Test Review Motion 7

Q and A

Q1

A model truck A of mass 1.2 kg is travelling due west with a speed of 0.90 m s^{-1}. A second truck B of mass 4.0 kg is travelling due east towards A with a speed of 0.35 m s^{-1}.

Calculate the magnitude of the total momentum of the trucks.

Use of $p = m\upsilon$ **(1)**

Total momentum = 0.32 kg m s^{-1} or N s **(1)**

The trucks collide and stick together. Determine their velocity after the collision.

Use of conservation of momentum **(1)**

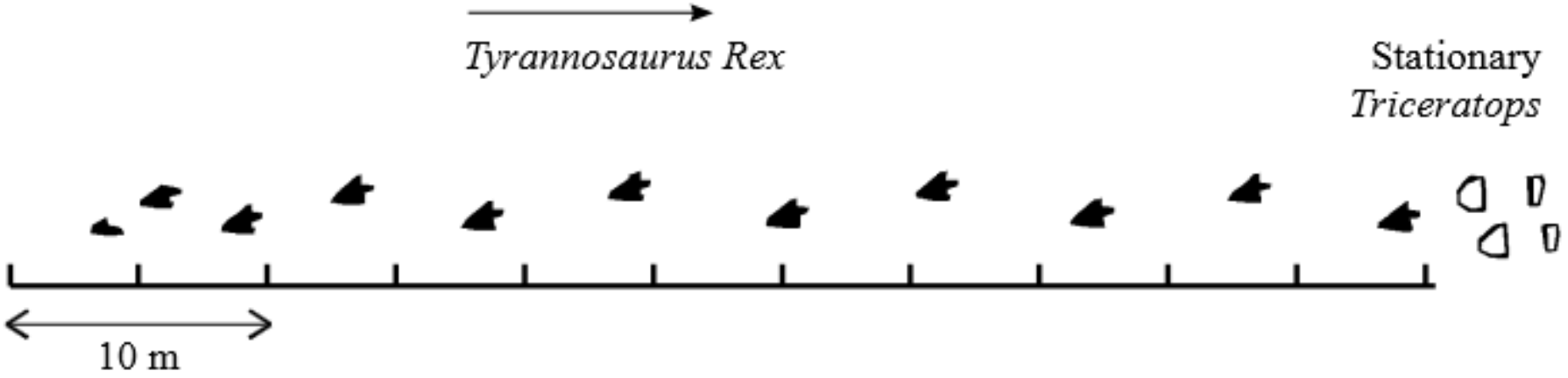
0.062 m s^{-1} [Allow e.c.f. from wrong first answer] **(1)**

East/in same direction as B moved originally **(1)**

Q2

Palaeontologists are able to deduce much about the behaviour of dinosaurs from the study of fossilised footprints.

The tracks below show the path of a *Tyrannosaurus Rex* as it attacks a stationary *Triceratops*.



The time between footprints is 0.62 s. Show that the maximum speed of the *Tyrannosaurus Rex* is about 10 m s^{-1}.

$$30 \text{ m} \div (5 \times 0.62 \text{ s})$$
$$= 9.7 \text{ m s}^{-1}$$

Q2 continued

Tyrannosaurus Rex is believed to have attacked its prey by charging and locking its jaws on the prey. *Tyrannosaurus Rex* would be at its maximum speed when it hit the stationary prey.

This *Tyrannosaurus Rex* has a mass of 7000 kg. Calculate its momentum just before it hits the *Triceratops*.

$$(7000\ \text{kg} \times 9.7\ \text{m s}^{-1})$$
$$= 68\ 000\ (\text{kg m s}^{-1})$$

Triceratops has a mass of 5000 kg. Calculate their combined speed immediately after the collision.

