Subject:

“Like the lever, pulleys can also multiply force and change its direction.”

“This pulley does not multiply the input force. It does change the direction of the force from up to down, and for many people, that is an advantage.”

“A pulley changes the direction of the force, making it easier to lift things to high-rise areas.”

Deficiencies:

A person A is pulling on a rope, which runs over a pulley B and on which a load C is hanging, Fig. 1.

1. The citations refer to forces in parts $R_1$ and $R_2$ of the same rope. If a force is mentioned without specifying the body that exerts it and that on which it is exerted, the orientation of the vector arrow is not yet defined.

The force $F_{AB}$ that the person exerts on the pulley is oriented downwards, the force $F_{BA}$ which the pulley exerts on the person points upwards. The state of the left part of the rope, i.e. $R_1$ is unambiguously described by the one or the other.

Our citations claim that the direction of a force is changed. This statement will be understood as follows: When going from part $R_1$ to $R_2$ of the rope, the force changes its direction. But we see that it is left to our discretion if it does so or not. $F_{AB}$ has indeed the opposite direction of $F_{BC}$ and thus a force seems to change direction. But the directions of $F_{AB}$ and $F_{CB}$ are the same and thus the direction of forces seems not to be changed.
2. "Change a direction" means that something that first has a certain direction later has another one. Thus, the sentences suggest that the force is going from rope 1 (left) to rope 2 (right). But if that would be so, what about the third force: that which the suspension exerts on the pulley? Where does this force go? Actually the pulley changes the direction of something, and even of two things: first it changes the direction of the rope, and second that of the energy flow, Fig. 2. When the rope $R_1$ is pulled downwards by the person, there is an energy flow upwards in $R_1$, it then goes around the pulley and down in part $R_2$ of the rope towards C.

3. It is indeed possible to handle the force in the way that is suggested by the citations. A force can be identified or interpreted as a flow of momentum. The momentum flow of our pulley arrangement can easily be given. However, momentum does not flow as one might suspect when reading our citations. It does not follow the rope around the pulley. If we take the upwards direction as the positive momentum direction, then momentum is flowing from the suspension into the pulley. There it branches into two currents of equal magnitude, one of them flowing through $R_1$ and the other through $R_2$, Fig. 3.

**Origin:**

The arrangement suggests a description with something that is flowing around the pulley in addition to the rope. But apparently the behavior of the energy flow is projected on that of the force, see also [1].

**Disposal:**

The idea of a force that changes direction is not much good. Things become clear when describing the pulley as well as the tackle with the flows of energy and momentum whereby one carefully keeps one apart from the other, just as in electricity one thoroughly has to distinguish between the energy flow and the flow of electric charge.

[1] F. Herrmann, *Force and energy*, no. 45 in this series

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