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Energy from Nothing?

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- **BODY OF ARTICLE**

When reading “Galilean Relativity and the Work—Kinetic Energy Theorem” by Brandon and James Tefft (*TPT* **45**, 218–220, April 2007), one might ask a question, “What is the source of the kinetic energy the ball is obtaining?” The natural answer would be that this source is the muscles of the man throwing it (i.e., electrochemical processes in the arm). This answer is described mathematically by Eq. (7), where F is the force acting on the ball from the arm of the man, and $d\vec{l}$ is the displacement provided by the arm. If we mention that this is right only for the system resting relative to the train, the answer, provided by Eq. (8), would sound like this, “The source of the energy is the muscles of the man throwing the ball and . . . .” Here we would have to stop, because the last term in Eq. (8), has, according to the authors, a purely kinematical (i.e., geometrical) origin. Without giving to this term a dynamical explanation, one can get an impression that the work done on the system can be the result of purely geometrical transformations.

In order to deepen our understanding of the situation, we need to consider forces acting on the man-train system. Without any external forces (or with the zero net force acting on the system made of the train, the man, and the ball), after the ball is thrown away, the speed of the train (with the man resting on it) would become less then 20 m/s as the result of the law of the conservation of the momentum of the system man-train-ball. In that case, the speed of the ball would be: a) less than 30 m/s relative to the woman, or b) greater than 10 m/s relative to the train; hence, the provided calculations would not be applicable. To keep the speed of the man-train system constant (i.e., 20 m/s), an external force F_{ext} has to be acting on the train. According to Newton's third law, the force F acting on the ball from the man is equal in magnitude and opposite in direction to the force acting on the man from the ball. According to Newton's second law, applied to the train-man system, the external force F_{ext} acting on the system has to be equal in magnitude and opposite in direction to the force acting on the man from the ball. Hence, the external force F_{ext} acting on the system is equal to the force F, and the additional work done on the ball calculated by the woman is equal to $F_{ext}\, u \Delta t = F_{ext} D$, where D is the displacement of the train during the toss. We should draw the conclusion that the additional work is equal to the work done by the external force on the man-train system when keeping the train moving at a constant speed and has a real source like an engine (or any other device, which can push or pull the train but which is working only when the man is throwing the ball).