Questions on Momentum

1. 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.

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Total momentum = ...

(2)

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

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Velocity = ...

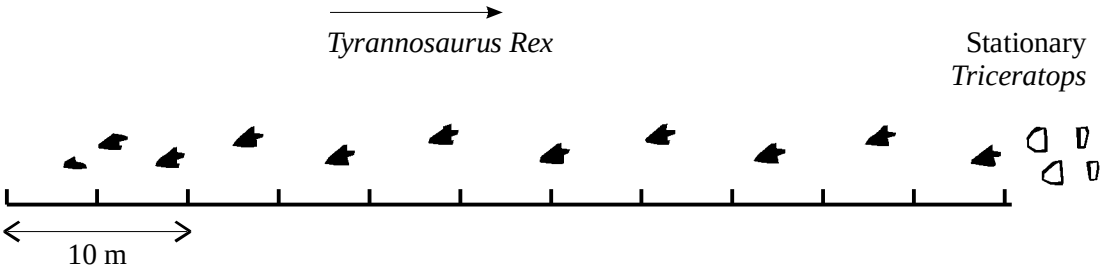
(3)

(Total 5 marks)

2.

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}.

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(2)

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*.

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Momentum =……

(2)

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

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Combined speed =……

(3)

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.

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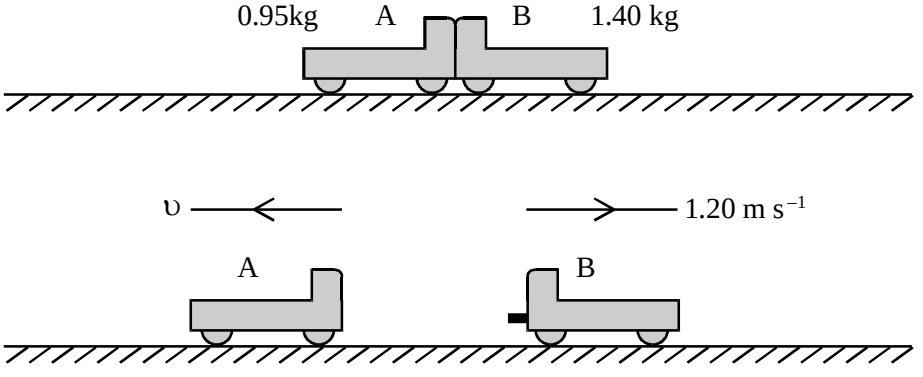
Force =……

(3)

(Total 10 marks)

3. The diagram shows an experiment with two trolleys.



Initially the trolleys are at rest, in contact, on a horizontal bench. A spring-loaded piston is then released in one trolley, pushing the trolleys apart.

Describe an experimental technique by which you could determine accurately the speeds of the trolleys after they separate.

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(3)

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

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(2)

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 υ of A.

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Speed .....

(3)
(Total 8 marks)

4. Define **momentum** and state its unit.

Definition: .....

Unit: .....

(2)

A stationary nucleus of thorium-226 decays by alpha particle emission into radium.
The equation for the decay is:

$$^{226}_{90}\text{Th} \rightarrow {}^{222}_{88}\text{Ra} + {}^{4}_{2}\text{He}$$

State the value of the momentum of the thorium nucleus before the decay .....

(1)

After the decay, both the alpha particle and the radium nucleus are moving.

Which has the greater speed? Justify your answer.

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What can be said about the directions of travel of the two particles?

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(3)
(Total 6 marks)

5. A car travelling at 30 m s^{-1} collides with a wall. The driver, wearing a seatbelt, is brought to rest in 0.070 s.

The driver has a mass of 50kg. Calculate the momentum of the driver before the crash.

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Momentum = ...

(2)

Calculate the average resultant force exerted on the driver during impact.

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Average resultant force = ...

(3)

Explain why the resultant force is not the same as the force exerted on the driver by the seatbelt.