Momentum before = momentum after

$$(7000\ \text{kg} \times 9.7\ \text{m s}^{-1}) + 0 = (7000\ \text{kg} + 5000\ \text{kg}) \times \upsilon$$
$$\upsilon = (7000\ \text{kg} \times 9.7\ \text{m s}^{-1}) \div (12\ 000\ \text{kg})$$

$$= 5.7\ \text{m s}^{-1}$$

Q2 continued

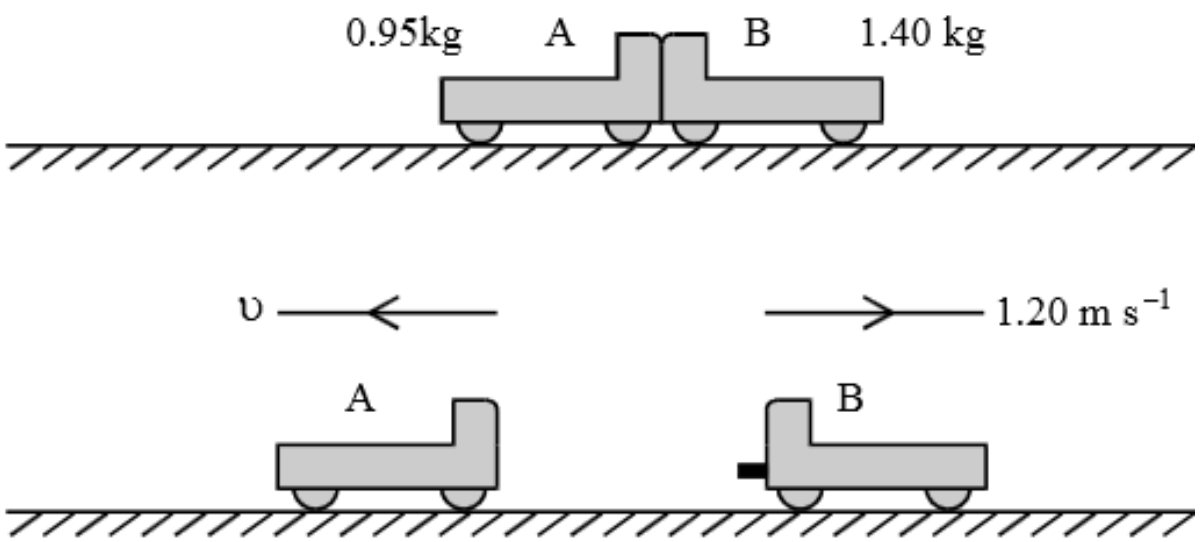
The skull of *Tyrannosaurus Rex* is heavily reinforced to withstand the force produced in such a collision.

Calculate the force exerted on the *Tyrannosaurus Rex* if the time taken to reach their combined speed after the collision is 0.30 s.

Force = change in momentum ÷ time
= 7000 kg × [9.7 m s^{-1} –5.7 m s^{-1}] ÷ 0.30 s
= 93 000 N [98 000 N if 10 m s^{-1} used]

Q3

The diagram shows an experiment with two trolleys.



State the total momentum of the trolleys as they move apart, and explain your answer.

Zero **(1)**

It was zero initially **or** momentum is conserved

Q3 continued

The masses of A and B are 0.95 kg and 1.40 kg respectively. B moves off at 1.20 m s^{-1}. Calculate the speed v of A.

Use of momentum = mass × velocity **(1)**
Use of mass × speed (A) = mass × speed (B) **(1)**

$1.8\ m\ s^{-1}$

Q4

A constant resultant horizontal force of 1.8×10^3 N acts on a car of mass 900 kg, initially at rest on a level road.

(i) the acceleration of the car,

(a)(i) (use of $F = ma$ gives) $1.8 \times 10^3 = 900\ a$ ✓

$a = 2.0\ \text{m s}^{-2}$ ✓

(ii) the speed of the car after 8.0 s,

(use of $v = u + at$ gives) $v = 2.0 \times 8.0 = 16\ \text{m s}^{-1}$ ✓

(iii) the momentum of the car after 8.0 s,

(use of $p = mv$ gives) $p = 900 \times 16$ ✓

$= 14 \times 10^3\ \text{kg m s}^{-1}$ (or N s) ✓

Q4 continued

(iv) the distance travelled by the car in the first 8.0 s of its motion,

(use of $s = ut + \frac{1}{2}at^2$ gives) $s = \frac{1}{2} \times 2.0 \times 8^2$ ✓

$= 64$ m ✓

(v) the work done by the resultant horizontal force during the first 8.0 s.

