Work and kinetic energy

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We show that work $W = \int F \cdot dx$ does not transfer kinetic energy $KE = (1/2)mv^2$. We do this without violating the laws of classical mechanics, the work-energy theorem $W = \Delta KE$, or the law of conservation of energy.

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In physics, like in all science, the last word has the experimental truth. The results presented in this article have been fully confirmed by experiment. Any other results violate Newton's second law $\boldsymbol{F} = d\boldsymbol{p}/dt = m\boldsymbol{a}$, which governs all motion.

A common misconception holds that levers and pulleys increase forces. But that is not true: levers and pulleys transmit forces, and if the masses of the levers or pulleys are negligible, the input and output forces are equal. The following example makes this clear.

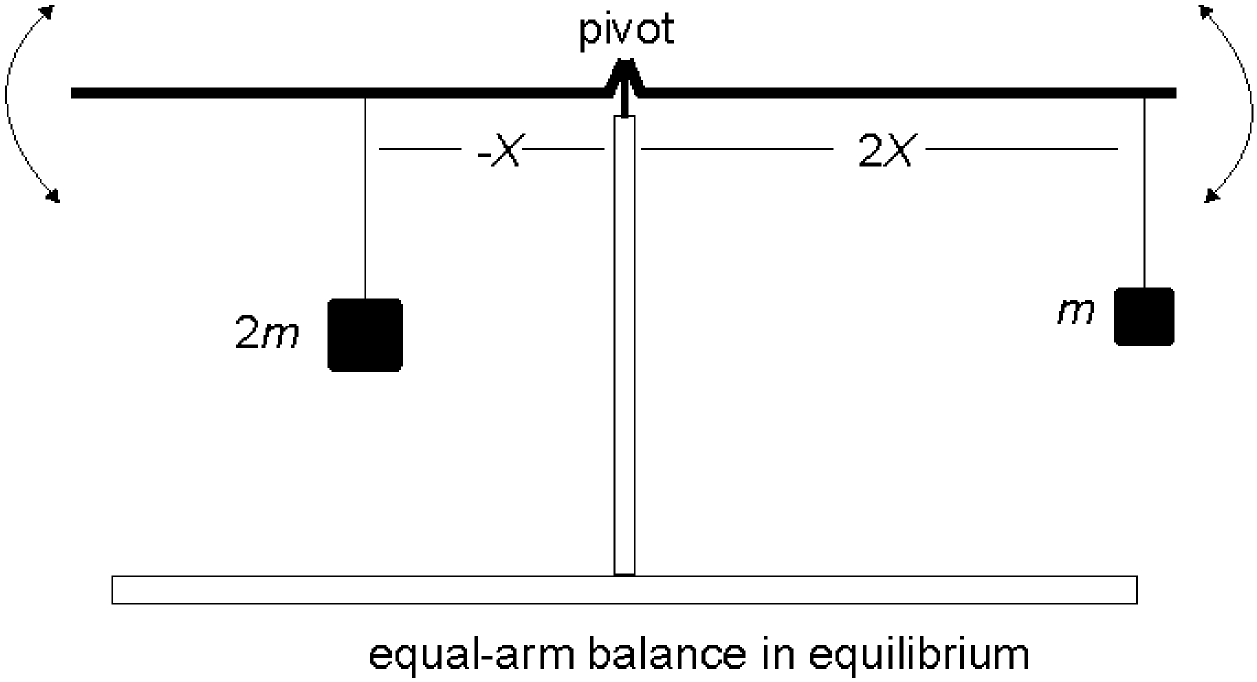

FIG. 1. This kind of balance is extremely sensitive. The slightest breeze will set the two blocks, of masses m and $2m$, placed at distances $2x$ and $-x$ from the pivot, in oscillation, and they will oscillate for hours. Clearly, the system is in stable equilibrium, and it is true that the magnitude of the force on one side of the lever $F = 2m\,a/2$, where m is mass, and $\boldsymbol{a}$ is acceleration, is equal to the magnitude of the force on the other side $F = m\,a$, because according to Newton's second law $F = 2m\,a/2 = m\,a$. The force on either side can be considered to be the input force, and the force on the other side, the output force.This shows that levers (like pulleys) do not increase nor decrease the magnitude of a force.

We demonstrate that applying the same constant force $\boldsymbol{F} = d\boldsymbol{p}/dt = m\boldsymbol{a}$, through the same distance x, i.e., doing the same amount of work $W = \int F \cdot dx$, through two-disk pulleys, on blocks of masses m, $2m$, and $m/2$, can impart different amounts of kinetic energy $KE = (1/2)mv^2$ to each block. This, without violating the laws of classical mechanics, the work-energy theorem $W = \Delta KE$, or the law of conservation of energy.

Three pulleys, with disks of radii r and $2r$, are mounted on vertical axles anchored on top of a frictionless air table. A cord, where the constant force is applied, is wrapped around one of the disks of each pulley. Each of the blocks is connected to a cord wrapped around either the same, or the other disk, depending on the mass of the block. This is illustrated in the following figure.

