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On a Definition of Work

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In a recent paper,[1] John W. Jewett Jr. tries to introduce a new definition of work. In conclusion he writes, “Much can be done to clarify the definition of work in textbook and classroom presentation to avoid conceptual inconsistencies and to remove the need for later correction to earlier statements and definitions.” I cannot agree more with this statement; however, instead of inventing a new definition for a rather old and well-developed concept, I used to use the standard and clear definition accepted by the most physicists. For example, take a classical physics textbook by Hans C. Ohanian.[2] The most general definition of work is provided on p. 168, where we can read that for “a particle” that “moves along some given path from a point P_1 to a point P_2…the total work”

$$W = \int_{P_1}^{P_2} F \cos\theta dr \qquad (27)$$

where the force *F* acts during the elementary displacement *dr* and θ is the angle between *F* and *dr*. Integrals (28) and (29) provide two alternative mathematical expressions for the work. *Any* of the expressions can be applied to calculate the work done on *a particle* by *any force* in *any* physics phenomenon. When we have more than one force acting on a particle, a definition of *net work* is to be introduced as the work done by the net force acting on the particle. To complete the definition of work, we need to say that the work done *on the system* is equal to a sum of all net works done on each particle included in the system (which can be represented by a set of different particles, as well as by a solid or deformable object). The art of teaching an introductory physics course is to be found in this case in the ways a teacher can introduce the concept without using a developed mathematical apparatus. For years the following definition (which can be found on p. 165 of the Ohanian textbook[2]) proved to be very effective: “If a constant force *F* acts on a particle, then the work done by this force on the particle during a displacement Δr is defined as the product of the force, the length of the displacement, and the cosine of the angle between the force and the displacement.” This definition is clear, mathematically consistent with Ref. **1** (p. 38), and does not have hidden contradictions, because it can be applied *only* to a point-like object and *only* when the force is constant. Starting from this definition, in a case of a one-dimensional motion (which is the most important case when teaching introductory physics), a teacher can follow students to an understanding of work as the area on a graph *F* versus *x*, which is an important generalization leading to work of a changing force (for example, elastic force). In addition, much confusion can be avoided if the work-kinetic energy theorem is stated in a correct manner, that is, “the change in the kinetic energy equals the work done on the *particle* by the *net* force” (Ref. **2**, p. 171) (in the general case, the change in the kinetic energy of a system equals the net work done on the system). All the examples provided by John W. Jewett Jr. in his paper[1] can be clearly explained in terms of a classical definition of work. In particular, in the example related to Jewett's Fig. 1, one can state that the work done by a hand *is* equal to *TL* and derive the expression *TL*(1+ *r/R*) for the *net work* done on the spool.

REFERENCES

1. John W. Jewett Jr., “Energy and the confused student I: Work,” **Phys. Teach. 46, 38–43 (Jan. 2008). first citation in article**

2. Hans C. Ohanian, *Physics*, 2nd ed. (expanded) (W.W. Norton & Company, Inc., New York, 1989). **first citation in article**

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