1 **(a)** A solar-powered ion propulsion engine creates and accelerates xenon ions. The ions are ejected at a constant rate from the rear of a spacecraft, as shown in Fig. 2.1.
The ions have a fixed mean speed of $3.2 \times 10^4\,\mathrm{m\,s^{-1}}$ relative to the spacecraft.
The initial mass of the spacecraft is $5.2 \times 10^3\,\mathrm{kg}$.

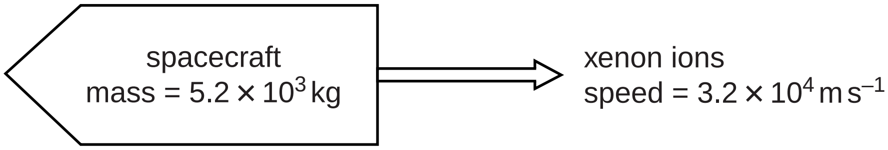

Fig. 2.1

(i) Calculate the mass of one xenon ion.
molar mass of xenon = $0.131\,\mathrm{kg\,mol^{-1}}$

mass .... kg **[1]**

(ii) The engine is designed to eject 9.5×10^{18} xenon ions per second.
Determine the initial acceleration of the spacecraft.

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

(iii) State in words the law that you have used to solve **a(ii)**.

In your answer, you should use appropriate technical terms spelled correctly.

....

....

.... **[1]**

(iv) State and explain how you would expect the acceleration of the spacecraft to change, if at all, while the engine is running.

....

....

....

....

.... **[3]**

(b) A small rocket is used to detach a satellite of mass 180 kg from the spacecraft. Fig. 2.2 shows the variation of the force *F* created by the rocket on the satellite with time *t*.

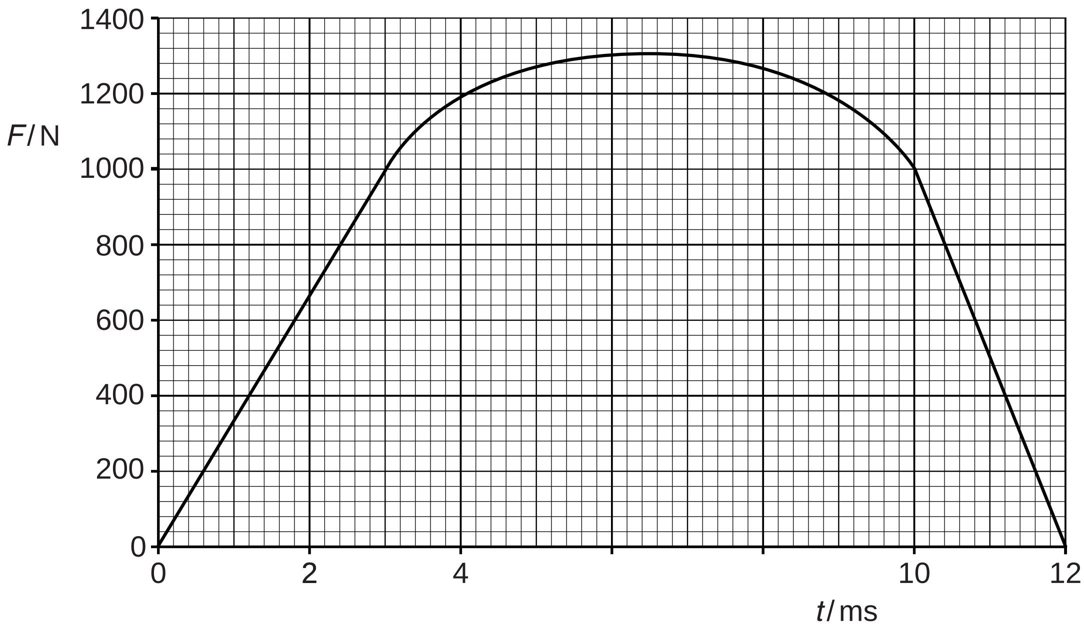

Fig. 2.2

Use Fig. 2.2 to

(i) determine the change in the velocity of the satellite as a result of the force *F* applied for the period of 12 ms.

change in velocity = ... $m\,s^{-1}$ **[4]**

(ii) describe how the acceleration of the satellite varies between 0 and 10 ms.

....

....

....

....

.... **[2]**

2 **(a** Collisions between two objects can be described as being either *elastic* or *inelastic*. Complete the table shown in Fig. 1.1 by placing a tick (✓) in the relevant column(s) for each statement which is true for that type of collision.

Statement	Elastic collision	Inelastic collision
Total momentum for the objects is conserved.		
Total kinetic energy of the objects is conserved.		
Total energy is conserved.		
Magnitude of the impulse on each object is the same.		

