Paper Class – Forces and Motion 1

1.

This question is about **upthrust** and other forces acting on a sealed hollow tube in water.

One end of a string is attached to the bottom of the tube and the other end of the string is attached to the bottom of the container. The string exerts a downward force *F* on the tube.
At time *t* = 0, the tube is half submerged in the water, as shown in Fig. 23.1.

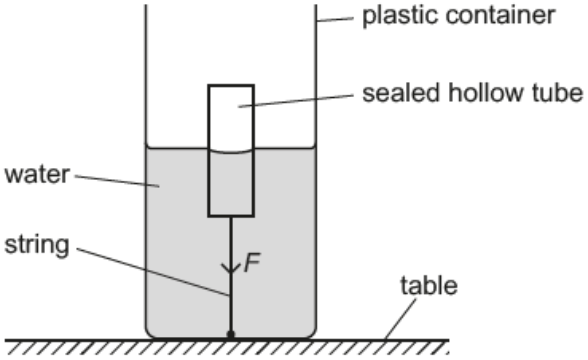


Fig. 23.1

The container is slowly filled with water at a constant rate until the container is full.
Fig. 23.2 shows the graph of *F* against time *t*.

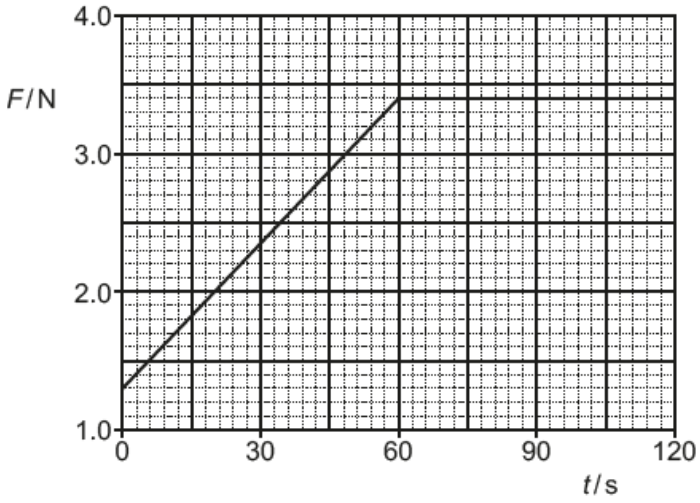


Fig. 23.2

(a) By considering the forces acting on the tube, explain the general shape of the graph shown in Fig. 23.2.

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..... **[3]**

(b) The container is now full of water.
The string is cut and the tube accelerates vertically upwards through the water.
The weight of the tube is 0.80 N and the upthrust on the tube is 4.2 N.

Calculate the **initial** upward acceleration *a* of the tube.

a = ... $m\,s^{-2}$ **[3]**

(c) State why the acceleration of the tube decreases as it travels vertically upwards through the water.

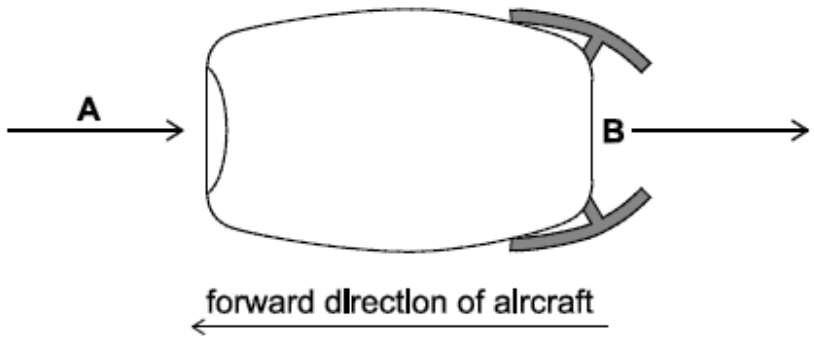
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..... **[1]**

2.

Figure 1 shows a jet engine.

Figure 1



Air enters the engine at **A** and is heated before leaving **B** at a much higher speed.

