

Misconceptions in Primary Level Science — Forces and Newton's Laws of Motion

小学科学的一些错误概念——力和牛顿定律

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In the Science Classroom in the previous issue, we talked about a misconception in one chapter in Life Science — photosynthesis. There are actually more misconceptions in Physical Science than in life science. Starting from this issue, I will use some examples from Physical Science for discussion. In this issue, we will discuss the misconceptions about forces and Newton's laws of motion. These misconceptions usually relate to Newton's first and third laws, and friction. Although these laws are not in the primary Science syllabus,[1] it is still necessary to clarify such concepts as they appear in the examination papers of local schools.

上一期的“科学教室”，我提到了生命科学的一个章节——光合作用中经常出现的错误概念。实际上，小学科学试题中的物理科学章节中有更多的错误。从本期开始，我会逐一举例说明，供大家讨论和交流。这期我们讨论出现在力和牛顿定律中的错误概念，它们通常涉及牛顿第一和第三定律以及摩擦力的概念。尽管小学科学大纲不包括牛顿定律[1]，但很多学校试卷考题涉及牛顿定律，因此非常有必要厘清这些概念。

Questions and Discussion 问题和讨论

Question 1 问题 1

Bryan and William are playing a pushing game. The winner is the one who can push the other person out of position. What can be said about the pushes exerted by Bryan and William if

- (a) Both boys remain stationary?
- (b) Bryan manages to move William backwards?

The answers based on common sense (and not Science) are:

- (a) The two forces are equal as both boys are stationary.
- (b) Bryan exerted more force as he managed to push William backwards.

Bryan和William在玩一个互推的游戏。谁把另一人推动了位置，谁就赢了。在以下两个情形中，他们各自施加给对方的推力，谁的大？

- (a) 两人都维持不动。
- (b) Bryan成功把William推动。

基于常识（而不是科学）的答案如下：

- (a) 双方的推力相等，因为谁也没有推动谁。
- (b) Bryan的推力大，因为他把William推动了。

Figure 1
图1



Discussion 1 讨论 1

According to Newton's Third Law, action and reaction come together. For any action, there is an equal and opposite reaction. In the question, the two pushes from Bryan and William constitute an action and a reaction. They are equal in any situation. But if both pushes are equal why did Bryan remain stationary and why did William move backwards? The answer lies in the fact that the motion status of an object depends on all the forces acting on it and not just the forces it exerts on other objects. Bryan kept stationary, because all the forces acting on him were in balance. On the horizontal plane, the push exerted by William and the friction between the ground and Bryan's feet were equal and balanced. William moved backwards, however, because the push exerted by Bryan was greater than the friction between the ground and William's feet. These were not balanced.

实际上，根据牛顿第三定律，作用力和反作用力 (action and reaction) 成对出现，它们大小相等，方向相反，分别作用在两个不同的物体上。本题Bryan和William的推力就是一对作用力和反作用力，在任何情况下，它们大小相等。有人可能有疑问：如果推力相等，那为什么一个不动，另一个却动了。根据力学中的隔离体分析法 (free-body diagram)，一个人动不动，取决于所有作用在他身上的力，而与他推别人的力无关。比如Bryan没动，那是因为所有作用在他身上的力平衡了。在水平方向上，那就是William推他的力和Bryan脚下的摩擦力相等，互相平衡了。William动了，那是因为Bryan推他的力超过William脚下的摩擦力，两者不平衡。

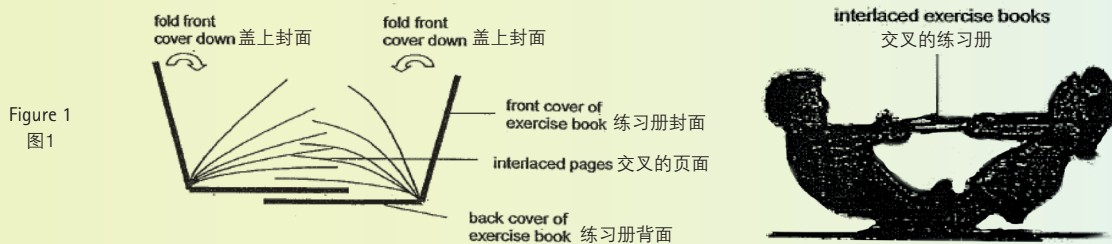
Question 2 问题 2

The diagram shows how Derek and Diana interlaced two exercise books. Then, they each took one end of the book and pulled hard. Explain in terms of forces why the children were not able to separate the books by pulling.

The answer based on common sense (and not science) is that because the friction between the interlaced pages of the two books (inwards direction) is greater than the pulling exerted by the two children (outwards direction), they are not able to separate the books by pulling.