[2]

Fig. 1.1

(b) A snooker ball is at rest on a smooth horizontal table. It is hit by a snooker cue. Fig. 1.2 shows a simplified graph of force *F* acting on the ball against time *t*.

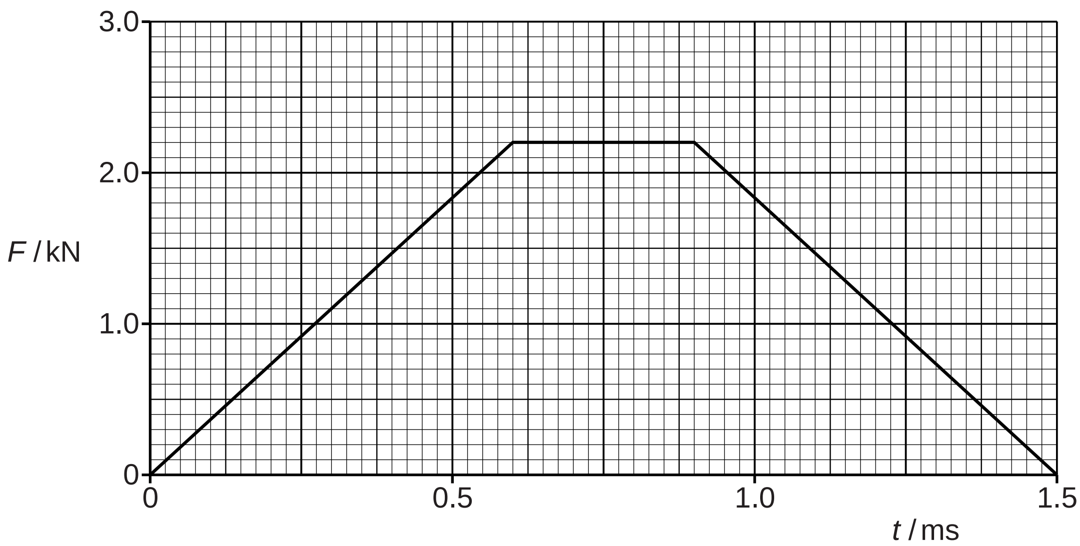

Fig. 1.2

(i) Describe how the velocity of the ball varies between t = 0.6 ms and t = 0.9 ms.

....

....

....

.... **[1]**

(ii) Use Fig. 1.2 to calculate the impulse acting on the ball.

impulse = ... N s **[2]**

(iii) The mass of the snooker ball is 140 g. Calculate the final speed of the snooker ball as it leaves the cue.

speed = ... m s^{-1} **[1]**

[Total: 6]

3 **(a)** **(i)** State in words Newton's second law of motion.

....

....

.... **[1]**

(ii) Show how this law leads to the expression $F = ma$ for an object of constant mass.

[2]

(b) The graph in Fig. 1.1 shows the variation with time of a force acting on an object of mass 2.5 kg.
The force is acting in the direction of the object's motion.

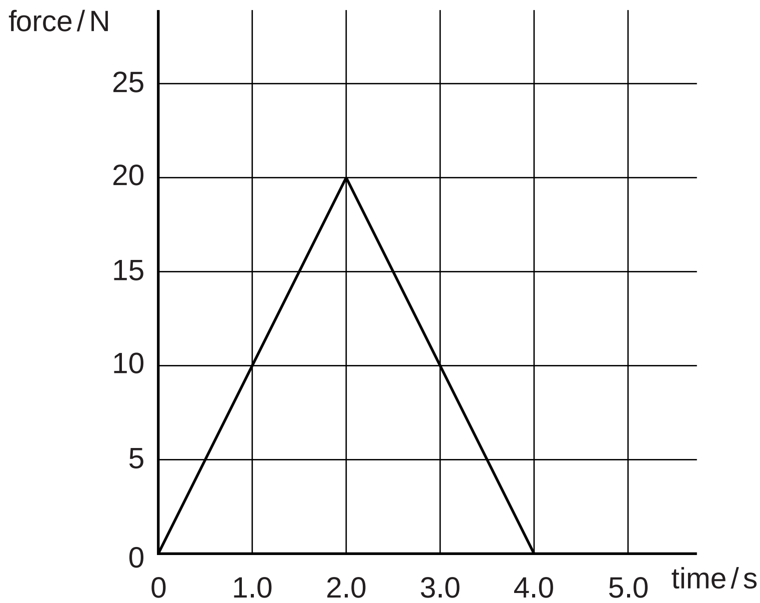

Fig. 1.1

Use Fig. 1.1 to

(i) determine the change in velocity of the object

change in velocity = ... $m\,s^{-1}$ **[3]**

(ii) calculate the mean acceleration of the object

mean acceleration = ... $m\,s^{-2}$ **[1]**

(iii) describe how the acceleration of the object varies between 0 and 4.0 seconds.

