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A SiQuENC for solving physics problems

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Students often struggle in AP Physics 1 because they have not been previously trained to develop qualitative arguments. Extensive[1] literature on multiple representations and qualitative reasoning provides strategies to address this challenge. Table I presents three[1-4] examples, including SiQuENC, which I adapted from a strategy promoted by Etkina et al.[4] To remind students that they can use qualitative reasoning (e.g., arguing from proportionalities), rather than relying only on algebra, I replaced “Solve” with “Analyze.” I added a “Communicate” step to guide planning of written responses to AP Physics 1[5] and 2[6] questions. To perform this step, draw a circled number around each key point identified in figures, equations, and sentence fragments. Then, convert numbered points into sentences.

Table I. Problem-solving strategies that separate qualitative/pictorial steps from mathematical steps.

Larkin et al.[2,3]	Etkina et al.[4]	SiQuENC[1]
“sketch”	“Sketch and translate”	Neatly and graphically represent situation(s)
“abstract problem representation containing physical entities (such as forces and energies)”	“Simplify and diagram”	Graphically represent quantities and their relationships
“rerepresent the problem as a set of equations”	“Represent mathematically”	Identify relevant allowed starting point (in)equation(s)
	“Solve and evaluate”	Analyze
		Communicate

Sample problem

I based the following sample question on free response question 1 from the 2006 AP Physics C Mechanics exam.[7]

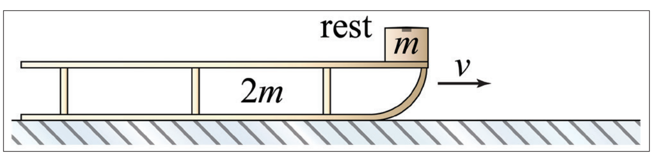

Fig. 1. Box initially at rest on sled sliding across ice.

Initially, a box of mass m is at rest on a sled of mass $2m$ that is sliding horizontally with speed v across ice, as shown in Fig. 1. Friction is present between the box and the sled, but not between the sled and the ice. The sled is very long, so scraping between the box and the sled concludes without the box falling off of the sled. The scraping between the box and the sled produces a skid mark on the top of the sled. In a second experiment, both mass m and mass $2m$ are increased by the same factor. In a clear, coherent paragraph-length response[8] that incorporates relevant principles of physics, explain whether the skid mark in the second experiment will be longer than, shorter than, or as long as the skid mark in the first experiment.

Sample solution

A solution developed using SiQuENC starts in Fig. 2 and then continues in the (long) paragraph-style response below.

(1) Friction between the box and the sled causes (2) the box to speed up and the sled to slow down until both objects move with the same velocity and no longer scrape. The box is vertically at rest, (3) so by Newton’s first law, (4) the magnitude of the normal force supporting the box equals the magnitude of the box’s weight, (5) mg. According to (6) Newton’s second law, the magnitude of the box’s acceleration is proportional to the magnitude of the net force on the box and inversely proportional to the box’s mass. The magnitude of the net force on the box (7) equals the magnitude of the friction force on the box, which (8) is proportional to the magnitude of the normal force on the box, and, thus, (9) proportional to the box’s mass, m. (10) Increasing m by a given factor increases the magnitude of the net force on the box by that same factor, so the box’s acceleration is unchanged. According to (11) Newton’s second law, the magnitude of the sled’s acceleration is proportional to the magnitude of the net force on the sled and inversely proportional to the sled’s mass, $2m$. The magnitude of the net force on the sled (12) equals the magnitude of the friction force on the sled, which, by (13) Newton’s third law, is the same as the magnitude of the friction force on the box. This means that the magnitude of the net force on the sled is also (14) proportional to m. Thus, (15) increasing m increases both the magnitude of the net force on the sled and the mass of the sled, $2m$, by the same factor, leaving the sled’s acceleration unchanged. Since the accelerations of the box and the sled remain the same when m is increased, (16) the motion diagrams for the box and the sled remain the same when m is increased. This means that the distances traveled by the box and the sled until scraping concludes, and the *difference* between these distances, (17) which is the length of the skid mark, are all unchanged.

