6 Wooden trucks on a toy railway have permanent magnets that hold the train together.

The magnets are arranged so that an N-pole touches an S-pole between each truck, as shown in Figure 15.

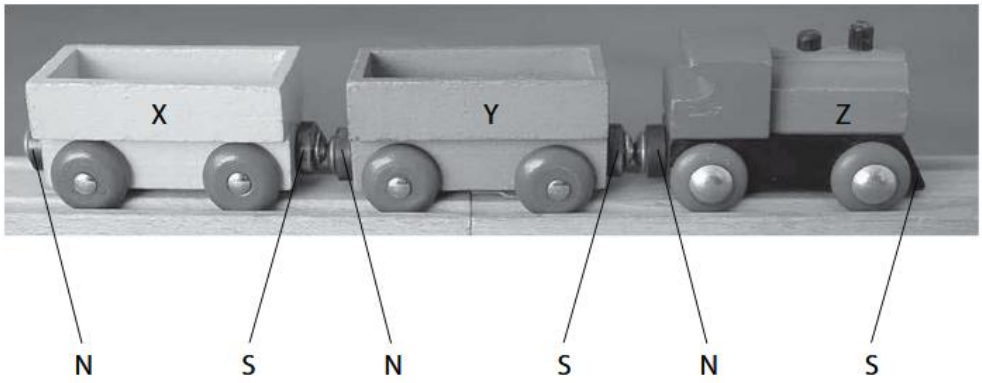


Figure 15

(a) Truck Y is removed from the train, turned through 180° and is then replaced between truck X and Z.

How does this affect the train?

(1)

- ☒ **A** Y attracts both X and Z as before
- ☒ **B** Y still attracts X but now repels Z
- ☒ **C** Y still attracts Z but now repels X
- ☒ **D** Y now repels both X and Z

(b) The structure of a truck, seen from above, is shown in Figure 16.

The permanent magnets cause a magnetic field both inside and outside the truck.

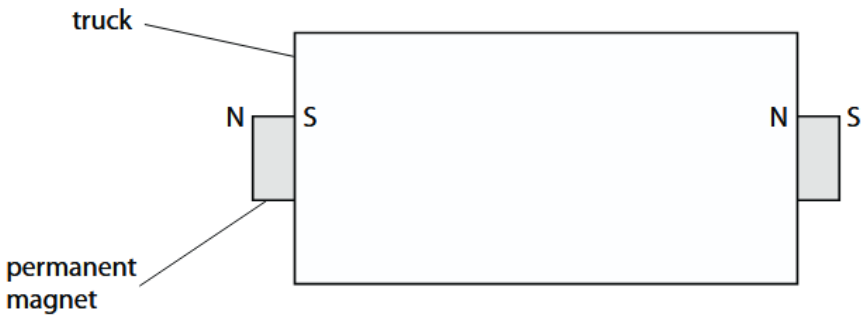
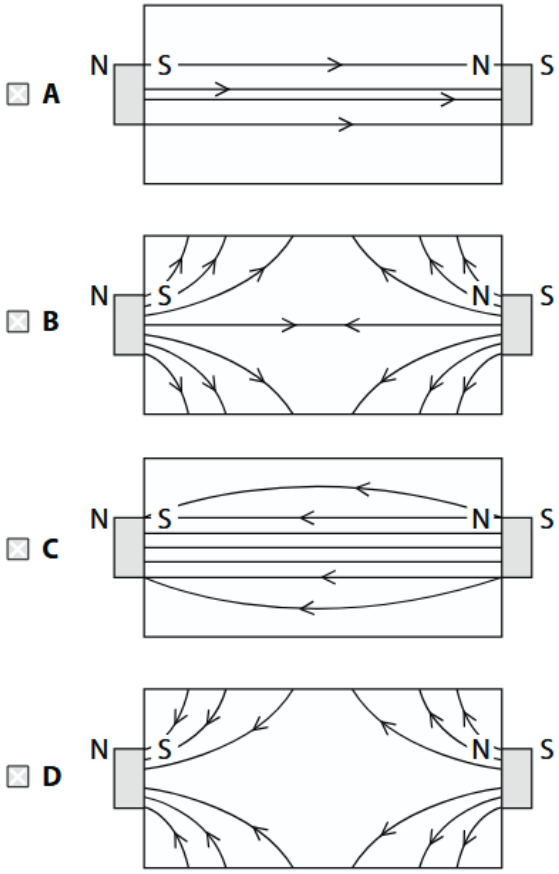


Figure 16

Which of these correctly shows the field inside the truck?