(use of $W = Fs$ gives) $W = 1.8 \times 10^3 \times 64$ ✓

$= 1.2 \times 10^5$ J ✓

[or $E_k = \frac{1}{2}mv^2 = \frac{1}{2} \times 900 \times 16^2$ ✓

$= 1.2 \times 10^5$ J ✓

Q5

A golf club undergoes an *inelastic* collision with a golf ball and gives it an initial velocity of $60\,\text{m s}^{-1}$. The ball is in contact with the club for 15 ms and the mass of the ball is $4.5 \times 10^{-2}\,\text{kg}$.

(a) Explain what is meant by an inelastic collision.

kinetic energy not conserved ✓
[or velocity of approach is equal to velocity of separation]

(b) Calculate

(i) the change in momentum of the ball,

(use of $p = mv$ gives) $p = 4.5 \times 10^{-2} \times 60$ ✓

$= 2.7\,\text{kg m s}^{-1}$ ✓

Q5 continued

(ii) the average force the club exerts on the ball.

(use of $F = \dfrac{\Delta(mv)}{\Delta t}$ gives) $F = \dfrac{2.7}{15 \times 10^{-3}}$ ✓

$= 180\,\text{N}$ ✓

[or $a = \dfrac{v-u}{t} = \dfrac{60}{15 \times 10^{-3}} = 4000\,(\text{m s}^{-1})$

$F = (ma) = 4.5 \times 10^{-2} \times 4000 = 180\,\text{N}$]

Q5 continued

(c) (i) State the value of the force exerted by the ball on the club and give its direction.

180 N ✓

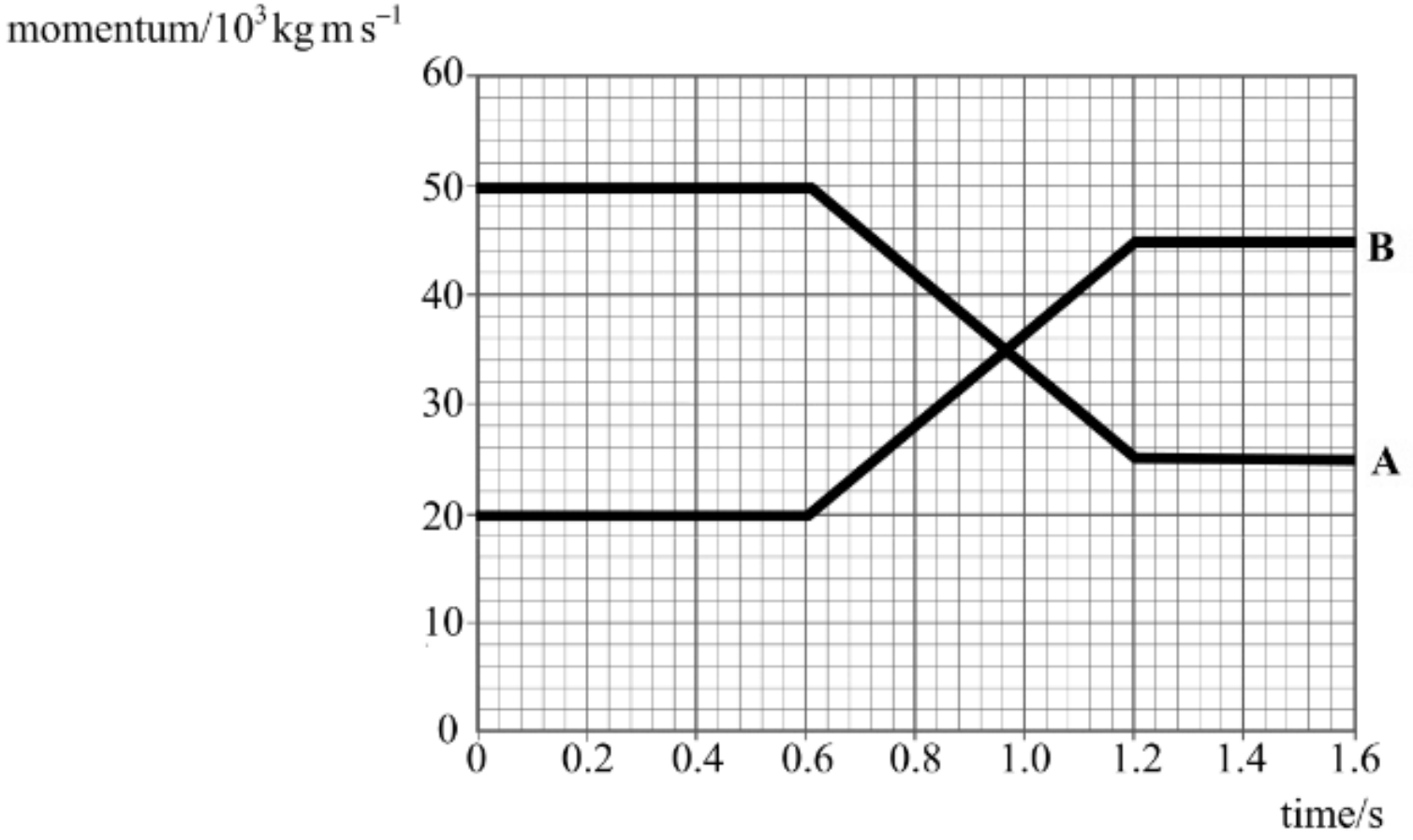
in opposite direction (to motion of the club) ✓

