

1. In gravity-free space does an object have any weight? _____ -Does it have any mass? _____
2. We need a method for comparing the masses of two objects in gravity-free space. Classify the proposals below as "A" if they will work anywhere, as "B" if they will work only in a uniform gravitational field, or "C" if they will not work. Then explain what's wrong with the "C" proposals.
 - a. _____ Place each object on a spring scale and compare the readings.
 - b. _____ Place each object on an equal-arm balance.
 - c. _____ Explode a firecracker between the two objects to drive them apart. The less massive one will move away _____ rapidly than the more massive one. (more, less)
 - d. _____ Tie the two objects to the ends of a stretched elastic cord, as on page 6R, and release them. The one with _____ acceleration is the one with greater mass.
 - e. _____ Fasten the two objects to the two ends of a nearly massless stick. Push on the stick at its center, in a direction perpendicular to it. If the masses are equal the stick _____ rotate. (will, won't)
3. Suppose you measure the diameter of a standard kilogram and find that it is 5.00 centimeters.
 - a. Is it then correct to say that on this planet one kilogram is *equal* to five centimeters? _____
 - b. Kilograms are units of _____. Centimeters are units of _____. Can kg be "converted" into cm.? _____
 - c. Pounds are units of _____. Newtons are units of _____. "Weight" is a type of _____. (See page 0.)
4. Saying that gravity exerts "one kilogram of force" on an object makes as much sense as saying that it exerts one "inch" of force. *Inches and kilograms are not force units.* In #12 on RS I we wrote that the gravitational force on a kilogram in Connecticut is _____ N or _____ lb. That fact tells us something about _____. (kilograms, pounds, the earth's gravity, the moon's gravity)
5. Occasionally you may read that a kilogram is "equal" to a certain number of pounds. Is it possible for such a statement to be correct? _____ (See 3a) -The author probably meant to say that "one kg of material _____s a certain number of pounds if it is on the _____." (See page 6.)
- * 6. How much gravitational force does the earth exert on a *two*-kilogram object located near the surface? (Use #4. Answer with the same SI *and* British force units that you used in 3, 4, & 5.)
7. Comparing #4 with #6, we see that doubling the *mass* of a sample causes the *gravitational force* acting on it to be _____ed. This indicates that the _____ acting on an object is proportional to the object's _____. (Use the *italicized* words.) -Does #6 agree? _____
8. According to #4 & 7, you can predict the gravitational force acting on any object near the earth's surface by multiplying the object's _____ (in _____s) by _____s per _____. (*number* with SI units.) To predict that same force in *British* units you would multiply the object's _____ in _____ by _____s per _____. Do those two products have the right units? _____ -Do those rules agree with 3c, 4, & 6? _____--with #12 on RS I? _____ Are these examples of "converting" units? _____ (See #8 on page 6.)
9. That "number" used above in calculating gravitational force is called the "strength of the _____al field". On page 6 gravitational field strength was represented by the letter "g", **not capitalized**. According to #8 you can calculate the gravitational FORCE on an object by *multiplying* the object's _____ by "_____". On page 6 we used single-letter abbreviations to summarize that sentence with a simple *formula*: Gravitational Force = _____. The letter "m" in that formula represents the object's _____, and "g" = _____ per _____ or _____ per _____. Does this formula agree with #4, 6, & 8? _____ -It is recorded in # _____ on RS I *and* # _____ on RS III. When you want to abbreviate "gravitational force", always use the *two-letter formula* which you just recorded. *If you want to abbreviate "grams", write "gram", not "g".*
10. How strong is the *moon's* gravity? In British units, $g =$ _____ In SI units, $g =$ _____.
 - a. How much gravitational *force* will the moon exert on a 3.00-kg object? $F =$ _____ or _____
 - b. How much will 30 liters of water weigh on the moon? $W =$ _____ or _____
 - c. Does #10 contradict #8, 9, or 3c? _____ Which has more significant digits: 10a or 10b? _____
11. Imagine a spacecraft falling freely in the gravitational field of a planet or star. Looking outside and waiting for impact are not allowed. Is there any *other* procedure that can be performed inside the craft to detect the star's gravity? _____ If so, please explain. (See #3 on page 31b.)

