Misconceptions or mental models

David SANDS  
Department of Physics and Mathematics, University of Hull, HU6 7RX, UK

Abstract. This paper presents a detailed study of inconsistent thinking by entry-level students on a troublesome question on the Force Concept Inventory. Two cohorts of students separated by three years were asked a series of questions after completing the Force Concept Inventory. The questions were aimed at eliciting their background knowledge of Newton’s laws of motion along with their approach to question 26. For example, were they guessing, eliminating some impossibilities, reasoning the answer, etc. There was no common or even predominant approach and considerable evidence of inconsistent thinking. The results are discussed in the light of recent literature on the nature of thinking and in particular the debate over logical reasoning versus reasoning by mental models. It is argued that the mental-models perspective explains many aspects of the data and moreover is more conducive to teaching approaches than the misconceptions perspective.

1. Introduction
In 2013, at the ICPE/EPEC conference in Prague, I presented the results of a study into students’ responses on two troubling questions on the FCI, questions 15 and 26 [1] The questions are troubling because, first, the number of respondents answering correctly is very low compared with other questions and, secondly, the questions are not very discriminating. Quite a number of students who achieve a high total score get question 15 wrong, but there are students with a low total score who get it right. Question 26 is more discriminating in as much as nobody with total score below 15 answered correctly, but many students with high scores answered incorrectly.

Question 15 asks about the force exerted on a truck being pushed by a car relative to the force exerted in the opposite direction by the truck on the car when both are accelerating. This requires no more than a straightforward application of Newton’s third law, but the majority of students choose the option corresponding to a greater force exerted by the car on the truck. Even students who expressed the third law in the form, the force exerted by object A on object B is equal and opposite to the force exerted by B on A, thought the car exerted a greater force on the truck than vice versa. By contrast, the vast majority of students answered the follow-on question correctly. This asks about the magnitude of the forces exerted by the car and truck when cruising speed has been reached and there is no acceleration.

The difficulty with question 15 turned out to be relatively easy to address. Students overwhelmingly gave as the reason for the greater force exerted by the car as the need for a net force in the direction of acceleration, which is consistent with the response to the follow-on question: if there is no acceleration there is no net force. What was clearly missing was an appreciation that the action-reaction pairs of Newton’s 3rd law act on different bodies and therefore cannot cancel out. I developed a teaching sequence showing explicitly that even though the bodies are accelerating, the action-reaction pairs are equal, but act on different bodies. Thereafter, students tended to answer this question correctly.

Question 26, on the other hand, was harder to address. Following on from question 25, which asks about the speed of a box being pushed along the floor with a constant speed, the force pushing the box
is doubled and students are asked what happens to the speed of the box. The Newtonian answer is that box accelerates because the force pushing it exceeds the frictional force. However, this is not stated explicitly: students have to recognise this from the preceding question. Even though there was some improvement following instruction, the number of correct responses consistently remained low. I interpreted these results in 2013 in terms of dual processing theory and in particular the notion that prior belief might be biasing students’ responses. I set out to examine the nature of this bias and in particular, the suggestion from some of the respondents in 2013 that the resistive force increases.

One of the difficulties in trying to understand approaches to problem solving by questionnaire is foreseeing the kinds of responses that might be generated. Without explicitly asking about students’ views of the magnitude of the resistive force during the push, I was left with some answers that implied a change in resistive force without any clear justification for this view or any indication of the effect on students’ reasoning about the problem. Questions about this aspect of the problem were therefore incorporated into a subsequent questionnaire on approaches to answering question 26 and in this paper the details of that investigation are reported.

As in 2013, the analysis of the current data reveals similarly confusing and contradictory responses from the students as well as inconsistent or incomplete reasoning. Although the original intention was to elicit data on prior beliefs and how these might influence the answers to the questions, a different approach became apparent during the analysis. That approach entailed looking at the responses in as mental models rather than conventional misconceptions and helps to explain the faulty reasoning.

Historically, as described in Leighton and Sternberg [2], there have been two approaches to reasoning: mental rules or mental models. Mental rules correspond to some innate logical process whereas the mental models account postulates that we build iconic, analogical models which form the basis of our reasoning [3]. Research into reasoning using syllogisms, conditionals or selection tests reveals that most subjects do not give logically complete answers. The famous Wason selection test comprising four cards provides a good example. Two of the cards are face up on a table and show two numbers, say a four and a seven, two are face down and show two colours, say red and blue. A proposition links one of the numbers, say four, with a colour, say red, such that any card that has the number four on the front also has the colour red on the back. The reasoner is asked which cards should be turned over to demonstrate the truth of the proposition.