(a)

State what happens to the momentum of the air as it passes through the engine.

[1 mark]

(b)

Explain, using appropriate laws of motion, why the air exerts a force on the engine in the forward direction.

[3 marks]

(c)

In one second a mass of 210 kg of air enters at **A**. The speed of this mass of air increases by 570 m s^{-1} as it passes through the engine.

Calculate the force that the air exerts on the engine.

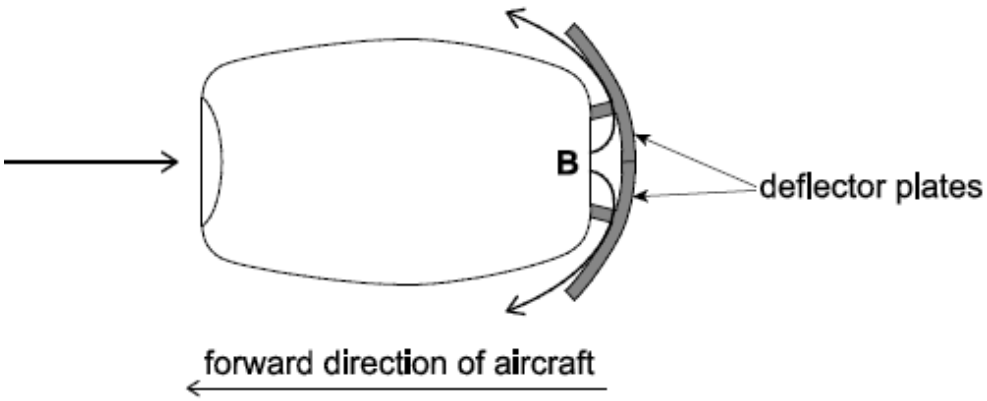
[1 mark]

force = _____ N

(d)

When an aircraft lands, its jet engines exert a decelerating force on the aircraft by making use of deflector plates. These cause the air leaving the engines to be deflected at an angle to the direction the aircraft is travelling as shown in **Figure 2**.

Figure 2



The speed of the air leaving **B** is the same as the speed of the deflected air.

Explain why the momentum of the air changes.

[2 marks]

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(e)

The total horizontal decelerating force exerted on the deflector plates of the jet engines is 190 kN.

Calculate the deceleration of the aircraft when it has a mass of 7.0×10^4 kg.

[1 mark]

deceleration = _____ m s^{-2}

(f)

The aircraft lands on the runway travelling at a speed of 68 m s^{-1} with the deflector plates acting.

Calculate the distance the aircraft travels along the runway until it comes to rest. You may assume that the decelerating force acting on the jet engines remains constant.

[2 marks]

distance = _____ m

(g)

Suggest why in practice the decelerating force provided by the deflector plates may not remain constant.

[2 marks]

3.

An electric wheelchair, powered by a battery, allows the user to move around independently.

One type of electric wheelchair has a mass of 55 kg. The maximum distance it can travel on level ground is 12 km when carrying a user of mass 65 kg and travelling at its maximum speed of 1.5 m s^{-1}.

The battery used has an emf of 12 V and can deliver 7.2×10^4 C as it discharges fully.

(a)

Show that the average power output of the battery during the journey is about 100 W.

[3 marks]

(b)

During the journey, forces due to friction and air resistance act on the wheelchair and its user.

Assume that all the energy available in the battery is used to move the wheelchair and its user during the journey.

Calculate the total mean resistive force that acts on the wheelchair and its user.

[2 marks]

total mean resistive force = _____ N

Figure 3 shows the wheelchair and its user travelling up a hill. The hill makes an angle of 4.5° to the horizontal.

Figure 3



(c)

Calculate the force that gravity exerts on the wheelchair and its user parallel to the slope.

[1 mark]

force parallel to the slope = _____ N

(d)

Calculate the maximum speed of the wheelchair and its user when travelling up this hill when the power output of the battery is 100 W.

