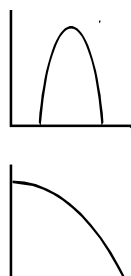


1. Newton's second law (on RS V) says that if the symbol "TF" represents the ____ force *acting on an object*, "m" represents the object's mass, and "a" represents its acceleration, then $\mathbf{TF} = \underline{\hspace{2cm}}$.
 - a. The total force needed to accelerate a 1.00-kg object at 1.00 m/s², is ____ N.
 - b. Inserting those numbers and units into Newton's law, we find that **one newton = one** _____. (That "short version" of the definition has been saved on RS__.)
2. The definition of "acceleration" on RS IV says $\mathbf{a} = \underline{\hspace{2cm}}$.
 - a. The letter "v" in that equation represents velocity, so the *two-letter* symbol "Δv" in that equation represents the object's *change* in velocity during a short time interval.
 - b. The letter "t" in that equation represents time, so the two-letter symbol "Δt" represents the duration of the short time *interval*.
3. Use that definition to eliminate the letter "a" from Newton's second law: $\underline{\hspace{2cm}} = \underline{\hspace{2cm}}$
Then multiply both sides of the resulting equation by the time interval: $\underline{\hspace{2cm}} = \underline{\hspace{2cm}}$
- * 4. Prove that if mass is conserved, then the mass of an object times its change in velocity is equivalent to the change in the product of mass and velocity. Then use that fact to rearrange equation 3.
5. If a force acts *on* an object for some amount of time, the product of the force and the time interval is called the "**impulse**" exerted on the object. *Save that definition.* Impulses often come in *groups*, because *several* forces usually act on an object at the same time. In chapter IV the product of the object's mass and its velocity was defined as the "*momentum*" of the _____. (Copy from RS IV.)
 - * a. Use the words defined in #5 to state the law discovered in 3 & 4. Do *NOT* delete important words.
 - * b. A copy of this "**Impulse and Momentum Law**" is being saved in #__ on RS V.
 - * c. Prove that the SI unit of impulse is equivalent the SI unit of momentum. (Use 1b.)
6. Have someone roll a basketball toward you rapidly on a level floor. Kick it with a brief impulse so that it makes a right-angle turn *without* any change in speed.
 - a. Draw diagrams showing the right and wrong ways to kick it. Label them clearly.
 - b. Draw and label vector diagrams for *both* kicks showing what 5a says about the original momentum, the impulse, and the final momentum. Remember to define your symbols.
 - c. Which of those three vectors is equivalent to the ball's change in momentum? (See 5a.) _____
 - d. What could you do with an *original* momentum and a *change* in momentum to predict a *final* momentum? Illustrate your equation with tail-to-head diagrams. (Use the *italicized* words.)
7. A 3.0-newton eastward force acts for 5.0 seconds on a 1.5-kilogram object.
 - a. Show that the resulting change in momentum is 15 N*s eastward.
 - b. Calculate the magnitude and direction of the resulting change in velocity.
 - c. Can you determine the final velocity from the information given above? ____ (If so, show how.)
 - d. The object's initial velocity was 12.5 m/sec, 36.87 degrees south from west. Use that *new* information *with* the information already given to determine the magnitude and direction of the final momentum. Explain your reasoning. (Use p. 31R, 34, 34R, 35, 6d above, and #11 on RS III.)
8. The force exerted on the ball by your foot in #6 probably increased and then decreased very quickly, as in the force vs time graph at the right. The force exerted on an arrow by a bowstring decreases after release as in the second graph. The definition of impulse given above is not adequate for cases like these in which forces are not constant. To *improve* the definition, imagine dividing the graph into many narrow vertical slices. The width of one slice represents a very short amount of _____. Its height represents the _____ on the ball, which is nearly constant during that short interval. *Please illustrate.*

 - a. The product of the strip's height and width is called the "*impulse*" delivered to the object during the short interval, as explained in #5.
 - b. Geometrically, the product of the strip's height and width is the _____ of the strip.
 - c. Therefore the impulse for the whole graph must be equivalent to the total _____ the graph. This "**improved definition**" of _____, has been saved in #__ on RS__.
9. The process used in #8 for calculating impulse from a force-time graph is called "*integration*". (See RSII.) With the *reverse* process we can use an object's momentum vs _____ graph to calculate the _____ force acting on the object, if its path is linear. Write a sentence describing this new discovery. Also copy the *name* of the process from RS II. That sentence is in #__ on RS ____.

