into the magnetic field in the problem were a positive charge, the resulting magnetic force on it as it enters the field would be out of the page. However, because it is a negative charge, the orientation of the force is reversed. The particle experiences a force into the page.

2. A

The magnetic force acting on a particle moving through a magnetic field is proportional to the component of the particle's velocity perpendicular to the field. The particle's velocity in this problem, however, is completely parallel to the magnetic field, so no magnetic force results.

3. D

The charged particle will experience an electrostatic force in the direction of the electric field and begin to accelerate in that direction. Because the particle's velocity will be completely parallel to the magnetic field, no magnetic force results, so it will continue moving in a straight line.

4. D

The magnitude of the magnetic force is the product of the charge, the speed of the particle, the magnetic field strength and the sine of the angle between particle velocity and the field. (You can also think of it as the product of the charge, the field, and the speed perpendicular to the field).

$$F = qvB \sin\theta$$

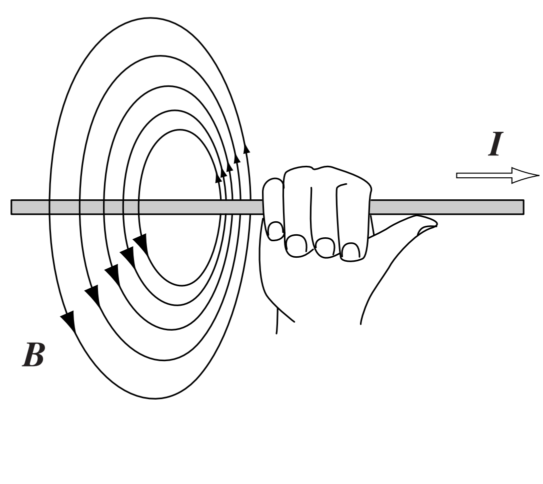
$$= (1.6 \text{ X } 10^{-19} \text{ C})\ (2.0 \text{ X } 10^{6} \text{ m/s})\ (300 \text{ T})\ (0.5)$$

$$= 4.8 \text{ X } 10^{-11} \text{ N}$$

Orienting our right hand rule with our thumb in the direction of the velocity component perpendicular to the field predicts a force into the page for a positively charged particle into the page.

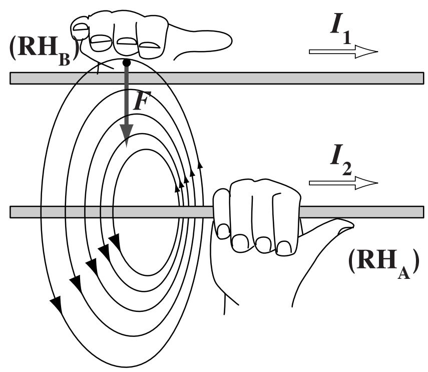
5. B

The magnetic field of a straight current carrying wire encircles the wire. With the thumb of your right hand pointed in the direction of positive current, wrapping your fingers around the wire gives the orientation of the magnetic field.



6. A

Use both right hand rules: Use the first rule, (**RH_A**), to predict the orientation of a field produced by the current of one of the wires. The second rule, (**RH_B**), predicts the orientation of the magnetic force. In the figure below, we see that the magnetic field produced by current I_2 exerts an attractive force on current I_1. The two wires attract each other.

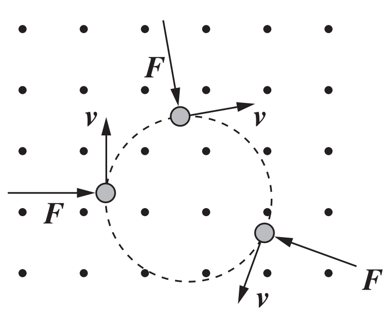


RH_A – Point the thumb of your right hand in the direction of positive current, then wrap your fingers around the wire to show orientation of the magnetic field.

RH_B – With your thumb of your right hand in the direction of the component of the current that is perpendicular to the magnetic field from the other wire and your fingers in the direction of that field, the direction of the magnetic force is out of your palm.

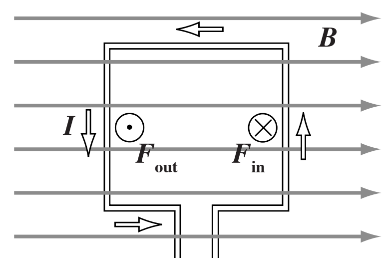
7. B

The magnetic force is perpendicular both to the particle velocity and to the magnetic field. The particle moves in a circle. The magnetic force is a centripetal force.