下图所示Derek和Diana如何把两本练习册相互交叉在一起。然后，他们分别拉住练习册的一端用力拉开。用力的概念解释为何他们不能把练习册分开。

基于常识（而不是科学）的答案如下：因为书本页与页之间的摩擦力（方向向里）大于两个孩子施加的拉力（方向向外），所以孩子们不能把书分开。



Discussion 2 讨论 2

According to Newton's First Law, when the resultant force is zero, the object will continue in its original state of motion. The two books are not able to be separated by pulling, which means that the resultant force is zero. The friction between the interlaced pages (inwards direction) and the pulling exerted by two children (outwards direction) are equal. If the friction between the pages (inwards direction) was actually greater than the pulling exerted by the two children (outwards direction), the books would move inwards — which would be very funny.

和问题1类似的错误也发生在以上题目。这次是违反了牛顿第一定律。根据牛顿第一定律：如果作用在一个物体上的合力为零时，物体就维持原来的运动状态。书本拉不开，维持原状，说明合力为零，即页与页之间的摩擦力（方向向内）和两个孩子施加的拉力（方向向外）相等。如果摩擦力（方向向内）大于两个孩子的拉力（方向向外），书本就会往里缩。当然，这个结论非常滑稽。

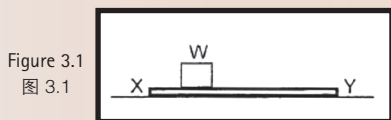
Question 3 问题 3

Another common misconception appears in questions relating to friction. The example below is a question from the 2012 Primary School Leaving Examination (PSLE) Science paper. Some schools, and even the publisher of the assessment books for PSLE questions, provided the wrong answer.[2]

Siva conducted an experiment using a wooden block W and a flat wooden plank XY placed horizontally as shown in Figure 3.1.

另一个很常见的错误发生在关于摩擦力的题目中。下面一例是2012年的小六会考科学试题。有些学校，甚至随试题一起出版的参考答案也错了[2]。

Siva 用木块W和一个水平放置的平板XY 演示了如下图3.1所示的实验。



He raised end X of the plank slightly as shown in Figure 3.2 but the block did not slide down. When end X was raised high enough, Siva observed the block sliding down as shown in Figure 3.3.

他把平板的X端稍稍抬高，但木块并未滑下。如图3.2所示。当X端抬到足够高时，Siva观察到木块向下滑动，如图3.3所示。

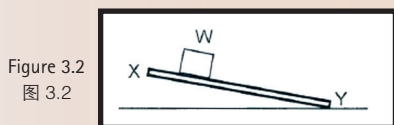
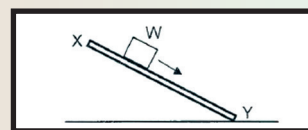


Figure 3.3
图 3.3



Which of the following statement(s) is/are correct?

- A Frictional force acted on the block when it was resting on the plank in Figure 3.1.
 - B Frictional force acted on the block when the plank was being raised in Figure 3.2.
 - C Frictional force acted on the block when it was sliding down the plank in Figure 3.3.
- 1) A only
 - 2) C only
 - 3) B and C only
 - 4) A, B, and C

The answer provided is:

Frictional force acted on the wooden block even when it was stationary. Thus, all three statements are correct.[1]

下列哪些描述是正确的？

- A 当木块静止在平板上时，摩擦力作用在木块上，如图3.1所示。
 - B 当平板被抬高时，摩擦力作用在木块上，如图3.2所示。
 - C 当木块从在平板上往下滑时，摩擦力作用在木块上，如图3.3所示。
- 1) 只是A
 - 2) 只是C
 - 3) B和C
 - 4) A, B, 和 C

出版的参考答案认为摩擦力作用在以上所有情况，即使当木块静止在水平木板上时。

Discussion 3 讨论 3

In reality, there is friction because of motion or potential motion (even though the object moving at that moment) and the direction of the friction is always against the motion (kinetic friction) or against the potential motion (static friction). In figure 3.1, there is no motion or potential motion, so there is no friction. If there was friction, the forces on the horizontal plane would not be balanced and the wooden plank would move. That would be funny. In figure 3.2, there is no motion but there is potential motion, so there is static friction against the direction of the motion. In Figure 3.3, there is motion, so there is kinetic friction against the motion.

实际上，摩擦力的产生是因为有运动或有运动的趋势（即使当前状态时物体不动），而摩擦力是反抗运动（动摩擦力）或反抗运动的趋势（静摩擦力）。图3.1的情况是木块既无运动又无运动趋势，所以不存在任何摩擦力。如果存在摩擦力，那水平方向的力就不平衡，木块就会随着摩擦力的方向运动，那是非常滑稽的。图3.2的情况是木块虽然没有运动，但有运动趋势，所以静摩擦力产生来反抗这种运动趋势。而图3.3的情况是木块有运动，所以动摩擦力产生来反抗这种运动。

Question 4 问题 4

Ken was dragging a box across the floor and up a ramp as shown below in Figure 4. The floor and the ramp are made of the same type of material.