Assume that the resistive forces due to friction and air resistance are the same as in question **03.2**.

[2 marks]

maximum speed = _____ $m\ s^{-1}$

(e)

Explain how and why the maximum range of the wheelchair on level ground is affected by

- the mass of the user
- the speed at which the wheelchair travels.

[4 marks]

Effect of mass _____

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Effect of speed _____

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4.

A student uses a motion sensor to investigate the motion of a trolley crashing into a soft barrier. Fig. 21 shows the displacement *s* against time *t* graph for the trolley in one experiment.

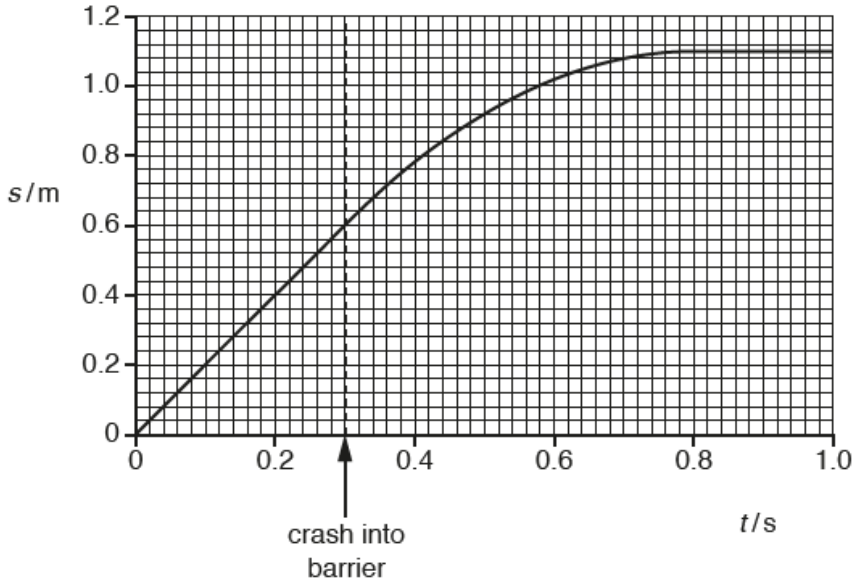


Fig. 21

The trolley has mass 900 g and an initial speed of 2.0 m s^{-1}. It crashes into the barrier at time $t = 0.3$ s.

(a) Calculate the initial kinetic energy of the trolley.

kinetic energy = ... J **[1]**

(b) Use Fig. 21 to describe and explain the variation of the velocity of the trolley from $t = 0$ to $t = 1.0\,s$.

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..... **[4]**

(c) The student assumes that the deceleration of the trolley is constant during the crash. Use Fig. 21 to determine the magnitude of the deceleration.

deceleration = ... $m\,s^{-2}$ **[2]**

5.

(a) A massive ball is released from rest above the ground.
According to a student, the principle of conservation of momentum is violated because the ball gains momentum as it falls.
Explain why the student's observation is incomplete and discuss how momentum is conserved in this situation.

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..... **[2]**

(b) Two balls **X** and **Y** are travelling in the same direction along a horizontal track.
Ball **X** makes a head-on collision with ball **Y**.
Fig. 23 shows the momentum against time *t* graph for ball **X** before, during and after the collision.