Most people turn over the two cards identified in the proposition, that is, the four and the red. However, there is nothing in the proposition that requires the red card to have a four on the other side. This would be a bi-conditional; if and only if the card shows a red will it have a four on the other side. It is consistent with the proposition, therefore, for the red card to have any number on the back but if the proposition is true it is not possible for the other colour, blue, to have the four on the other side. Therefore, the cards to turn over are the four, to check that it does indeed have a red back, and the blue to check that it has any number other than a four on the other side.

Tests with explicit conditionals of the form, if \( p \) then \( q \), yield similar results. When asked to identify true and false conditions most people correctly identify \( p \) and \( q \) as true and \( p \) and \( not q \) as false, but the configurations \( q, not p \) and \( not p, not q \), which are also true, are rarely recognised. Chronometric studies [4] of reaction times have revealed that assessing \( not p \) statements takes considerably longer than assessing the statements in which \( p \) occurs [5]. This is direct evidence in support of the mental models account. The implication is that we form a mental model that connects \( p \) with \( q \) [6] and the cases involving \( not p \) tell us nothing about that relationship and are therefore deemed irrelevant. In other words, they do not feature in the initial mental model and we have to engage in deliberate, conscious reasoning to assess their validity.

Real-world problems are considerably more complex than these simple conditionals. Question 26 involves a straightforward application of Newton’s 2\(^{nd}\) law and can be expressed as a conditional: if there is a nett force, then there is an acceleration. However, in order to arrive at the correct solution to the problem it is necessary to recognise that a nett force exists and to understand the nature of acceleration. There is considerable scope for errors, as the analysis of students’ responses reveals. Those errors are interpreted in this work not just as misconceptions, but as errors in reasoning. The paper is
therefore organised as follows. After the methodology is described in section 2, the results are presented in section 3 and in section 4 the results are analysed in the context of the mental modelling account of reasoning.

2. Methodology
Two cohorts of students were tested under similar conditions to the tests reported in 2013. That is, students were presented with the FCI on entry to the university and following completion of the FCI were asked to complete a subsequent questionnaire, details of which are given in the appendix. As with the previous test, students were asked to write down Newton’s three laws of motion in their own words. This provides a baseline knowledge against which subsequent responses can be judged.

The presupposition underlying this questionnaire is that belief bias was responsible for the large number of incorrect responses, but the nature of that belief or how it affected the approach to answering the question was not immediately clear. Therefore, following on from the statement of Newton’s laws of motion, students were asked to reaffirm their answer to question 26 and then asked a series of questions about their response: was it a reasoned response, an educated guess or a random choice? Then, students were asked whether the resistive force opposing the push remains constant or not and to explain their reasoning. As described above, previous research had revealed that some students believed the resistive force increases and this question was aimed at eliciting the extent of this belief among the cohort as well as the underlying reason for it. Finally, in order to test whether this belief affected their reasoning, students were told to imagine that the resistive force remained unchanged as the pushing force increases and were asked whether they wished to change their answers. Owing to various constraints, the two entry-level cohorts, labelled A and B (N=75 and N=51 respectively), were tested three years apart.

3. Results
Students’ self-reported approaches to answering question 26 are contained in tables 1 and 2, corresponding to cohorts A and B separated and colour-coded according to whether the students believe the resistive force increases or remains the same. 49% of students in cohort A and 63% in cohort B believe the resistive force increases. Regardless of whether students believe the resistive force increases or not, most choose an option corresponding to a constant speed. Option A corresponds to double the original speed and B corresponds to a speed less than double, but still constant. Very few chose the correct option, E, none chose C and more who believe the resistance increases chose D as their answer than those who believe the resistive force remains unchanged.

