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PHYSICS XV: MOTION/FORCE DEFINITIONS

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Scientists understand mass primarily in terms of its motion; thus, mass is the measure of the linear inertia of a body (an operational definition), i.e., of the extent that a body resists acceleration when a force is applied to it. An applied force of, say, ten pounds to a tennis ball will result in considerable movement of the light-weight ball (mass), while the same ten pounds of force applied to a 20 ton boulder will not result in any measurable movement of the boulder.

The term "applied force" is an interesting one. If I am standing at home plate and swing my bat as hard as I can and it connects with the baseball thrown by the pitcher as hard as he can, at the point and time of connection of the bat with the ball there is a split second of "applied force." Let us say that the amount of force applied by my bat was 1,000 lbs. per square inch, while the amount of force imparted to the hurling ball by the pitcher's arm was 500 lbs. per square inch. Now, suppose we put the ball in a vice that applied 500 lbs. of gripping pressure to it and then very slowly apply 1,000 lbs. of pressure force to the ball, which means that the applied pressure on the ball starts at zero and slowly climbs to 1,000 lbs. over an hour's duration. Under these conditions, do we expect that the ball will behave the same as it did under the first set of conditions and fly over the center field fence for a home run? Hardly. We may, therefore, feel the need to understand the effects of the rate of any applied force in the behavior (motion) of a mass, and from the two examples just given come to "feel" that rate of applied force may be a critical factor in the consequences or results of it.

The mass of a tennis ball offers little inertial resistance to an applied force on it of, say, ten lbs.; hence, the ball is of a small mass, while the mass of the boulder offers "massive" resistance to such a small applied force, hence it is of much greater mass than the tennis ball. All too obvious, isn't it? Mass can also be described as a measure of the amount of matter in a given body. There is more "matter" in a cube of lead than there is in a same-sized cube of polyethylene foam, hence the lead is heavier, denser, more massive, though the size of the two cubes is identical. Note that there is no consistent relationship between size and massiveness because of the variability of density.

Density is the ratio of mass to volume for a given material or object, i.e., mass per unit volume of a substance, usually expressed in pounds per cubic foot or grams per cubic centimeter. Specific gravity is the ratio of the density of a substance to that of water as the agreed upon standard of density measurement. However, the volumes of most substances vary with temperature and pressure; therefore, accurate determination of the density requires correction of these factors. The same amount of matter can occupy different volumes (volumetric displacements in space) depending on the temperature of the substance as well as the pressure it is under: higher temperatures usually equal greater volume but greater pressures usually equal smaller volume, while the amount of matter (its mass) of the substance remains the same.

Inertia is considered a property of all mass and is its (reluctance, drag) resistance to any alteration in its state of motion or rest. A more dense body of the same size as a less dense body will exhibit greater resistance (inertia) to changes in motion. The mass of a body is a measure of its inertia to any outside force applied to it.

To summarize: 1) Mass(m) is the measure of the amount of matter in a body; the mass of a body is constant. 2) Weight(W) is the measure of the Earth's gravitational pull on a body. Thus, the weight of a body depends on its position with respect to the Earth. Mass and weight have approximately the same value at the Earth's surface. 3) Volume(V) is the measure of the space occupied by a body. The volume of regular solids is found by geometric formula; other volumes are found by the displacement of water. 4) Density(D) is the mass per unit of volume of a body: D = m/V(gm per cc); it is the ratio of a body's weight to its volume: small volume, large mass = large density. 5) Specific gravity (S.G.) is the ratio of weight of body to the weight of an equal volume of water. 6) Force(F) is a something which changes the shape or motion of a body. A given force can produce a pressure of any magnitude depending on the amount of surface on which it acts. 7) Velocity(v) is the rate of change of distance, as feet per second. Note that while (v) is a dynamic phenomenon over time, the computation of v is for any one specific time and thus appears as a static measurement. Constant velocity: d = vt. Varying velocity: average velocity = d/t. Constant acceleration from zero velocity and the acceleration of falling bodies in a gravitational field: $d = 1/2\ at^2$ ($g = 32\ ft/sec^2$) 8) Acceleration (a) is the rate of change of velocity. 9) Energy(E) is the ability to do work(ft-lb or gm-cm); Potential energy (P.E.) = Wt x Ht. Kinetic Energy (K.E.) = $1/2\ mv^2$. 10) Work(W) is the exertion of a force through a distance; work is performed only by force in the direction of motion. 11) Power(P) is the rate of doing work (gm-cm/sec): power = work/time. 12) Newton's Laws of Motion once again: #1 Law of Motion or the law of inertia, #2 Law of Motion or law of momentum which is the rate of change of momentum (mass) x linear velocity) of a body is equal to and in the direction of the force causing the change. Momentum is a vector quantity having both magnitude and direction, #3 Law of Motion, or the Law of Reaction (explains the recoil of guns, ball bouncing back, etc.) 13) Equilibrium: a body is in equilibrium when the sum of the forces and moments acting upon it is zero. (Moment: the product of a quantity and its distance from some specific point connected with it: moment = quantity x distance. The moment of a force about a point equals the product of the force and the distance from the line of action to the point (fulcrum). Opposite moments produce rotation in opposite directions, while equal and opposite moments balance. When several forces are acting on a body simultaneously, their effects may compensate or offset one another with the result that there is no change in motion or direction. In this instance the body is said to be in equilibrium (with the opposing forces). On the whole, a body in equilibrium either remains at rest or moves in a straight line with constant speed, or a body is either not rotating at all, or is in rotation at a constant rate. 14) The Center of Gravity (c.g.) of a body is the point at which its weight appears to be concentrated.

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