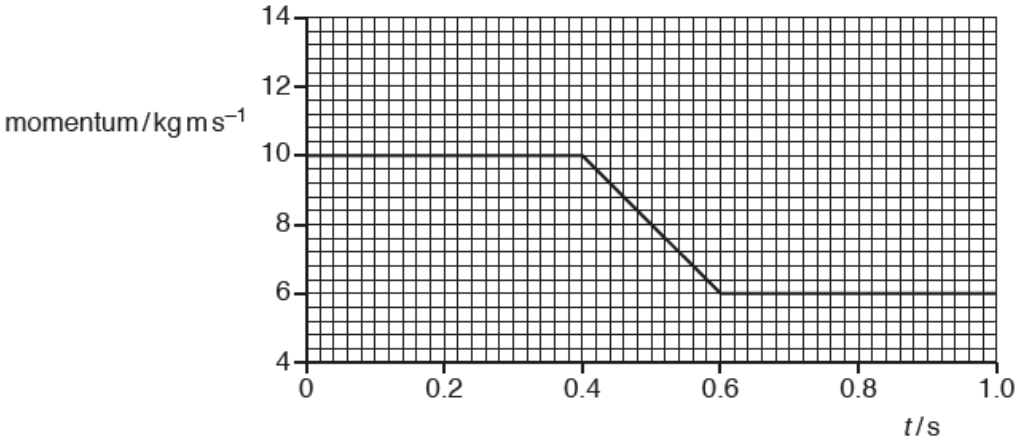


Fig. 23

(i) Use Fig. 23 to calculate the force *F* acting on ball **X** during the collision.

F = ... N **[2]**

(ii) The momentum of ball **Y** before the collision is 8.0 kg m s^{-1}.
On Fig. 23 sketch a graph to show the variation of the momentum of **Y** with time *t*. Label this graph **Y**. **[3]**

6.

A student drives a go-kart up a slope.

(a) The slope is at an angle of 5.7° to the horizontal. The go-kart moves with a constant velocity of $2.8\,m\,s^{-1}$.

Calculate the power of the go-kart.

mass of go-kart and driver = 60 kg
resistive force on the go-kart = 18 N

(4)

Power = ...

(b) The go-kart is powered by a battery connected to a motor. The rate of thermal energy transfer by the wiring in the motor is 55 W.

Calculate the resistance of the wiring in the motor.

current in motor = 24 A

(2)

Resistance of the wiring in the motor = ...

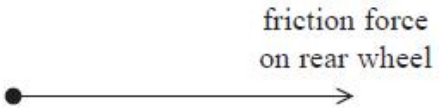
7.

The photograph shows a cyclist cycling at a constant velocity on horizontal ground.



(a) Complete the free-body force diagram to show the four forces acting on the bicycle. Treat the bicycle and cyclist as a single object. One force has been added for you.

(3)



(b) The cyclist stops pedalling and comes to rest in a time of 5.2 s.

(i) Sketch a graph to show how the cyclist's velocity changes during this time.

Assume the deceleration is constant.

(2)



(ii) The cyclist travels 7.80 m while coming to rest.

Calculate the average resistive force on the cyclist and bicycle.

mass of cyclist and bicycle = 28.0 kg

(4)

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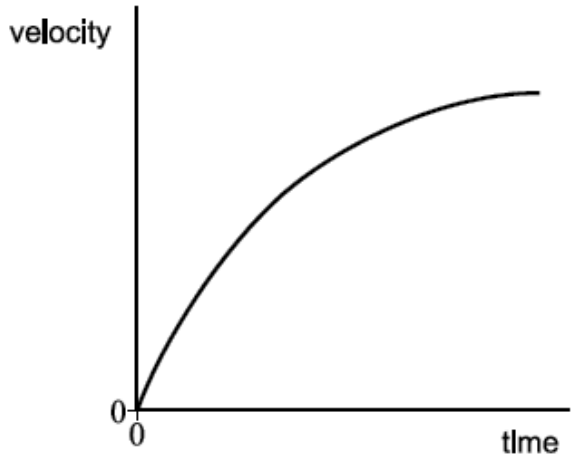
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Average resistive force = ...