Table 1a. The self-reported approaches from cohort A corresponding to those who believed the resistive forces opposing the push increases.

|                        | A | B | C | D | E |
|------------------------|---|---|---|---|---|
| Educated Guess         | 4 | 3 |   |   |   |
| Guessed from narrow choice | 1 | 1 | 2 | 1 |   |
| Intuitively knew and matched the answer | 2 | 4 | 2 |   |   |
| Reasoned correct answer | 1 | 5 | 4 | 2 |   |
| Understood the physics and knew the answer | 2 | 1 | 1 | 1 |   |
Table 1b. The self-reported approaches from those students in cohort A who believed the resistive force to remain the same.

|                                      | A | B | C | D | E |
|--------------------------------------|---|---|---|---|---|
| Educated Guess                       | 3 | 7 |
| Guessed from narrow choice           | 1 | 1 |
| Intuitively knew and matched the answer | 7 | 2 |
| Reasoned correct answer              | 4 | 6 | 4 | 1 |
| Understood the physics and knew the answer | 1 | 1 |

Table 2a. The self-reported approaches from those students in cohort B who believed the resistive force to increase.

|                                      | A | B | C | D | E |
|--------------------------------------|---|---|---|---|---|
| Educated Guess                       | 1 | 1 |
| Guessed from narrow choice           | 1 | 3 |
| Intuitively knew and matched the answer | 1 | 1 |
| Reasoned correct answer              | 2 | 5 | 8 |
| Understood the physics and knew the answer | 1 | 3 | 4 | 1 |

Table 2b. The self-reported approaches from those students in cohort B who believed the resistive force to remain the same.

|                                      | A | B | C | D | E |
|--------------------------------------|---|---|---|---|---|
| Educated Guess                       |   |   |   | 1 | 1 |
| Guessed from narrow choice           | A/B | 1 |
| Intuitively knew and matched the answer | 1 | 1 | 1 |
| Reasoned correct answer              | 2 | 5 | 2 |
| Understood the physics and knew the answer | 1 | 3 |

Tables 3 and 4 show the effect of telling the students that the resistive force remains constant and inviting them to change their answer. The original choice is shown in the first column and the new choice is shown along the top. Again, the data is separated and colour-coded such that Table 3a corresponds to the students in Table 1a, Table 3b to the students in Table 1b, etc. The yellow cells show the number of students who retained their original choice. Within each cohort, one student did not give a final answer so the total numbers do not match those in tables 1 and 2.

It is clear that there is a great deal of what can only be described as inconsistent thinking. There are students in both cohorts who have expressed a view that the resistive force increases yet have not changed their answer on being told the resistance does not change and also students who originally expressed the opposite view but changed their answer. It would appear that for these students the
resistive force does not really figure in their reasoning. The additional comments that students were
asked to provide to explain their thinking shed light on some, but not all, of these decisions, but what is
striking is that there is no simple, consistent picture. Many students who chose A as their final answer
in tables 3 & 4 wrote that doubling the force implies doubling the speed without elaborating on the
mechanisms. Others did give an insight into their thinking, in particular the small fraction who changed
their answer from D to E in tables 3a. Answer D describes what would happen if the resistance did
increase to the point where it matched the pushing force, so changing to E, a constantly increasing speed,
is correct. The explanations given by most of these students shows their reasoning to be correct. Explanations given by other students shed light on the thinking of individuals and these will be discussed in the next section.

Table 3a. The effect of telling students in cohort A (Table 1a) that the resistive
force remains constant.

|     | A | B | C | D | E |
|-----|---|---|---|---|---|
| A   |   |   |   |   | 1 |
| B   | 6 | 1 | 2 | 3 |   |
| C   |   |   |   |   |   |
| D   | 2 |   | 1 | 6 |   |
| E   | 2 |   |   |   |   |

Table 3b. The effect of telling students in cohort A (Table 1b) that the resistive
force remains constant.

|     | A | B | C | D | E |
|-----|---|---|---|---|---|
| A   |   | 4 |   |   | 4 |
| B   | 7 | 7 | 2 |   |   |
| C   |   |   |   |   |   |
| D   | 1 | 1 | 2 |   |   |
| E   |   |   | 1 |   |   |

Table 4a. The effect of telling students in cohort B (Table 2a) that the resistive
force remains constant.

|     | A | B | C | D | E |
|-----|---|---|---|---|---|
| A   | 3 | 1 | 1 |   |   |
| B   | 4 | 3 | 1 |   | 4 |
| C   |   |   |   |   |   |
| D   | 2 | 2 |   | 6 |   |
| E   |   |   |   | 1 |   |
Table 4b. the effect of telling students in cohort B (Table 1b) that the resistive force remains constant.

|   | A | B | C | D | E |
|---|---|---|---|---|---|
| A | 2 |   |   | 1 |   |
| B | 2 | 1 | 1 | 2 | 1 |
| C |   |   |   |   |   |
| D |   |   |   | 4 |   |
| E |   |   |   | 3 |   |

4. Discussion
As described in the previous section, the range of responses and self-reported approaches to question 26 shows no obvious pattern. Nonetheless, it is possible to draw the following conclusions:

1. Regardless of whether students are making a guess, claiming to understand the physics or reasoning through to their choice, the vast majority believe that the final velocity will be constant at either double or nearly double the initial velocity.