1. Define "impulse": _____ Is impulse a vector? ___ -Is impulse a scalar? ___
2. Define "momentum": _____ Is momentum a vector? ___ Is it a scalar? ___
3. Using those words, state the "impulse and momentum law": _____ = _____
4. The process used to determine impulse from a graph of force vs time is called "_____tion".
5. The **total force** on an object is determined from its momentum vs time graph by "_____tion". (See #13 on RS V.) Have you checked #4 & 5 by dimensional analysis? ___
6. The SI unit of momentum is _____. The SI unit of impulse is _____.
7. By definition, one newton = one _____ per _____. Facts 1-7 are all recorded on RS _____.
8. Imagine a 4.0-kg object initially coasting northward at 6.00 m/s, influenced by a steadily decreasing westward force which diminishes from 6.0 N to zero in 3.0 seconds. No other forces act on it. Describe the resulting changes in momentum and velocity. Use 12 & 7 on RSV or #4 on p. 53.
- * 9. A 3.0-kg object is influenced by a decreasing eastward force. This time the force vs. time graph resembles the first quarter-cycle of a cosine curve. (If you don't know what that looks like, please ask someone.) The initial value of the force is 60 N, and it drops to zero in only 0.2 second. Estimate the resulting change in momentum *without* doing any tedious calculations. Try not to be off by more than 20%. Explain your reasoning.
10. A 0.100-kg ball is thrown horizontally southward at 10 m/sec. It moves freely for 1.50 seconds.
 - a. Describe the impulse delivered by gravity to the ball during that time interval: _____
 - b. Describe the ball's change in momentum during that interval. _____
 - * c. Show that the ball's final momentum is 1.78 kg-m/sec, 56 degrees down from south. (See p. 35R.)
 - * d. Velocity is also a vector. Describe the final *velocity* of the 4-kg object in #8 in similar language.
11. The mass of a basketball is 0.57 kg. Use the impulse-momentum law to determine the magnitude and direction of the impulse responsible for each of the changes described below. (Use #3 & #6.)
 - a. Slowing it from 6.0 m/s north to 4.0 m/s north requires an impulse of _____.
 - b. If it hits a wall at 6.0 m/s north and rebounds at 4.0 m/s south, the impulse = _____
 - c. It hits the wall at 6.0 m/sec north and rebounds elastically at 5.0 m/sec south: _____
12. A shotgun sends 50 grams of lead shot out of its muzzle with a speed of 300 m/s. When a small boy fires the gun, he is knocked over backwards. How much impulse is delivered by that "kick"? _____
13. A machine gun fires "N" bullets per second, each having velocity "v" and mass "m" for a time interval " Δt ". Using those symbols, write formulas for each of the following: Remember to check units!
 - a. The momentum carried by that group of bullets = _____.
 - b. The backward impulse felt by the person holding the gun = _____.
 - c. The average backward force exerted by the gun on the person who holds it = _____.
14. If a letter represents a variable then that same letter with a *dot* over it represents the *rate* at which that variable is changing. For example, if we use "x" to represent an object's displacement then its velocity can be represented by an x *with a dot over it*. We shall use that notation often in the future.
 - a. If "v" represent an object's velocity, then "v" with a *dot* above it must represent the object's _____tion. (That familiar fact is recorded on RS _____. Rewrite it there with "dot" notation.)
 - b. If the momentum of an object is represented by the letter "p", then #13 on RS V tells us that "p" *with a dot over it* represents the _____ acting on the object. (Copy from #5 and check units.)
15. A rocket propels itself by ejecting exhaust gas out through a nozzle. Let "M" represent the mass of the rocket and remaining fuel. Let " V_e " represent the velocity of the exhaust relative to the rocket:
 - a. According to #14, the mass ejection rate (in kg per _____) must be represented by "_____".
 - b. Use those symbols to write a formula for the rocket's thrust, as in 13c: _____ (Check units!)
 - c. When you need this formula on page 56 you will find a copy of it in #____ on RS _____.
16. Now you too can be a "rocket scientist": The impulse delivered to a rocket *by each kilogram of exhaust* is called the rocket's "specific impulse". In the early 1920's Robert Goddard at Clark University saw that specific impulse is a good measure of a rocket's quality. To calculate a specific impulse we must find the impulse delivered by a bunch of exhaust gas and _____ it by the mass of that material. Use the symbols defined in #15 to *write* that formula. *Clue #1:* Use 15b.
Clue #2: Ejected mass = () Δt . *Clue #3:* Remember to simplify and to check units!