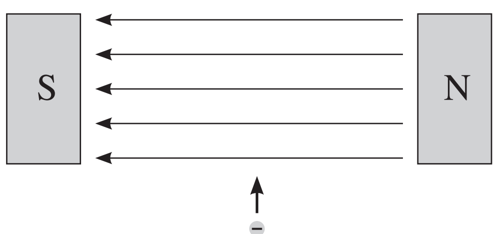
Magnetism Practice Items

1. What is the direction of the force on a negatively charged particle as it enters the magnetic field shown below?

A. to the left
B. to the right
C. into the page
D. out of the page



2. What is the magnitude and direction of a magnetic force acting on an electron (charge -1.6 $\times 10^{-19}$ C) moving in the opposite direction at 1000 m/s in the same plane and parallel to a 10 μT uniform magnetic field?

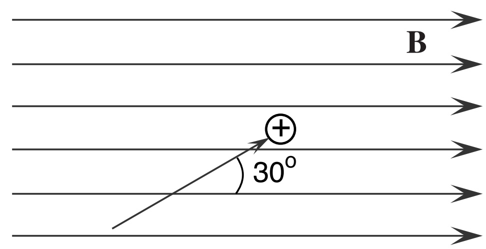
A. 0 N
B. 1.6×10^{-21} N out of the plane
C. 1.6×10^{-15} N into the plane
D. 1.6×10^{-15} N parallel to the plane

3. A positively charged particle is released from rest in a region where there is a uniform electric field and a uniform magnetic field. If the two fields are parallel to each other, the path of the particle is a

A. circle.
B. parabola.
C. helix.
D. straight line.

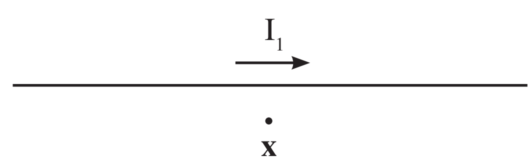
4. A proton (charge 1.6×10^{-19} C) moves at an angle to a the uniform magnetic field, **B** (300 Tesla) in the same plane as the field. The speed of the proton is 2×10^{6} m/s. What is magnetic force acting upon the proton?

A. 1.6×10^{-13} N, directed into the page
B. 4.8×10^{-11} N, directed into the page
C. 4.8×10^{-11} N, directed out of the page
D. 8.3×10^{-11} N, directed out of the page



5. What is the direction of the magnetic field at the point in space **x** near the current carrying wire pictured below?

A. Out of the page
B. Into the page
C. Upward in the plane of the page
D. Downward in the plane of the page

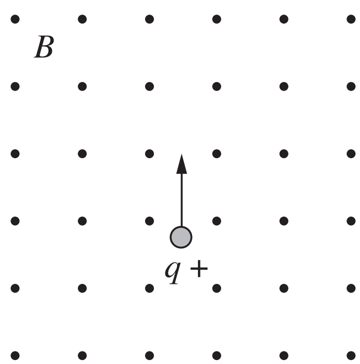


6. When electric current is flowing in the same direction through two, adjacent, parallel wires:

A. The wires attract each other.
B. The wires repel each other.
C. The wires exert no force on each others.
D. The wires oscillate.

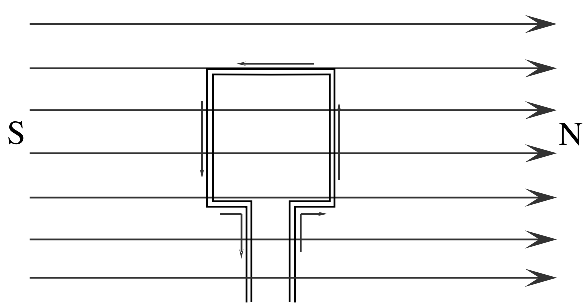
7. A positively charged particle is moving in the plane of the page in a direction perpendicular to the uniform magnetic field, ***B***, which points out of the page perpendicular to the plane of the page in the figure below. If the only force acting the particle is magnetic force, which of the following descriptions best applies to the motion of the particle?