2. Those claiming to have reasoned out the answer have invariably reached the wrong conclusion.

3. A small number of students were able to reason correctly on being told the resistance does not increase, but for the majority of students, whether the resistive force is believed to increase or not appears to have played little or no role in their thinking.

The notion that constant speed is associated with a constant force is a well-known misconception. A large part of physics education research has been concerned with identifying common misconceptions and finding ways to overcome them, but the title of this paper asks the question, should we consider these answers as misconceptions or faulty mental models. It may be that there is no factual difference between the two. If the formation of a mental model is the predominant mechanism of reasoning, and there is considerable support for the mental models account of reasoning, then it follows that our understanding of concepts, and by implication misconceptions, is encapsulated in mental models.

There is, however, one important difference. The notion of a misconception tells us very little about the nature of reasoning and interpreting the results and conclusions presented above in this light would require very little further discussion. On the other hand, interpreting these results in terms of mental models provides a much richer view and suggests possibilities for approaches to teaching. However, before trying to interpret these results, and in particular the conclusions above, it is necessary to elaborate on the account of mental modelling given earlier in the introduction.

Proponents of the mental modelling account assume that construction of the mental model occurs during the presentation of the problem. This is supported to some extent by neural imaging [7]. Kroger et al showed that on being presented with a problem, subjects engage the language processing regions of the brain, but once the problem statements have been understood, areas of the brain associated with spatial processing are engaged. The implication is that subjects are forming a mental model during the language processing stages, i.e. when the problem statements are presented, but then switch to spatial processing as the model is manipulated. Applying this to the present research, students will form a mental model of the situation presented in the question and then seek to manipulate that model to find the answer to the question.

Unlike the mental models formed in response to the usual problems presented in reasoning research, which tend to be very simple and self-contained, the mental model formulated to tackle a real-world problem will make reference to existing mental models that will influence the perception of the problem [8]. This is an inevitable consequence of the mental models account: if we reason primarily through the formation of mental models then it follows that as we build understanding of the world around us some
knowledge will be stored as mental models. Solving question 26 requires drawing on the prior mental models of frictional forces, acceleration and Newton’s 3rd law.

These models might be incorrect and would reveal themselves in what we would commonly call misconceptions. That is not to say that students do not possess the correct knowledge. The vast majority of students in this study could state Newton’s three laws of motion correctly, but when solving a problem did not appear to draw on that knowledge. Neuroscience explains why. Nenciovici et al [9] have reviewed the literature on functional magnetic resonance imaging (fMRI) related to scientific reasoning presented. In one of three studies cited, expert physicists presented with a problem pertaining to a well-known misconception exhibited brain activity associated with strong inhibitory processes. In the second study, students presented with pictures containing either correct or incorrect electrical circuits showed brain activity associated with the recognition of conflict but not inhibitory processes. Three conclusions follow. First, even experienced physicists are susceptible to misconceptions, which, according to the present discussion, means that they are accessing an existing mental model. Secondly, they have the cognitive resources to control their response and reason correctly. Thirdly, students can recognise a conflict but do not have the resources to inhibit their response. Taken together, these two imply that a base level of knowledge is needed to recognise when the mental model we are accessing is incorrect and overcome the misconception.

The puzzling persistence and resistance to change of misconceptions is thus explained by the co-existence of one or more conflicting mental models, an idea which, though surprising at first, is perfectly sensible. If we understand concepts through the formation of mental models, then there is no requirement, perhaps even no mechanism, to “erase” or forget one mental model as we form another. Which mental model we use to reason with will depend on which one we recognize first, whether we recognize that it is inappropriate or not and then whether we have the inhibitory control to suppress the inaccurate model.