第四个例子也是关于摩擦力的。
如下图4所示，Ken 正沿着平地往斜坡上拉一个箱子。

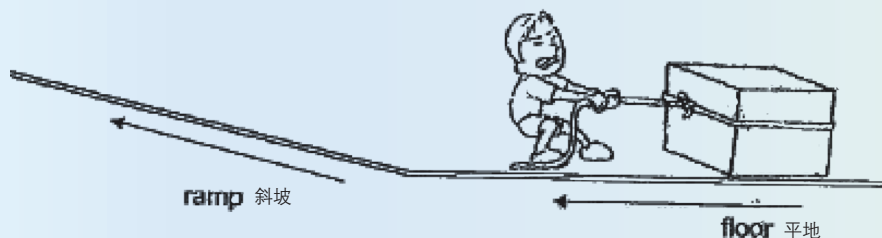


Figure 4
图 4

Which of the following statements is correct about the forces acting on the box as it is dragged across the floor and then up the ramp?

- A The frictional force increases.
- B The gravitational force increases.
- C The frictional force remains the same.
- D The gravitational force remains the same.

- 1) A and B only
- 2) A and D only
- 3) B and C only
- 4) C and D only

关于作用在正沿平地往斜坡上拉箱子上的力，下列哪个描述是正确的？

- A: 摩擦力在增加
- B: 重力在增加
- C: 摩擦力维持不变
- D: 重力维持不变

- 1) A 和B正确
- 2) A 和D正确
- 3) B 和C正确
- 4) C 和D正确

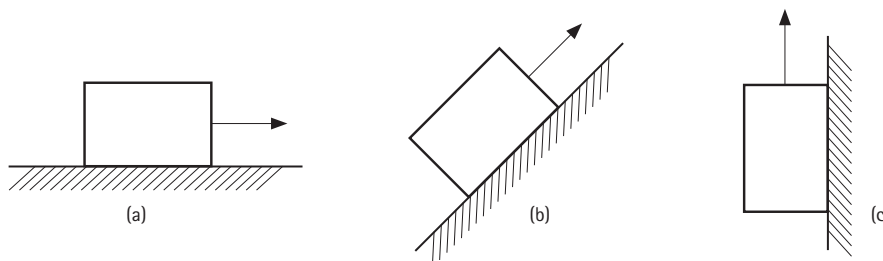
Discussion 4 讨论 4

All the choices provided in the question are wrong. The frictional force actually decreases when the box is dragged across the floor and then up the ramp. Frictional force is directly proportional to the perpendicular force acting on the contact surface. In Figure 5(a), the perpendicular force is equal to the gravitational force and thus the frictional force is the greatest. In Figure 5(b), the perpendicular force is less than the gravitational force and thus the frictional force is less than that in 5(a). In Figure 5(c), the perpendicular force is almost zero, so the frictional force is also zero. Therefore the frictional force decreases as the box is dragged and there is no correct choice for this question.

题目提供的所有选择都错了。实际上，从平地到斜坡，摩擦力是减少的。这里我们用如图5所示的几个典型的情形进行说明。

从 (a) 到 (b) 再到 (c)，摩擦力在逐渐减少。摩擦力的大小和接触面所受的正压力成正比。正压力是指向接触面的垂直压力。在 (a) 中，正压力的数值就是全部重力，摩擦力当然最大；在 (b) 中，正压力的数值是部分重力，摩擦力当然减小；而在 (c) 中，正压力是零，摩擦力也是零，所以摩擦力在减少。上面的题目没有正确答案。

Figure 5
图 5



Conclusion 小结

Looking at the wrong concepts behind the questions, we should pay attention to how Physics is taught in school. The most basic understanding of the principles of Physics seems to be absent, which may indicate a lack of teacher training. By 2014 it will be compulsory for all students to take Chemistry as a subject from Secondary 3 onwards, which means many of them may give up Physics. This will mean that such students will have only six years of foundation in Physics — four in primary school and two in secondary school. In addition, instead of pure Physics, they only study the subject as part of Combined Science in these six years.

Physics (and not Chemistry) is the basis of all science. Most of the revolutionary scientific breakthroughs and schools of thought have come from the field of Physics. One less school year of pure Physics training is probably enough, therefore, to cause significant harm to Singapore's scientific research sector.

References 参考资料

- [1] Singapore MOE Primary Science Syllabus, 2008.
- [2] PSLE Examination Questions, Year 2008–2012, EPH Pte Ltd.

以上几个例子反映出一些错误概念，背后的教学情况实际上应该引起重视。因为这里缺乏的是对最基本物理学的掌握，反映出小学师资关于物理学的培训可能不足。再者，从2014年开始中三学生必须修读化学，这可能意味着很多学生会放弃物理学。也就是说他们的物理学基础将仅仅只是小学四年加上中学两年。而这六年读的都是综合的科学而不是纯粹的物理学。

物理学（不是化学）是科学的基础。科学中大部分革命性的理论和思想都出自物理学。如果今后新加坡大部分的学生缺乏哪怕是一年的纯粹的物理学的训练，那将对新加坡的科学研究造成非常大的损害。

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