A. clockwise circular motion
B. counter-clockwise circular motion
C. clockwise helical motion out of the paper
D. counter-clockwise helical motion into the paper



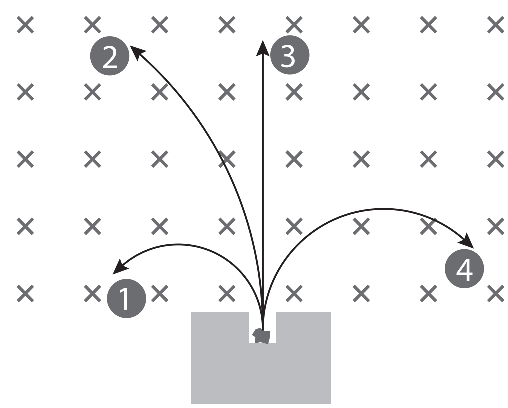
8. When current is flowing in the direction shown in the conducting loop below

A. the loop experiences a net torque.
B. the experiences a net force into the page.
C. the loop experiences compressive stress.
D. the loop is in a state of static equilibrium.



9. Radioactive emissions from an alloy in which several decay processes are occurring pass into a uniform magnetic field pointing into the page as shown in the figure below. The identity of particle 4 is most likely

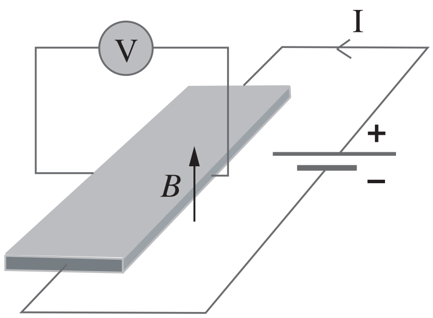
A. β^+
B. β^-
C. α
D. γ



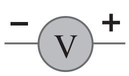
10. In a cyclotron particle accelerator, a beam of charged particles travels repeatedly round a loop. The purpose of the powerful magnets in a cyclotron is

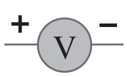
A. to record particle collisions.
B. to pull charged particles forward along the accelerator.
C. to steer and focus the particles.
D. to prevent the particles from colliding with gas molecules within the accelerator.

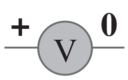
11. A voltage source is connected in series by copper wires to a steel plate, which is oriented perpendicular to the magnetic field, ***B***, as shown in the figure below.

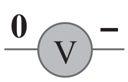


While current is flowing through the circuit, which of the following best represents the potential difference at the voltmeter pictured in the diagram above?

A. 

B. 

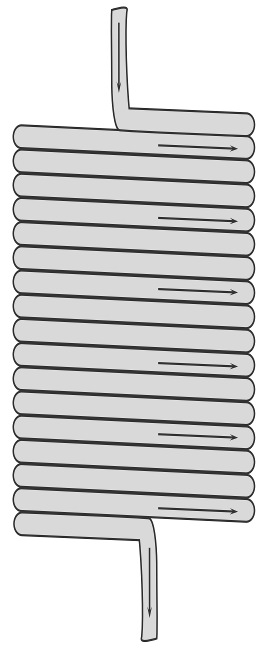
C. 

D. 

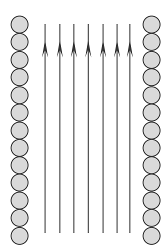
12. When subjected to an applied magnetic field, a material is magnetized in the same direction as the applied magnetic field with the induced field directly proportional to the applied field strength. This material is

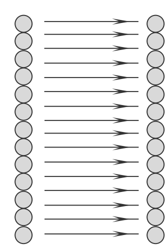
A. diamagnetic
B. paramagnetic
C. ferromagnetic
D. ferrimagnetic

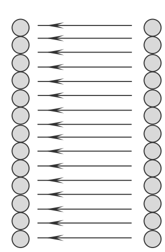
13. A coil of conducting wire is wound into a tightly packed helix. An electric current passing through the wire travels from left to right across the near face of the coil as shown in the figure below:

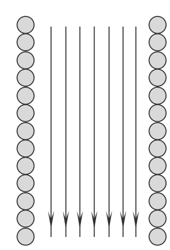


Which of the following most closely depicts the magnetic field in the volume of space within the coil?