The reasoning errors committed by the students in this study are directly related to the mental models they are accessing, but recognising the nature of those models is not always possible. Many students did not give a full explanation for their choice, but instead made a terse comment, such as, “faster means more friction”, “force not used up in overcoming friction” or simply, “double force, double speed”. However, there were cases where the lines of reasoning were clear. For example, those students who assumed that resistance increases until it matches the force and therefore chose option “D” but changed to “E” on being told that the resistive force is constant were clearly applying the second law consistently. However, their initial assumption about resistance was incorrect. It is known that prior knowledge can lead to extraneous elements being added to given premises [10] and these students were adding an assumption about the nature of the resistive force while forming their mental model.

Some of the students who chose A (double the speed) as their final answer simply stated without giving a reason that double the force implies double the speed. A small number seemed to base their arguments on the belief that the speed of the box will be constant and adjusted their thinking accordingly. This is a clear example of belief bias: the belief that a particular outcome will occur and adjusting the argument accordingly. Some students demonstrating this belief bias were not sure of the particular physical mechanism but were quite certain that force must increase to match the pushing force. In adjusting their thinking to match their beliefs these students seem to have associated force with acceleration, but they cannot be said to have an effective mental model of the problem.

Other students presented some quite complex arguments, including in one case a string of proportionalities: \( v \) is proportional to \( a \), \( a \) is proportional to \( F \), so \( 2F \) implies \( 2a \) which implies \( 2v \). For this line of reasoning to be valid, there is an implication that the time over which the acceleration occurs must be fixed. The question says nothing about the time involved and this is another example of a student who appears to be adding an assumption to the initial premises. In a similar vein, one student explicitly wrote that time is constant and used the expression, \( v=u+at \) to justify double the speed. Other comments along the lines of, “faster means more floor covered” also indicate an assumption about the time for which the force is applied.
There is a suggestion, though it is far from conclusive, that some students have an incorrect model of acceleration. A number of students expressed Newton’s 2nd law in terms of \( \frac{(v-u)}{t} \), which suggests they see acceleration not as a rate of change but as the change occurring between an initial and final velocity. One student wrote, “resistance not related to push; the box accelerates”, which on its own would be taken as correct, but then chose option “A” (double speed) as the final answer. The line of reasoning required to arrive at this answer is probably similar to both that involving a string of proportionalities described earlier and the argument that as \( v = u + at \) and \( t \) is constant, \( v \) must double. All these can be interpreted as an incorrect mental model of acceleration distorting reasoning about the problem.

Another justification for asserting double the speed used the idea that force is either used up in overcoming resistance or doesn’t reduce speed. One student wrote, “force accelerating the box, resistance SLOWING it to constant speed”. The emphasis is mine. It follows from this line of thinking, possibly with a model of acceleration as a change between an initial and final state, that no change in resistance means that all force goes into doubling speed and would explain why relatively large numbers chose option “A” (double speed) after being told the resistance remains constant, having initially chosen option “B” (constant speed, but not quite double).

The preceding illustrates some of the ways that incorrect mental models influence reasoning about a problem. The neuroscience cited in [9] suggests that forming new mental models of the underlying concepts will not be sufficient in itself to overcome these difficulties, as these new mental models will sit alongside existing models and compete with them. With sufficient development in the subject, students will be able to recognise when a conflict arises. The ability to inhibit the use of the incorrect mental model appears to require some further, as yet unidentified development. The implication is that students must be given opportunities to practise applying knowledge repeatedly not only to consolidate the correct mental models but also to be able to recognise when a mental model being accessed is incorrect.

5. Conclusion
In this follow-up study to work presented in 2013, the nature of inconsistent thinking underlying answers to questions 26 on the FCI has been investigated through a combination of self-reported approaches and elaboration of the reasoning behind some of the decisions. It was evident in the earlier study that some students believed the resistive force to increase, but that emerged from the findings and did not feature in the investigation itself. In this study, students were explicitly asked what happens to the resistive force and why. Roughly half the students believed it to increase while the remainder believed it to remain constant. Reasons for it increasing ranged from a mis-application of the third law, a belief that the final speed should be constant and therefore resistance must increase, extraneous effects not mentioned in the question, such as air resistance, and odd notions about the nature of friction. Amongst those who recognised the resistance remains constant, however, there was generally no recognition that this implied constant acceleration and many chose as a final option an answer consistent with a constant final speed.