8. A

If the plane of a horizontal current loop is parallel to a magnetic field, a downward magnetic force is produced on one side of the loop and an upward force on the other. The result is a net torque on the loop that increases with the current, loop area, and magnetic field strength.



9. A

Orienting our right hand with our fingers straight in the direction of the field lines into the page and our thumb in the direction of the velocity component perpendicular to the field predicts a force to the left for a positively charged particle. Therefore, particle 4 must necessarily be negatively charged.

The only negatively charged particle of the choices is β^-.

10. C

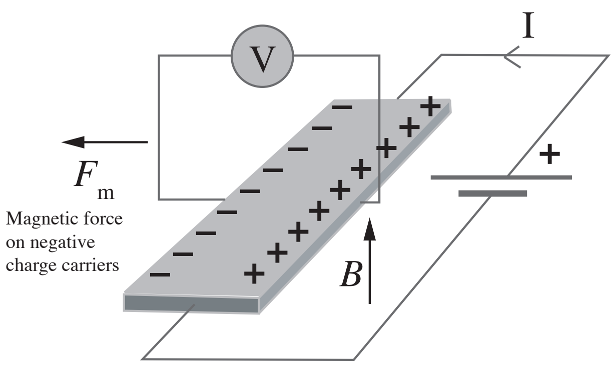
A charged particle moving perpendicular to a static uniform magnetic field will move in a circle due to magnetic force. The circular motion may be superimposed with an axial motion, resulting in a helix. In other words, charged particles spiral around magnetic field lines. This is how the magnets within a cyclotron can be made to steer and focus the particle beam.

The key to getting a question like this correct is not to be intimidated by out of scope reference. We can rule out choice '**B**' because the magnetic force is always perpendicular to the instantaneous velocity of the particle it acts on, so it does not perform work on the particle. The magnetic force steers the particles. It does not cause them to gain kinetic energy.

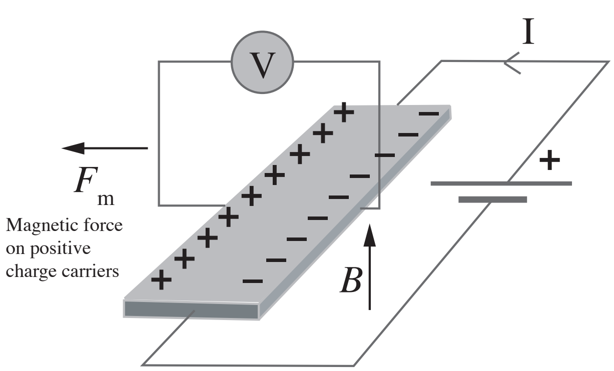
11. A

The magnetic field exerts a transverse force on the charge carriers moving through the flat conductor which tends to push them to one side of the conductor. The build-up of charge produces a measurable voltage between the two sides of the conductor. The presence of this measurable transverse voltage is called the Hall effect.

By convention, we always refer to the current as the flow of positive charge even when the charge carriers are electrons moving in the opposite direction, as you have in metallic conductors. However, the Hall effect is one of the few problems where the identity of the charge carriers makes a difference in the answer. For our problem involving a flat copper plate, the charge carriers are electrons flowing in the opposite direction of the positive current depicted in the figure. This produces the voltage as shown below:



You would have gotten a different answer if the current were actually composed of positive charge carriers flowing in the same direction as the current.



12. B

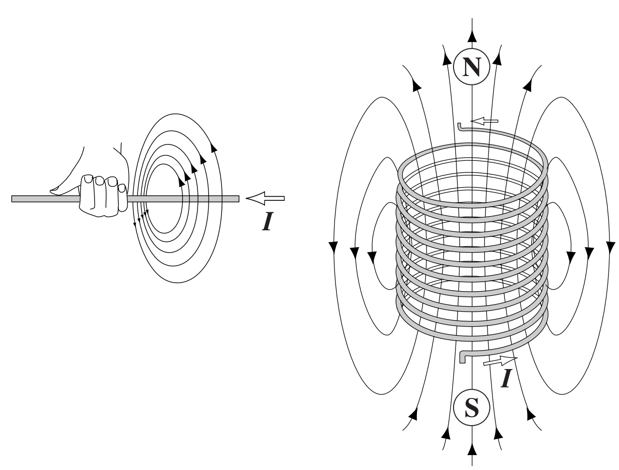
Paramagnetic materials possess unpaired electrons at the orbital level. Paramagnetic materials exhibit magnetization proportional to the strength of the external magnetic field in which the material is placed, and when the field is removed, the magnetization disappears.