A. 

B. 

C. 

D. 

The following passage pertains to questions 14 - 19.

Assigning oxygenated hemoglobin's oxidation state is difficult because oxyhemoglobin (Hb-O_2), by experimental measurement, is diamagnetic, yet the low-energy electron configurations in both oxygen and iron are paramagnetic.

Triplet oxygen, O_2, the lowest-energy molecular oxygen species, has two unpaired electrons in anti-bonding π* molecular orbitals. Iron(II) tends to exist in a high-spin configuration with unpaired electrons spread out among its d orbitals in accord with Hund's rule. Iron(III) has an odd number of electrons, and thus must have one or more unpaired electrons, in any energy state. Thus, a non-intuitive distribution of electrons in the combination of iron and oxygen must exist, in order to explain the observed diamagnetism and no unpaired electrons.

The three logical possibilities to produce diamagnetic (no net spin) Hb-O_2 are as follows. One possibility is that low-spin Fe^{2+} binds to singlet oxygen. Both low-spin iron and singlet oxygen are diamagnetic. However, the singlet form of oxygen is the higher-energy form of the molecule. Another possibility is for low-spin Fe^{3+} to be bound to O^{2-} (the superoxide ion) and the two unpaired electrons couple antiferromagnetically, giving diamagnetic properties. The third possibility is that low-spin Fe^{4+} binds to peroxide, O_2^{2-}. Both are diamagnetic.

Compelling evidence from X-ray photoelectron spectroscopy and IR spectroscopy point to the second choice as the one that is correct of the three logical possibilities for diamagnetic oxyhemoglobin. This is not surprising because singlet oxygen (possibility #1) and large separations of charge (possibility #3) are both unfavorably high-energy states. Iron's shift to a higher oxidation state in Hb-O_2 decreases the atom's size, and allows it into the plane of the porphyrin ring, pulling on the coordinated histidine residue and initiating the allosteric changes seen in the globulins. All three models for diamagnetic Hb-O_2 may contribute to some small degree (by resonance) to the actual electronic configuration of Hb-O_2. However, the model of iron in Hb-O_2 being Fe(III) is more correct than the classical idea that it remains Fe(II).

14. As described in the passage which trait do triplet oxygen, high spin iron II, and iron III all have in common?

A. They are paramagnetic.
B. They have an even number of electrons.
C. They contribute to the structure of oxyhemoglobin by resonance.
D. They represent unfavorably high energy states.

15. Which medical imaging technique might be used to detect the relative abundance of the oxygenated and deoxygenated forms of hemoglobin in living tissue?

A. functional magnetic resonance imaging (fMRI)
B. electroencephalography (EEG)
C. positron emission tomography (PET)
D. computed tomography (CT)

16. Ferritin is a ubiquitous intracellular protein that stores iron and releases it in a controlled fashion. Based on information presented in the passage, ferritin is most likely

A. diamagnetic.
B. paramagnetic.
C. ferromagnetic.
D. anti-ferromagnetic.

17. According to the information presented in the passage, which value for bond order would most likely correspond to the O-O bond in Hb-O_2?

A. 1
B. 1.5
C. 2
D. 3

18. Which of the following information in the passage supports the determination that low-spin iron(III) bound to superoxide represents the iron-oxygen binding state in Hb-O_2.

A. Both Fe^{3+} and O^{2-} are diamagnetic.
B. Spectroscopic evidence that Hb-O_2 is paramagnetic.
C. Infrared vibrational frequencies of the O-O bond suggests a bond length consistent with singlet oxygen.
D. Fe^{3+} has a smaller radius than Fe^{2+}.

19. Which of the following is suggested in the passage to explain the diamagnetic properties of Hb-O_2 given that neither iron(III) and superoxide are diamagnetic?