(ii) Explain how your answer to part (i) follows from an appropriate law of motion.

body A (or club) exerts a force on body B (or ball) ✓
(hence) body B (or ball) exerts an equal force on body A (or club) ✓
correct statement of Newton's third law ✓

Q6

The graph shows how the momentum of two colliding railway trucks varies with time. Truck **A** has a mass of 2.0×10^4 kg and truck **B** has a mass of 3.0×10^4 kg. The trucks are travelling in the same direction.



Q6 continued

(a) Calculate the change in momentum of

(i) truck **A**,

(change in momentum of A) = − ✓ 25×10^3 ✓ kg m s^{-1} (or N s) ✓

(ii) truck **B**.

(change in momentum of B) = 25×10^3 kg m s^{-1} ✓

Q6 continued

(b) Complete the following table.

	initial velocity/m s^{-1}	final velocity/m s^{-1}	initial kinetic energy/J	final kinetic energy/J
truck **A**				
truck **B**				

	initial vel/m s^{-1}	final vel/m s^{-1}	initial k.e./J	final k.e./J
truck A	2.5	1.25	62500	15600
truck B	0.67	1.5	6730	33750
	✓	✓	✓	✓

Q6 continued

(c) State and explain whether the collision of the two trucks is an example of an elastic collision.

not elastic ✓
because kinetic energy not conserved ✓
kinetic energy is greater before the collision (or less after) ✓
[or justified by correct calculation]

Q7

(a) State **two** quantities that are conserved in an elastic collision.

momentum ✓
kinetic energy ✓

(b) A gas molecule makes an elastic collision with the walls of a gas cylinder. The molecule is travelling at 450 $m\,s^{-1}$ at right angles towards the wall before the collision.

(i) What is the magnitude and direction of its velocity after the collision?

450 $m\,s^{-1}$ ✓
in the opposite direction ✓

Q7 continued

(ii) Calculate the change in momentum of the molecule during the collision if it has a mass of 8.0×10^{-26} kg.

$$\Delta p = 8.0 \times 10^{-26} \times 900 \quad \checkmark$$
$$= 7.2 \times 10^{-23} \text{ N s} \quad \checkmark$$

Use Newton's laws of motion to explain how the molecules of a gas exert a force on the wall of a container.

force is exerted on molecule by wall ✓
to change its momentum ✓
molecule must exert an equal but opposite force on wall ✓
in accordance with Newton's second or third law ✓