(1)



(c) A student investigates the forces between the trucks in the toy railway.

She places another truck, **W**, next to truck **X**.

She pulls truck **Z** in the direction shown by the arrow.

The whole train travels at a constant speed as shown in Figure 17.

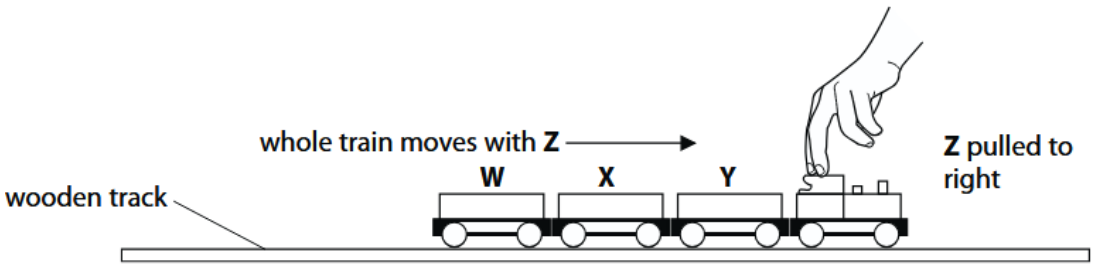


Figure 17

The student repeats this method of adding trucks and pulling the train each time.

When there are seven trucks in total, the train comes apart between **Y** and **Z** when tested as shown in Figure 18.

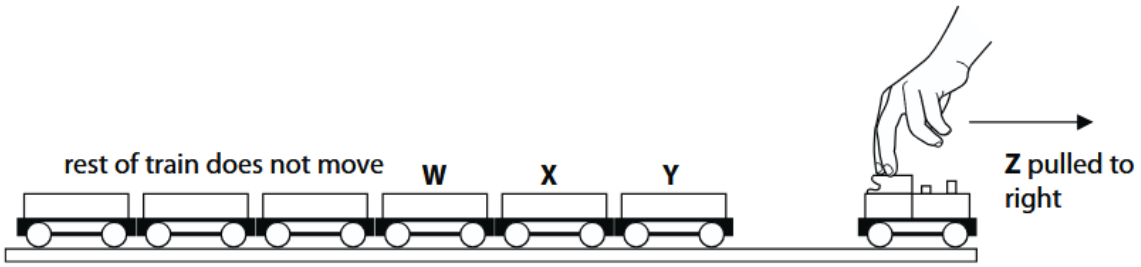


Figure 18

(i) Explain why the train acts in this way by considering the forces involved.

(2)

(ii) Devise an experiment to investigate the horizontal force needed to separate the trucks from the engine.

(3)

(iii) Explain why a larger force is needed to separate the trucks from the engine if the force is applied at an angle to the horizontal.

(2)

(Total for Question 6 = 9 marks)

Question number	Answer	Mark
6(a)	D	(1)

Question number	Answer	Mark
6(b)	C	(1)

Question number	Answer	Additional guidance	Mark
6(c)(i)	An explanation that combines identification – application of knowledge (1 mark) and reasoning/justification – application of understanding (1 mark): • frictional forces increase as more trucks are added (1) Plus **one** from: • hence, in order to keep constant speed, the student must increase the force she applies to **Z** (1) • when **Y** and **Z** separate, the frictional forces (to the left) are more than magnetic attraction between **Y** and **Z** (1)		(2)

Question number	Answer	Mark
6(c)(ii)	An answer that combines the following points to provide a plan: • use of a Newton meter used horizontally (1) • record largest force observed (1) • repeat readings several times under same conditions (1)	(3)

Question number	Answer	Mark
6(c)(iii)	An explanation that combines identification – understanding (1 mark) and reasoning/justification – understanding (1 mark): • the applied force must be resolved horizontally to determine the force that separates the engine from the trucks • and since the (size of) the resolved force is always less than the (size of) the actual force then a larger force (applied at an angle) is needed to separate the trucks from the engine	(2)