All electrons are paired in diamagnetic materials. When an external magnetic field is applied to a diamagnetic material, the tiny electron current loops at the atomic level align in such a way as to oppose the applied field. This magnetization also disappears after the external field is removed.

In ferromagnetic materials, unpaired electron spins line up parallel with each other in large scale magnetic domains. The bulk material is usually unmagnetized because the domains will be randomly oriented. However, in an external field the magnetic domains align and the ferromagnetic material becomes magnetized. Magnetization is rapid and nonlinear up to a saturation point. With ferromagnetic materials, there may also be remanence, meaning that magnetization may persist even after removal of the external field.

13. B

A current carrying conductor wound into a tight helix is known as a solenoid. The magnetic field inside a long, narrow, tightly wound solenoid is uniform.
Use the right hand for predicting the orientation of the magnetic field of a current to determine the orientation of the field within the coil:



14. A

Triplet oxygen, high spin iron II, and iron III all have unpaired electrons. As such, they are all three paramagnetic.

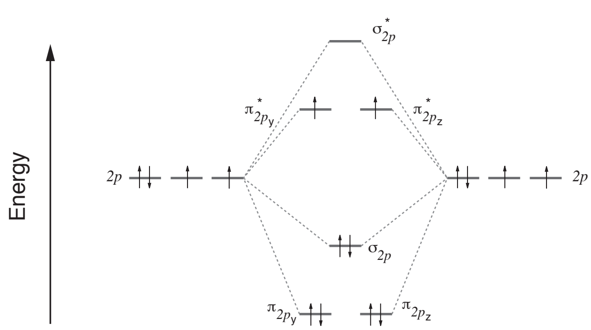
15. A

The basic underlying phenomenon making fMRI possible is that when oxyhemoglobin loses oxygen to become deoxyhemoglobin, it shifts from being diamagnetic to paramagnetic. In other words, the magnetic properties of blood are a function of oxygen saturation.

17. B

According to the passage, multiple lines of evidence support the hypothesis that the configuration of O_2 in oxyhemoglobin is superoxide radical anion.

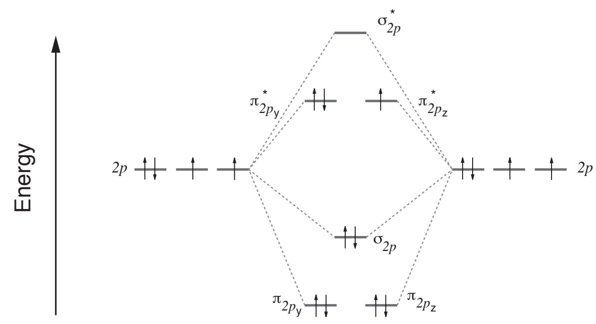
To understand the bond order in superoxide, it's very helpful if you have a mental picture of the molecular orbital diagram of normal ground state O_2 (sometimes called triplet oxygen after the number of its spin states). It's not too unreasonable to expect this mental picture to be present because O_2 is the classic example of a molecule whose Lewis structure makes it look diamagnetic but which is actually paramagnetic.



Ground state O_2

Just like the Lewis structure would show, the bond order of O_2 is 2, but after overlap of its *p* subshells the molecule yields three pairs of electrons in bonding orbitals and two singlets in anti-bonding orbitals. This is why the passage refers to O_2 as paramagnetic.

Superoxide radical anion would have the following molecular orbital diagram.



Superoxide O_2^-

There are six electrons in bonding orbitals and three in anti-bonding orbitals, so the bond order is 1.5.

18. D

The passage mentions that iron's shift to a higher oxidation state in Hb-O_2, which would be Fe^{3+}, decreases the atom's size, and allows it into the plane of the porphyrin ring. (Porphyrin is the organic component of the heme prosthetic group in hemoglobin).

19. A

Even though superoxide and low spin Iron III are both paramagnetic, Hb-O_2 is diamagnetic. That is a central theme in the second half of the passage. The plausible explanation given is antiferromagnetic coupling. Even if you have never encountered this concept, it should be clear that answer choice '**A**' is the only plausible description of antiferromagnetic coupling.