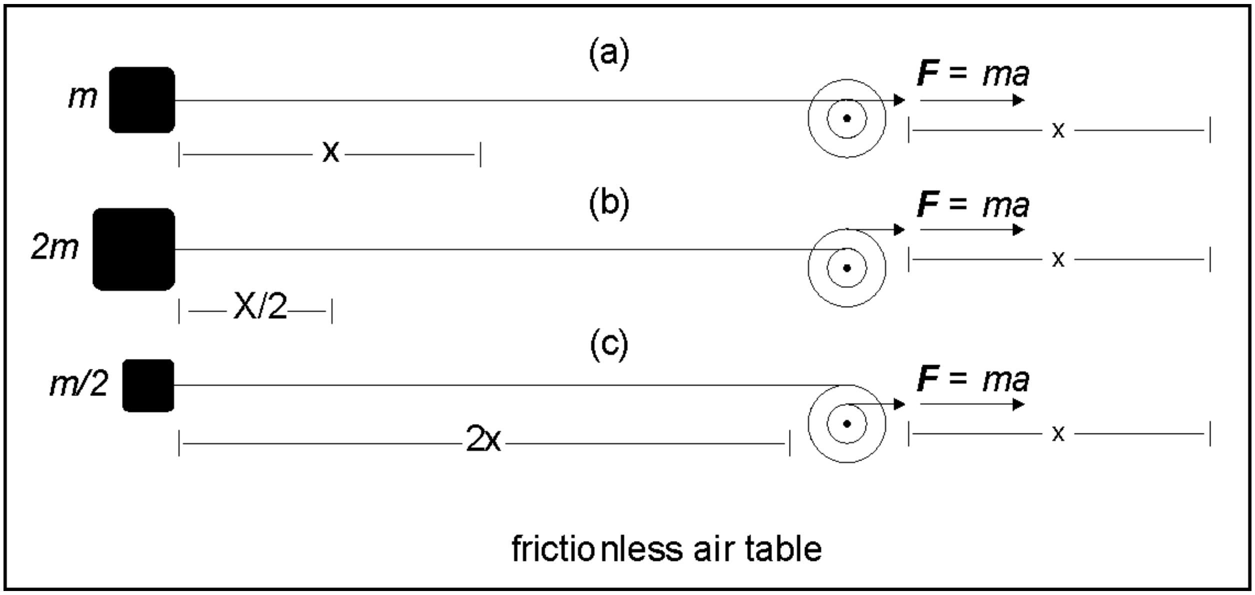

FIG. 2. A constant force $\boldsymbol{F} = m\boldsymbol{a}$ is applied on the loose end of the cord of each pulley, in the direction shown in the figure, through the same distance x. By their respective geometric constraints, the block of mass m is displaced a distance x, the block of mass $2m$ is displaced a distance $x/2$, and the block of mass $m/2$ is displaced a distance $2x$, as shown in the figure.

To calculate the acceleration and kinetic energy of each block, as customary, for simplicity, we assume the pulleys and cords have negligible mass, the cords are unstretchable, and we ignore friction. Thus, by Newton's second law $\boldsymbol{F} = d\boldsymbol{p}/dt = m\boldsymbol{a}$ the acceleration of block m is $m\boldsymbol{a}/m = \boldsymbol{a}$, the acceleration of block $2m$ is $m\boldsymbol{a}/2m = \boldsymbol{a}/2$, and the acceleration of block $m/2$ is $m\boldsymbol{a}/(m/2) = 2a$.

Since, with constant acceleration, according to one of the kinematic equations, $v^2 = 2ax$, where $\mathbf{v}$ is the instantaneous velocity, a the acceleration, and x the displacement, the kinetic energy of each of the blocks is, respectively,

$$K_{(a)} = (1/2)m2ax = max, \quad (1)$$

$$K_{(b)} = (1/2)2m2(a/2)x/2 = (1/2)max, \quad (2)$$

and

$$K_{(c)} = (1/2)(m/2)4a2x = 2max, \quad (3)$$

These results show clearly that work does not transfer kinetic energy, because, if that were true, equal amounts of work would always transfer the same amount of kinetic energy; they do not violate the law of conservation of energy, which is only valid in closed, isolated systems; rather, they suggest that we are not in such a system; and they do not violate the work-kinetic energy theorem $W = \Delta KE$, because the force applied on each block, times the distance through which it is applied, equals the change in the kinetic energy of the block.

The above results are backed by numerous quantitative experiments.

The foregoing is part of a theory, currently in preparation, based on the premise that to do work or any activity, energy in some form is always required.

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[1] Halliday D., Resnick R., and Walker J., *Fundamentals of Physics* (John Wiley & Sons, Inc., New York) 2001.

[2] Feynman R. P., Leighton R. B. and Sands M. *The Feynman Lectures on Physics* (Addison-Wesley Publishing Co., Reading, MA) 1966.

[3] Giancoli D. C., *Physics for Scientists and Engineers* (Prentice Hall, Englewood Cliffs, NJ) 1989.

[4] Sears F. W.,, Zemansky M. W. and Young H. D., *University Physics* (Addison-Wesley Publishing Co., Reading, MA) 1977.

[5] Serway, R. A. and Beichner, R. J., *Physics for Scientists and Engineers* (Brooks/Cole, Kansas City, MO) 2000,