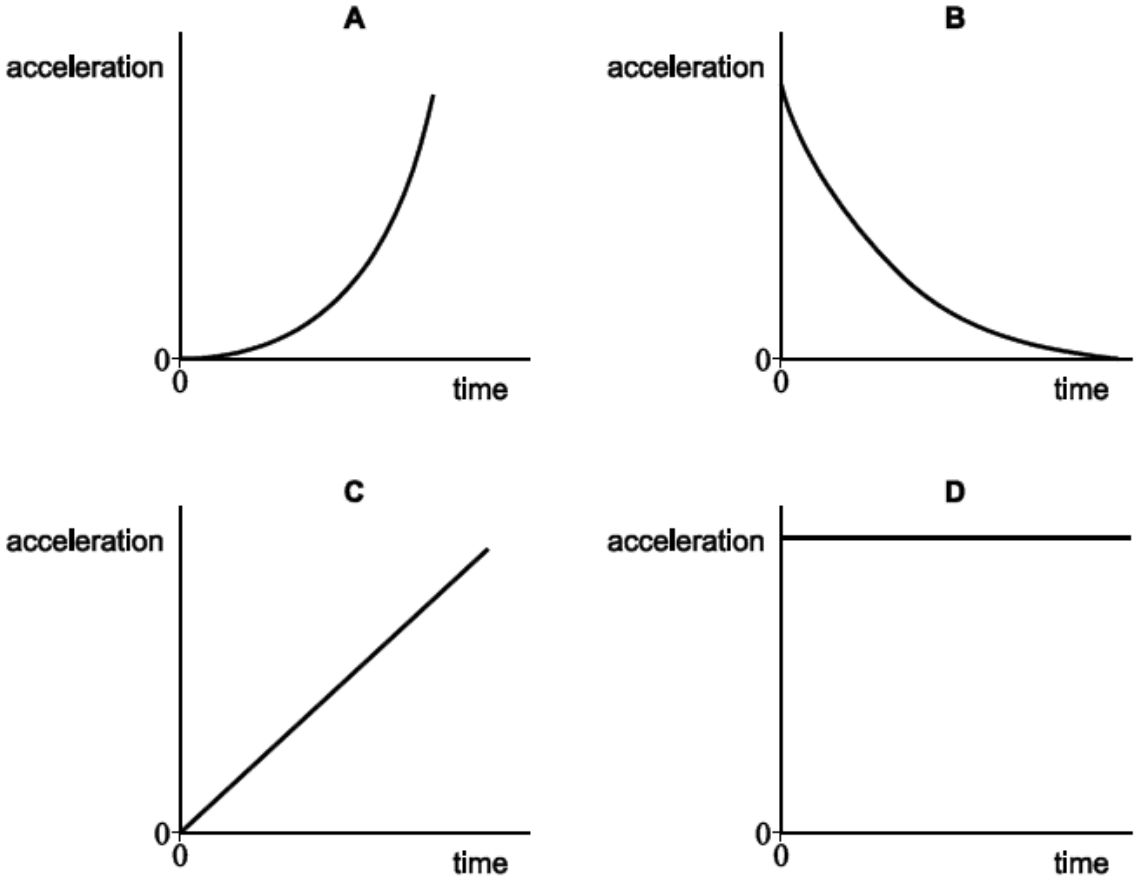
8.

The velocity–time graph for a falling object is shown.



Which of the following shows the corresponding acceleration–time graph?

[1 mark]



A ⬭

B ⬭

C ⬭

D ⬭

9.

A deep-space probe travelling forward at constant speed is briefly acted on by a force at right angles to its motion.

What is the effect of this force on the forward speed and sideways speed of this probe?

[1 mark]

A Its forward speed increases and sideways speed increases. ⬭

B Its forward speed decreases and sideways speed increases. ⬭

C Its forward speed is unchanged and sideways speed increases. ⬭

D Its forward speed decreases and sideways speed is unchanged. ⬭

10.

The mass of fuel in a racing car decreases during a race. As a result the lap time decreases.

Which of the following could explain this decrease?

[1 mark]

A	There is less friction on the race track.	○
B	The maximum speed of the car has increased.	○
C	The maximum acceleration and deceleration are greater.	○
D	The engine is more efficient.	○

11.

What is represented by the area under a force–displacement graph?

[1 mark]

A	rate of change of kinetic energy	○
B	change in momentum	○
C	work done	○
D	acceleration	○