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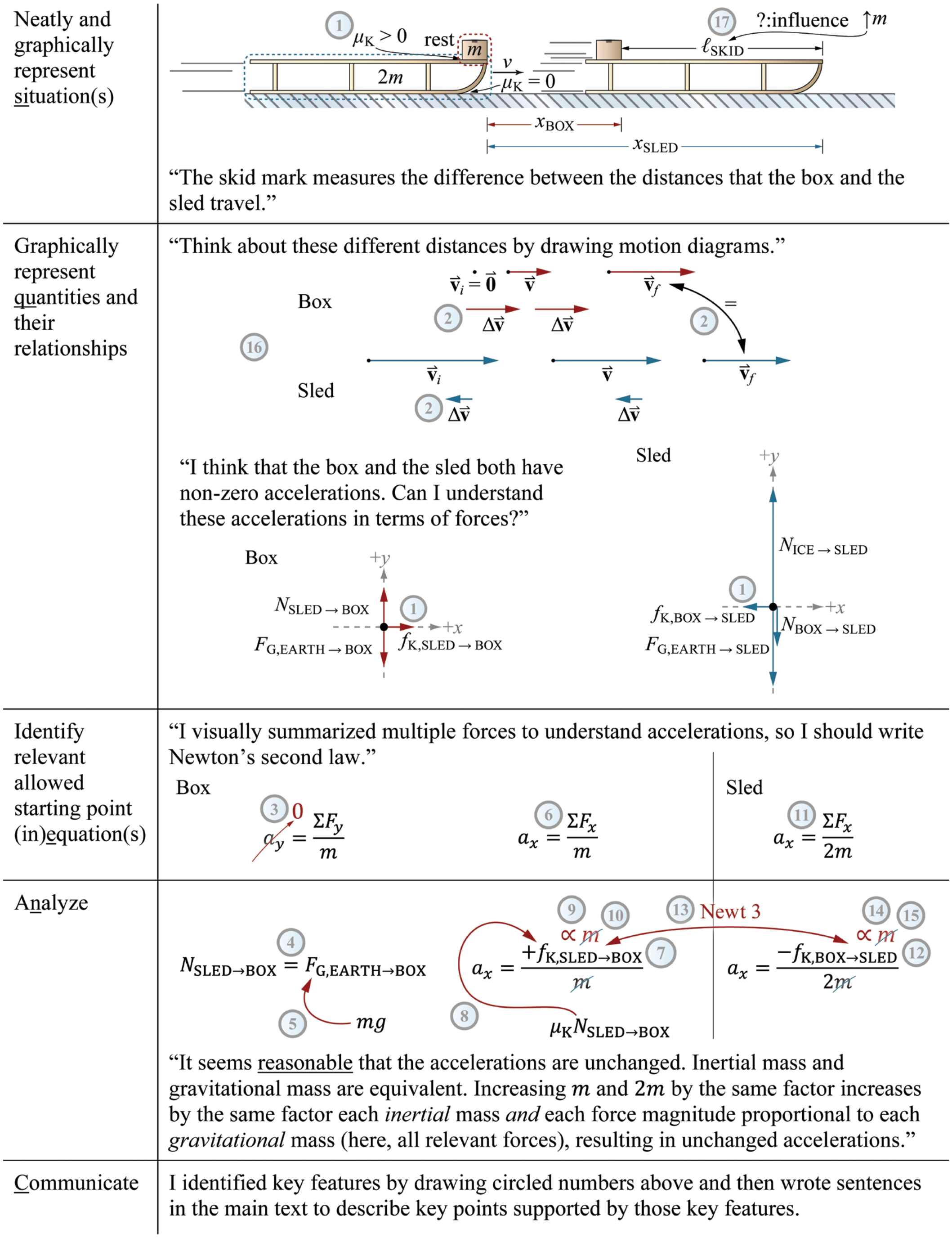

Fig. 2. Using SiQuENC for the sample problem.

who pointed me toward helpful references.[3,4] I thank Ryan Yamada for checking the sample solution.

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