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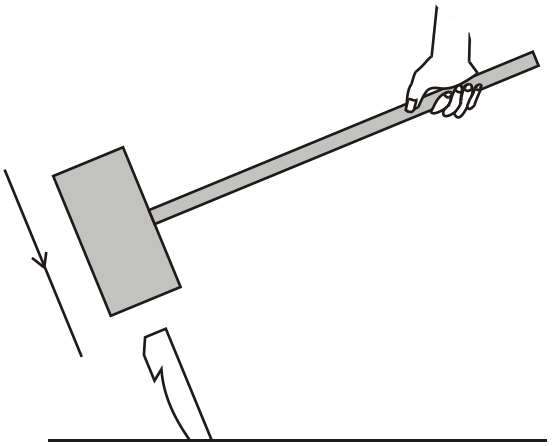
(1)
(Total 6 marks)

6. A wooden mallet is being used to hammer a tent peg into hard ground.



The head of the mallet is a cylinder of diameter 0.100 m and length 0.196 m. The density of the wood is 750 kg m^{-3}. Show that the mass of the head is approximately 1.2 kg.

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(3)

The head strikes the tent peg as shown at a speed of 4.20 m s^{-1} and rebounds at 0.58 m s^{-1}. Calculate the magnitude of its momentum change in the collision.

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Momentum change = ...

(3)

The head is in contact with the peg for 0.012 s. Estimate the average force exerted on the peg by the head during this period.

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Average force = ...

(2)

Give a reason why your value for the force will only be approximate.

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(1)

With reference to your calculations above, discuss whether a mallet with a rubber head of the same mass would be more or less effective for hammering in tent pegs.

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(2)
(Total 11 marks)

7. (a) State Newton's second law of motion in terms of momentum.

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(2)

(b) A wind blows steadily against a tree. The area of the tree perpendicular to the direction of the wind is 10 m^2 and the velocity of the wind is 20 m s^{-1}.

(i) Show that the mass of air hitting the tree each second is about 250 kg. (Density of air is 1.23 kg m^{-3}.)

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(2)

(ii) Calculate the momentum of this mass of air when it is moving at 20 m s^{-1}.

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Momentum = …….

(iii) Assuming that all the air is stopped by the tree, state the magnitude of the force exerted on the tree by the wind.

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Force = …….

(2)

(Total 6 marks)

8. Define linear momentum.

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(1)

The principle of conservation of linear momentum is a consequence of Newton's laws of motion. An examination candidate is asked to explain this, using a collision between two trolleys as an example. He gives the following answer, which is correct but incomplete. The lines of his answer are numbered on the left for reference.

1. During the collision the trolleys push each other.

2. These forces are of the same size but in opposite directions.

3. As a result, the momentum of one trolley must increase at the same rate as the momentum of the other decreases.

4. Therefore the total momentum of the two trolleys must remain constant.

In which line of his argument is the candidate using Newton's second law?

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(1)

In which line is he using Newton's third law?

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(1)

The student is making one important assumption which he has not stated. State this assumption. Explain at what point it comes into the argument.

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(2)

Describe how you could check experimentally that momentum is conserved in a collision between two trolleys.

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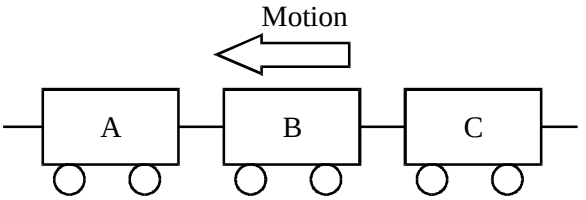
(4)
(Total 9 marks)

9. The diagram shows three trucks which are part of a train. The mass of each truck is 84 000 kg.



The train accelerates uniformly in the direction shown from rest to 16 m s^{-1} in a time of 4.0 minutes. Calculate the resultant force on each truck.

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Resultant force =.....

(3)

The force exerted by truck B on truck C is 11 200 N. Draw a free-body force diagram for truck B, showing the magnitudes of all the forces. Neglect any frictional forces on the trucks.

(4)

The total mass of the train is 3.0×10^6 kg. Calculate the average power delivered to the train during the accelerating process.

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Average power =.....

(3)

The locomotive is powered by an overhead cable at 25 kV. Neglecting any power dissipation, calculate the average current drawn from the supply during the accelerating period.

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Average current =.....

(2)

(Total 12 marks)