The explanations given by students in support of their reasoning have been interpreted as showing incorrect mental models of the underlying concepts that have distorted reasoning about the problem. In particular, there is evidence that many students have a model of acceleration as the change in velocity between initial and final states rather than a rate of change. Some students appear to have added assumptions about the time the force in the question is applied and quite possibly this is linked to this model of acceleration. Studies from neuroscience have been cited to show that students use of a wrong mental model, or misconception, can occur if they fail to recognise and control a conflict between a correct and incorrect model. The implication is that students must use and become familiar with correct models, which in turn implies opportunities for repeated practice.

6. Appendix
Students were given a series of questions immediately after completing the FCI in order to probe their thinking on questions 15 and 26. The questions related to question 15 on the FCI are not reproduced.
here and only those questions related to question 26 are given. Each set of questions was given on a separate page, but they are combined here in order to reduce space. The questions started as follows:

You also answered the following two questions:

25. A woman exerts a constant horizontal force on a large box. As a result, the box moves across a horizontal floor at a constant speed “v_o”.

26. If the woman in the previous question doubles the constant horizontal force that she exerts on the box to push it on the same horizontal floor, the box then moves:
   (A) with a constant speed that is double the speed “v_o” in the previous question.
   (B) with a constant speed that is greater than the speed “v_o” in the previous question, but not necessarily twice as great.
   (C) for a while with a speed that is constant and greater than the speed “v_o” in the previous question, then with a speed that increases thereafter.
   (D) for a while with an increasing speed, then with a constant speed thereafter.
   (E) with a continuously increasing speed.

In relation to question 26, please tick from the following the option, or options, that best describes the way you answered this question:

☐ When I read the question I understood the physics principles involved and knew the answer. I just looked down the choices until I found the right one.
☐ Having read the question I knew intuitively what the answer was and chose the option that best matched my answer.
☐ Having read through all the choices I was able to reason which was correct
☐ Having read the answers I had no idea which was correct and made a random choice
☐ Having read the answers I couldn’t be certain about any of the answers, but I was able to make an educated guess.
☐ After I had read the question I didn’t know the right answer, but:
   ☐ after reading through the choices I was able to recognise some as being incorrect
     (indicate which those were by underlining or circling the appropriate letters: A B C D E ), but had to make a random choice from the remaining options.
   ☐ Having read through all the choices I narrowed it down to two or three from which I was able to make a sensible guess as to the final answer (from which alternatives did you guess? A B C D E )

Looking again at questions 25 and 26.

25. A woman exerts a constant horizontal force on a large box. As a result, the box moves across a horizontal floor at a constant speed “v_o”.

26. If the woman in the previous question doubles the constant horizontal force that she exerts on the box to push it on the same horizontal floor, the box then moves:
   (A) with a constant speed that is double the speed “v_o” in the previous question.
   (B) with a constant speed that is greater than the speed “v_o” in the previous question, but not necessarily twice as great.
   (C) for a while with a speed that is constant and greater than the speed “v_o” in the previous question, then with a speed that increases thereafter.
   (D) for a while with an increasing speed, then with a constant speed thereafter.
   (E) with a continuously increasing speed.
Please answer the following:

1. What do you think happens to the resistance with which the box opposes the woman’s push? Does it:
   A. increase
   B. decrease
   C. stay the same

   Explain the reasoning behind your answer and explain what you think will happen to the speed of the box.

2. Do you want to change your answer to question 26?

As before:

25. A woman exerts a constant horizontal force on a large box. As a result, the box moves across a horizontal floor at a constant speed “\(v_0\).”

26. If the woman in the previous question doubles the constant horizontal force that she exerts on the box to push it on the same horizontal floor, the box then moves:
   (A) with a constant speed that is double the speed “\(v_0\)” in the previous question.
   (B) with a constant speed that is greater than the speed “\(v_0\)” in the previous question, but not necessarily twice as great.
   (C) for a while with a speed that is constant and greater than the speed “\(v_0\)” in the previous question, then with a speed that increases thereafter.
   (D) for a while with an increasing speed, then with a constant speed thereafter.
   (E) with a continuously increasing speed.

Please answer the following:

1. Suppose you were told that the resistive force is independent of the speed of the box and therefore does not change as the woman applies more force. Disregard any previous answer you might have given and assume for the purposes of this question that this information is true. Which of the options (A-E) in the answer to Q26 above would this require?

2. Please explain your reasoning.

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