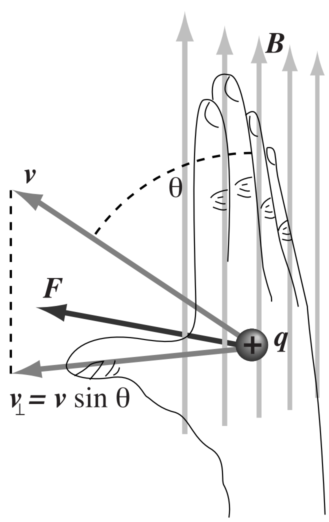
A. Neighboring singlet electrons may align with spins pointing in opposite directions.
B. Electron sharing between O^{2-} and high-spin Fe^{3+} produces a hybrid orbital.
C. A decrease in the size of the iron atoms allows it into the plane of the porphyrin ring.
D. Binding with superoxide forces the iron(III) *d* orbitals into a spherical arrangement in which they are degenerate.

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).

$$F = qvB \sin\theta$$

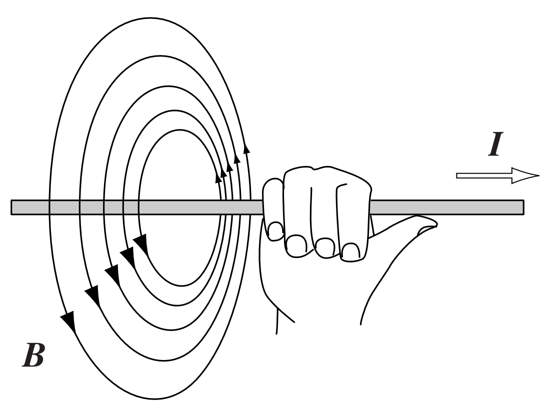
$$= (1.6 \text{ X } 10^{-19} \text{ C})\ (2.0 \text{ X } 10^{6} \text{ m/s})\ (300 \text{ T})\ (0.5)$$

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

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.

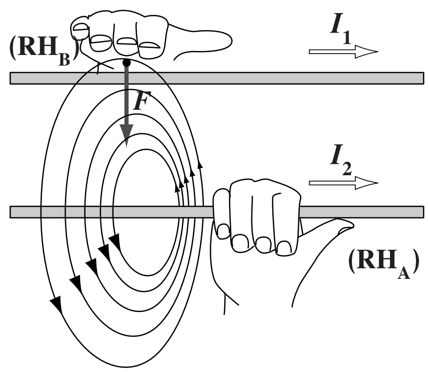
5. B

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.

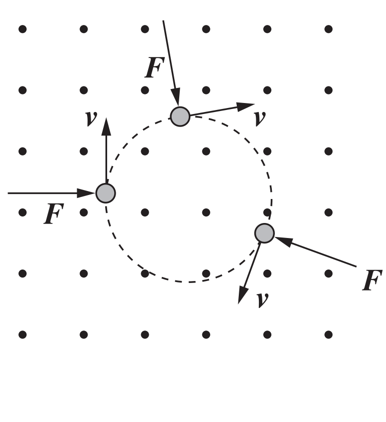


RH_A – Point the thumb of your right hand in the direction of positive current, then wrap your fingers around the wire to show orientation of the magnetic field.

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.

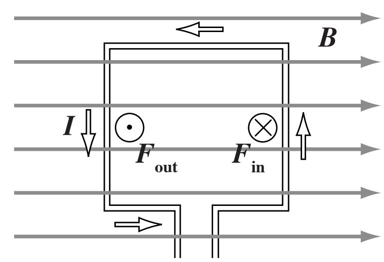
7. B

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

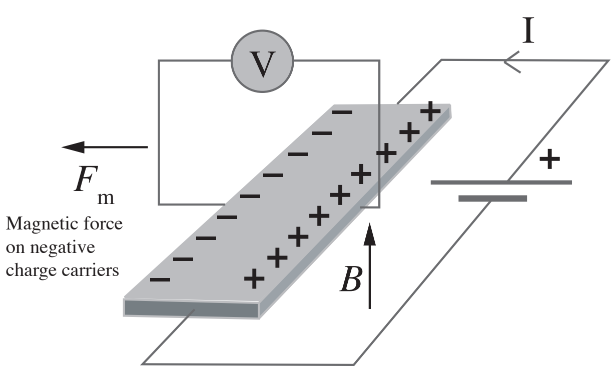
A charged particle moving perpendicular to a static uniform magnetic field will move in a circle due to magnetic force. The circular motion may be superimposed with an axial motion, resulting in a helix. In other words, charged particles spiral around magnetic field lines. This is how the magnets within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