- The sketch at the right shows a cart on an inclined ramp. The “inclination angle” is represented by the letter “ θ ”. In this sketch that angle is roughly ___ degrees.
- Let “ m ” represent the mass of the cart. To calculate the gravitational force on the cart we would use the familiar two-letter formula _____, which is still recorded on RS I and in #8 on RS III. Draw an arrow from the center of the cart to represent that force. Then use the two-letter formula to *label* that arrow.
- Imagine that someone is pulling uphill on the cart, pulling just hard enough to prevent it from rolling downhill. Let \mathbf{P} represent that pull. Make a sketch showing how \mathbf{P} can be measured with a spring scale. *Label the spring scale clearly in your sketch.*
- There is one more force on the cart, exerted by the ramp. It prevents the cart from falling. Using a pencil, draw another arrow from the center of the cart to describe that force. Label it with the letter “ \mathbf{N} ”. (You may want to adjust it later.)
- If the cart is not accelerating then the vector sum of the three forces acting on it must be _____. (See #3 on RS III.) That sum is called the “total force acting on the _____”.
 - Draw a “tail-to-head diagram” carefully to show how the forces are added to get that sum. Remember that the gravitational force arrow points in the “six o’clock” direction, or “downward”.
 - We have not yet decided on the exact direction of “ \mathbf{N} ”, but the the “ \mathbf{P} ” arrow points in the ____-o’clock direction, parallel to the surface. That means the inclination angle must be ___ degrees.
 - Does #4 agree with 5a? ____ Are all of the arrows in #4 and #5 labelled clearly? ____
 - The three arrows in 5a form a familiar geometric figure called a _____.
 - Is there an angle in that figure which is the compliment of θ ? *If so, please label it clearly.*
- Set up an inclined ramp with an inclination angle equal to the one described in #5b. According to page 31R, its height “ H ” must be _____ of the ramp’s length. *Check those measurements carefully.*
 - Place a cart on it and use a spring scale to measure \mathbf{P} and \mathbf{mg} . *Remember to zero in the scale.*
 - Record the MLV’s and uncertainties (SDC’s) of the two lengths and the two forces.
 - As nearly as we can tell, it seems that \mathbf{P} is just _____ of \mathbf{mg} . *Write a fraction into the blank.*
 - Use those measurements to make a larger and more precise version of the tail-to-head diagram that you sketched in 5a. *Use at least half a sheet of paper. Use a ruler and protractor.*
- Exciting New Discovery:* The diagram in 6d shows that if the wheels are frictionless, then the angle between \mathbf{P} and \mathbf{N} in this figure is _____ degrees. Since \mathbf{P} is parallel to the surface, \mathbf{N} must be in a direction _____ to the surface. (That’s why it’s called a “normal” force. In math the word “normal” always means “perpendicular to the surface”.) *Correct #4 if necessary.*
 - Do *both* of your diagrams agree with that fact reasonably well? ____
 - According to #5, the angle between \mathbf{P} and \mathbf{mg} in both figures should be ___ degrees. Is it? ____
 - If drawn correctly, the shortest side of this triangle must be _____ of the hypotenuse. *Put a fraction into the blank. Copy it from page 31R or 34R. That short side is called _____.*
- Repeat #6 & 7 with inclination angles of 0° , 37° , 45° , 53° , 60° , and 90° . *Plot P vs H immediately.*
- Using #7 & 8, make a graph of \mathbf{P} vs inclination angle. Then show (with as sketch) how it must appear if extended in both directions.
- What kind of curve does the P vs θ graph seem to be, and what new graph can you make to find out if that guess is correct? (See pages 16 & 16R. A graphing calculator or a computer can be helpful here.) Calculate the slope of that new *linear* graph and explain why it has that value.