....

....

....

.... **[2]**

[Total: 9]

4 **(a)** State the effect a net force has on the motion of an object.

....

....

.... **[1]**

(b) **(i)** Define the *impulse of a force*.

....

.... **[1]**

(ii) A force F is applied to an object. The graph in Fig. 1.1 shows the variation of this force with time t.

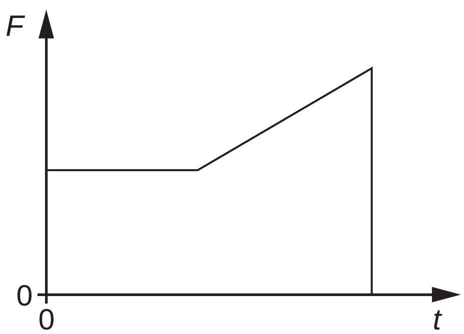

Fig. 1.1

The initial velocity of the object is zero and its mass is known. Explain how this graph can be used to determine the final velocity of the object.

....

....

....

.... **[2]**

(c) A tennis ball is hit by a racket as shown in Fig. 1.2.

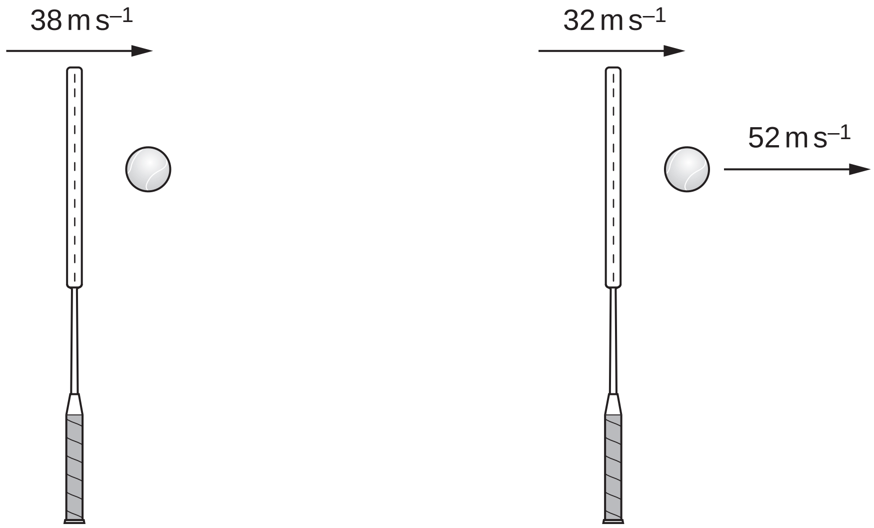

Fig. 1.2a **Fig. 1.2b**

Fig. 1.2

The mass of a tennis ball is 0.058 kg. During a serve the racket head and the ball are in contact for 4.2 ms. Just before contact, the racket head is travelling towards the ball at 38 m s^{-1} and the ball is stationary. Fig.1.2a shows the situation just before contact. Immediately after contact, the racket head is travelling in the same direction at 32 m s^{-1} and the ball is travelling away from the racket at 52 m s^{-1}. This is shown in Fig. 1.2b.

(i) Calculate the mean force provided by the racket on the ball.

mean force = ………………N **[2]**

(ii) Estimate the mass of the racket.

mass = ……………….. kg **[2]**

(iii) Suggest why the value of the mass calculated in **(ii)** will be different from the actual mass of the racket.

....

.... **[1]**

[Total: 9]

5 **(a)** State, in words, Newton's second law of motion.

In your answer you should use appropriate technical terms spelled correctly.

....

....

.... **[2]**

(b) Fig. 1.1 shows the masses and velocities of two objects **A** and **B** moving directly towards each other. **A** and **B** stick together on impact and move with a common velocity *v*.

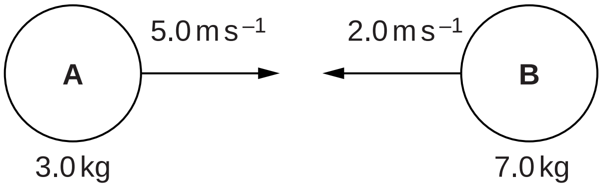

Fig. 1.1

(i) Determine the velocity *v*.

magnitude of velocity = ... $m\,s^{-1}$

direction = ...

[3]

(ii) Determine the impulse of the force experienced by the object **A** and state its direction.

impulse = ... N s

direction = ...

[2]

(iii) Explain, using Newton's third law of motion, the relationship between the impulse experienced by **A** and the impulse experienced by **B** during the impact.

....

....

....

....

....

.... **[2]**

[Total: 9]