1. We say that there is a **GRAVITATIONAL FIELD** at a point in space if a particle with **MASS** experiences an otherwise unexplainable force when placed at that location. In other words, a gravitational field is a *condition in space* which causes a force to be exerted on any particle placed there, ***if*** the particle has the essential property of a gravitational field detector called ____.

2. Gravitational fields are created by *matter*, i.e. material that has ______. A large concentration of _____ always produces a strong gravitational field in its neighborhood.

3. The strength of a gravitational field is usually represented by the letter "**g**", as on RS III. By definition it is the quotient obtained when you divide the gravitational force on a g-field detector by the _____ of the detector. (Once again, a g-field detector is a particle with ____.) In symbols, the definition says **g =** ______, where "___" represents the gravitational force ***on*** *a particle*, and "___" represents the _______ ***of*** *that particle.*

4. According to that definition, the SI unit for gravitational field strength must be ___ per ___. *Does RS III agree?* __

5. The law which describes the force of gravitational attraction between any two massive particles or spheres is called "Newton's Universal Law of Gravitation". (See #2 on RS XIII.) It says:

   F = ______,

   In that equation "___" and "___" represents the masses, "___" represents their separation, and "G" represents the __________ _________ ________. According to RS XIII the numerical value of "G" is:

   G = _________ _________.

6. In #2 on page 114 the universal gravitation law was combined with the definition of "g" to create a new formula for the gravitational field strength at any distance from an isolated spherical object such as a star. You saved a copy in #3 on RS XIII:

   g = _____,

   where"__"represents the mass of **that object,** "__" represents distance *from its center*, and "__" represents the universal ___________ constant. Does #5 agree? ____

7. Is "g" a vector? ____ -Is it a scalar? ____
   -Does this contradict #3? ___

8. Copies of #1, 3, 5, & 6 have been saved on RS ___.

1. We say that there is an **ELECTRIC FIELD** at a point in space if an otherwise unexplainable force acts on a particle with _______ whenever the particle is placed at that location. An electric field is a *condition in space* which causes a ________ to be _______ed on any particle placed there, ***if*** that particle has the essential property of an __________ic field detector which we call__________. (Saved on RS ___)

2. Electric fields are generated by material which has electric ________. A large concentration of _________ produces a strong electric field in its neighborhood.

3. The strength of an electric field is represented by the letter "**E**". By definition, it is the quotient obtained when you divide the electrostatic force exerted **on** an E-field detector by the _________ **of** that detector. *(Again, an E-field detector is a particle with __________.)* In symbols, the definition says: **E =** ____, where...

Please define your symbols precisely, as at the left.

4. According to that definition, the SI unit for electric field strength must be a ________ per ________. *(Recorded on RS ___)*

5. The law describing the electrostatic force of attraction or repulsion between two particles or spheres is called "Coulomb's Law". It says:

   F = ______,

   where "__" and "__" represent the _______s of the particles, "__" represents their separation, and "k" represents Coulomb's constant.

6. Coulomb's law can be combined with the definition of "E" to create a new formula predicting the strength of the electric field generated by an isolated spherical charged *object* such as an atomic nucleus or the globe of a Van de Graaff generator:

   E = _____

   In that equation "__" represents the _______ of the ________, "__" represents ______________, and "__" represents ________________.

7. Is "E" a vector? ____ -Is it a scalar? ____
   Does this answer contradict #3? ____
   You'll need copies of #1, 3, 5, & 6 for pages 118 & 120. Where have you recorded them? ______

1. What kind of force "holds atoms together, making steel wires strong and making water practically incompressible"? _______ (See #7 on page 82.)

2. Electrons have ______tive charge.
   If we remove some electrons from a neutral object, we leave it with a _____tive charge.

3. Two objects with identical charges will _______ (attract or repel?) each other. The strength of this force depends on the __________s of the objects and also depends on the __________ between them.

4. To investigate the rule mentioned in #3, that force was measured at distances of one "span", two spans, and three spans, using a very sensitive spring scale. Sketch the resulting graph of F vs D.

5. Which one of the following graphs would be linear?
   - Force vs Distance
   - Force vs the square root of distance
   - Force vs the reciprocal of distance squared
   - Force squared vs the square root of distance
   - Force vs Distance squared
   - Force vs the reciprocal of distance
   - Other:___________________

6. How did Professor Rogers remove exactly half of the electric charge from one of the metal spheres? *Please include ALL of the necessary details so I can repeat the procedure successfully.*

7. Exactly how was the force of repulsion in 3 & 4 affected by the removal of half the charge from one sphere? (Please answer with a verb or a verb phrase. If necessary, repair your answer to #3.)

8. Will the method in #6 fail if we use spheres made of a non-conducting material? ____ Will it work if one sphere is copper and the other is aluminum? ____ -Will it work if the third sphere does not touch the first? ____ -Will it work if the sizes are unequal? ___ -Will it work if both spheres are charged before contact? ____ -Were *all* of those details mentioned in #6? ____

9. Using symmetry, Rogers led us to conclude that the electrostatic force is proportional to the ________ of the charges of the spheres. (sum, difference, product, quotient, square)
   Does #3 agree? ____

10. By combining conclusions 9 and 5 and then inserting a proportionality constant, he produced a complete law. Write that law here as an equation. Use "F" to represent the electrostatic force, "Q_1" and "Q_2" to represent the two charges, "D" for the distance between them, and "k" for the proportionality constant: **F =** _________ -Does that law agree with #3, #5, & #9? ____

11. ***To find out if this new law is correct,*** he used it to make a remarkable prediction and then he *tested* that prediction: He proved that *IF* the law in #5 and 10 is valid, *THEN* the total force exerted by a charged, hollow metal sphere on a charged particle *inside* the sphere must be ___.

12. The prediction in #11 was then tested in several ways. In one test the metal sphere was replaced by a wire cage. A young woman *in the cage* played the role of the test particle. Did she feel anything when the good professor drew lightning bolts from the cage? ____ -Was her hair affected? ____

13. One statement below describes an *opinion*, one describes an *observation*, and one is a *conclusion*. Label each statement with one of those words. *Then use the same criteria in #14.*
    a. If we shoot a brass ball horizontally with great enough speed then gravity will not act upon it.
    b. The acceleration caused by gravity does not depend on the object's velocity.
    c. When we shot a brass ball horizontally and released another one at the same time from the same altitude we saw the two balls hit the floor simultaneously.

14. What was the real purpose of the experiments in 12, and what can we conclude from the results?