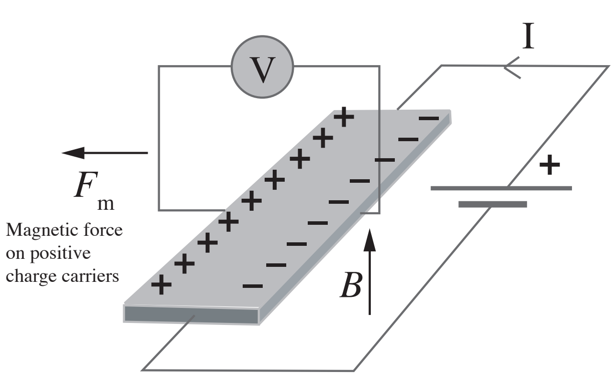
11. A

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

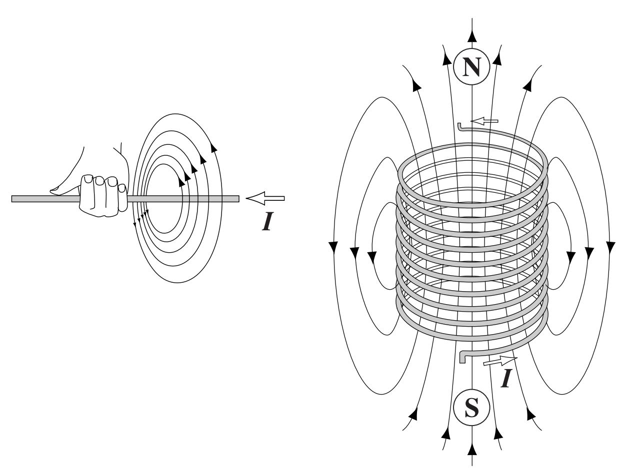
Paramagnetic materials possess unpaired electrons at the orbital level. Paramagnetic materials exhibit magnetization proportional to the strength of the external magnetic field in which the material is placed, and when the field is removed, the magnetization disappears.

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.

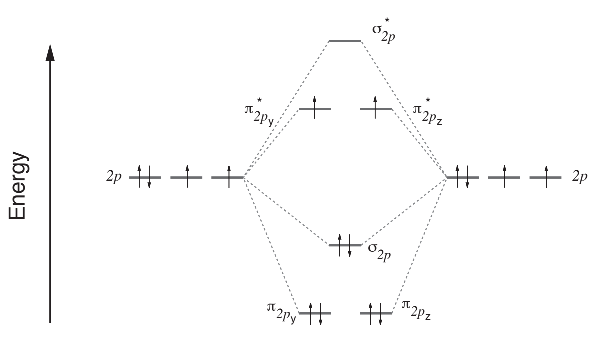
15. A

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.

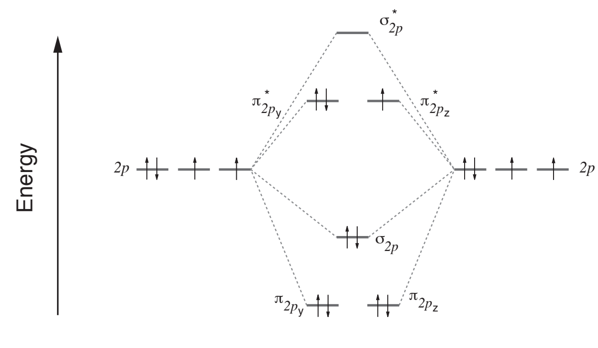
To understand the bond order in superoxide, it's very helpful if you have a mental picture of the molecular orbital diagram of normal ground state O_2 (sometimes called triplet oxygen after the number of its spin states). It's not too unreasonable to expect this mental picture to be present because O_2 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.