1. Use a small magnetic compass to explore the magnetic field around a bar magnet:
   a. Begin by placing the magnet on a sheet of paper and tracing its outline.
   b. Place the compass on the paper, touching the magnet beside one end. Trace the compass outline.
   c. Draw an arrow through the circle to show the direction indicated by the compass needle.
   d. Put the compass back in place, with the magnet still in place. Tap the compass gently and make sure that the needle points in the direction indicated by your arrow. *Fix the arrow if necessary.*
   e. Move the compass a short distance along the arrow. Repeat steps c-e, omitting the circular outline.
   f. Continue this process, always moving in the direction indicated by the compass needle, to form a long, chain of arrows connected tail-to-head. Stop when you reach the edge of the paper or when the line leads you back to the magnet.

2. The chain of arrows that you drew in #1 is called a "magnetic field line". Starting from several different points near the magnet, repeat 1a through 1g to form several field lines. You may omit the circular outlines of the compass.

3. A collection of field lines like the one in #2 is called a "field map". Compare your field map with the pattern of lines produced by iron filings on a sheet of paper placed over a bar magnet. Sketch the field *lines* indicated by the iron filings. Compare the sketch with the photo in your textbook.

4. Imagine a magnetic compass placed at a point where two magnetic field lines intersect:
   a. Will the needle be able to decide which field line to align itself with? ____ ** If so, explain how.*
   b. Can field lines ever intersect each other? ___ *Repair your field maps in #2 & 3 if necessary.*

5. Is there any reason to believe that a *gravitational* field map should resemble a magnetic field map? ____ If so, please explain the reason.

6. What short word best describes the local *direction* of the earth's *GRAVITATIONAL* field? _____
   a. If the gravitational field lines were visible in this room they would be __________ and ________. (Please insert adjectives which can describe a *line*.)
   b. What would the earth's gravitational field lines look like from a viewpoint far enough out into space so that the earth appears to be a dot? Answer with a sketch of field *lines* (not arrows) in the space at the right.

7. Make dots near the center of a sheet of paper, representing two identical planets. Label them "A" and "B". At any point in the space around these planets there are *two* gravitational fields:
   a. The gravity produced by A (called "g_A") must point toward the center of ____.
   b. The gravity produced by B must point toward the ________ of ___.
   c. At any point in space the gravity produced by the closer planet is ________er than the gravity produced by the more distant planet. (stronger, weaker)
   d. It is easy to estimate the direction of the vector sum of g_A and g_B at any point in the space around these planets. That "total g" vector must point toward some spot on line AB. That "aiming spot" will be somewhere between the _______ of the line AB and the ______er planet. (closer, farther)
   e. If we are at a location nearly equidistant from the two planets (or if we are very far from both) then the "total g" vector will point toward a spot close to the _______ of line AB.
   f. As we move along a field line in the direction of its arrows the two distances become more _____ (equal, unequal) so the aiming spot on line AB must move closer to the _____ of the_____er planet.
   g. Usually the "aiming spot"does NOT remain stationary as we move along a field line, but it DOES remain between A and __.
   h. Use those hints to make a "total g" field map for the pair of planets. Start your field lines at ten to fifteen evenly-spaced points all around the perimeter of your map, *avoiding* points on the perpendicular bisector of AB. *Use a ruler. Remember that no field line can end in empty space.*
   i. Does your sketch contradict 4b? ___ -Does it contradict 7d &e? ___ -Does it contradict 7f & g?___

1. Imagine that you are investigating the region of space near a charged object. Imagine placing a small charged particle in that region and measuring the electric force exerted on the particle by the object. *Please try not to confuse the "object" with the "particle":*
   a. If the particle is ***attracted*** by the object then their charges must be ________. (similar, opposite)
   b. If the particle is ***repelled*** by the object then the two charges must have ________ signs.
   c. To determine the magnitude and direction of the ***electric field*** in the region you must divide the force acting on the __________ by the __________ of the ___________, as in #14 on RS XIII.
   d. If the object's charge is positive and the particle's charge is *negative* then the force points _________ the object so E points _________ the object. (toward, away from) -Does this contradict 1a or 1c?__
   e. If the object is positive *and* the particle is positive then F points ________ the object and E points ________ the object. (toward, away from) -Have you been ignoring 1b or 1c?___
   f. Conclusion: The electric field produced by a positively charged object *always* points __________ the object. Does this contradict 1d? ___ A copy of this conclusion is being saved in #__ on RS ___.
   g. Suppose you reverse the sign of your *test particle.* Does that affect the conclusion? _____
   h. Similar logic shows that the field produced by a *negative* object points __________ the object.

2. A certain electron experiences a westward force. The magnitude of that force is 3.2×10^{-15} newtons.
   a. It's neither a gravitational nor a magnetic force. What kind of *field* must exert that force? ______
   * b. What is meant by the "strength" of that field? (Copy from 1c or from RS XIII. *Don't be vague.*)
   * c. Describe the strength *and direction* of the field in 2a, explaining how you get your answers.
   d. Reversing the *sign* of a vector is equivalent to reversing its ________. The definition of "E" mentions two vectors. It clearly states that if the test particle is negatively charged (like an electron) then those vectors must have __________ directions. (similar, opposite) *-Do 1g & 2c agree with 2d?*
   e. Describe the force which that same field would exert on an alpha particle (helium nucleus) at the same location. Don't confuse "force" with "field"; remember that *both are vectors*. (Use #9 on RS IX.)

3. Imagine a small, isolated charged object represented by a dot on the back of this paper. At some location near the object draw a small arrow indicating the direction of the electric field. Starting at the tip of that arrow make another one, also indicating the local direction of the field. A long chain of arrows drawn in this way is called an **"electric field line".** Many field lines can be drawn in the region around the charged object. A diagram showing many such lines is an **"electric field ____**". At either end of an electric field line there must be an object with _______. (Name of a property.)

4. The "field map" described in #3 resembles the map of the _______'s ___________al field that you sketched on page 117. You sketched some more interesting field maps on that same page. Use similar logic (as in 1f, 1h, & 3 above and #7 on p. 117) to sketch field maps for the examples below:
   a. Two positive particles a few cm. apart. (These sketches resemble the ones on p. ___ in the textbook.)
   b. Two particles with opposite charges placed a few centimeters apart.

* 5. How can we use a field map to determine which regions have the strongest field and where the field is weakest? -Does #4 agree? (Explain) *You may use a book. Save this trick on RS XIII.*

* 6. An **"electric dipole"** is a short stick with oppositely charged end points.
   a. Describe the forces that will act on such a dipole if it is placed in a uniform electric field, not parallel to the field. Make a sketch showing *where* the two forces act on it and also showing the *directions* of those forces. Label the arrows representing the forces and indicate the direction of E.
   b. The dipole has fixed length but is completely free to move: How will it be affected by those forces? *Describe the resulting motion in as much detail as possible. Compare it with something familiar.*
   c. Will the motion ever stop momentarily or permanently? If so, name and describe the forces which cause it to stop. Then explain why the electric forces no longer have any effect OR explain what will happen after the motion stops momentarily and what will cause it to happen.
   d. Make sketches to illustrate your step-by-step descriptions of the motion and of the forces which change the motion. For each sketch indicate the direction of rotation and describe what is happening to the rotational speed at that moment as a result of the forces described in your sketch.
   e. Let "θ" represent the angle between the dipole and "E". Sketch a graph describing how θ changes as time goes on. *Try not to contradict 6d.*