1)

(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*.

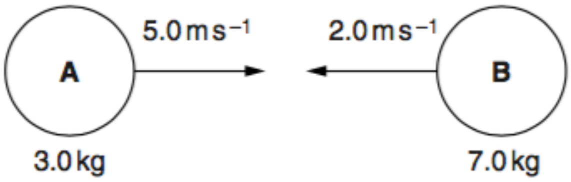

Fig. 1.1

(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]

2)

(a) Apollo-11 was the first manned spacecraft to land on the Moon. Fig. 1.1 shows part of the equipment left on the surface by the astronauts and the forces acting upon it.

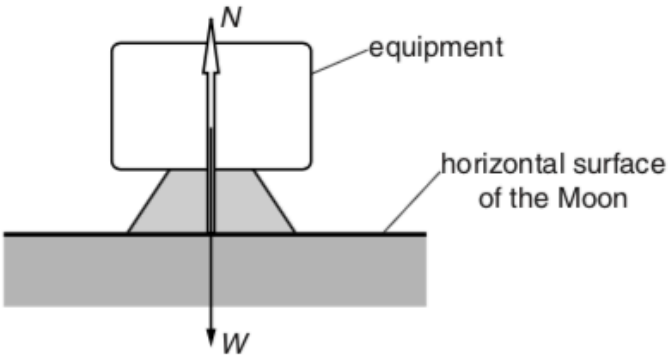

Fig. 1.1

According to Newton's third law interacting forces always occur in pairs. A student states that the normal contact force *N* is equal in magnitude to the weight *W* because of Newton's third law.

(i) Give **two** reasons why the student's statement is incorrect.

....

....

....

....

....

.... **[2]**

(ii) Use Newton's third law to state the magnitude and location of the force pairing up with the weight *W*.

....

.... **[1]**

(b) While on the surface of the Moon one of the astronauts hit a golf ball with a club and declared that it went for 'miles and miles'. The ball was given an initial velocity u at a fixed angle θ to the horizontal. Show that the horizontal distance travelled by the ball is directly proportional to u^2.

[3]

(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 $5.2 \times 10^3\,\mathrm{kg}$.

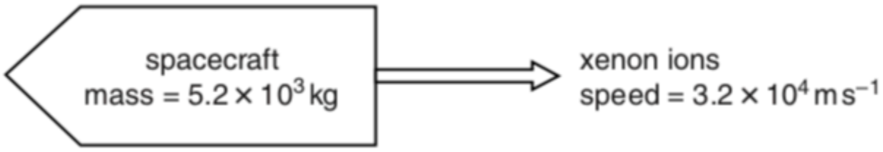

Fig. 2.1

(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]**

3)

(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*.

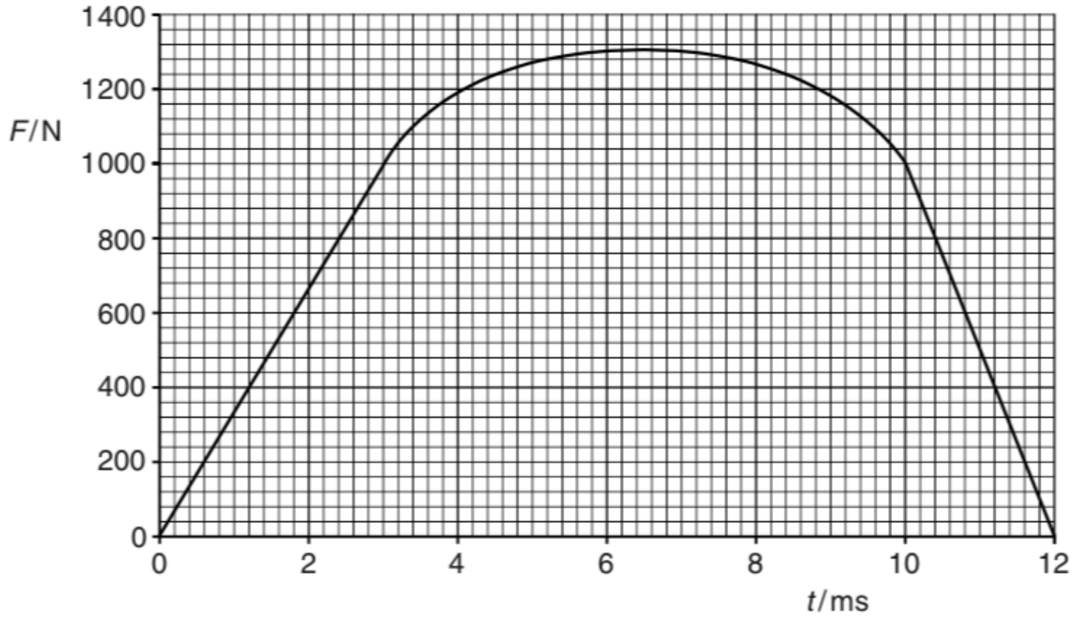

Fig. 2.2

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]**

4)

A ball is held above level ground. It is then dropped from rest at time $t = 0$.
Fig. 1.1 shows the velocity v against time t graph for this ball bouncing vertically.
Ignore the effect of air resistance.

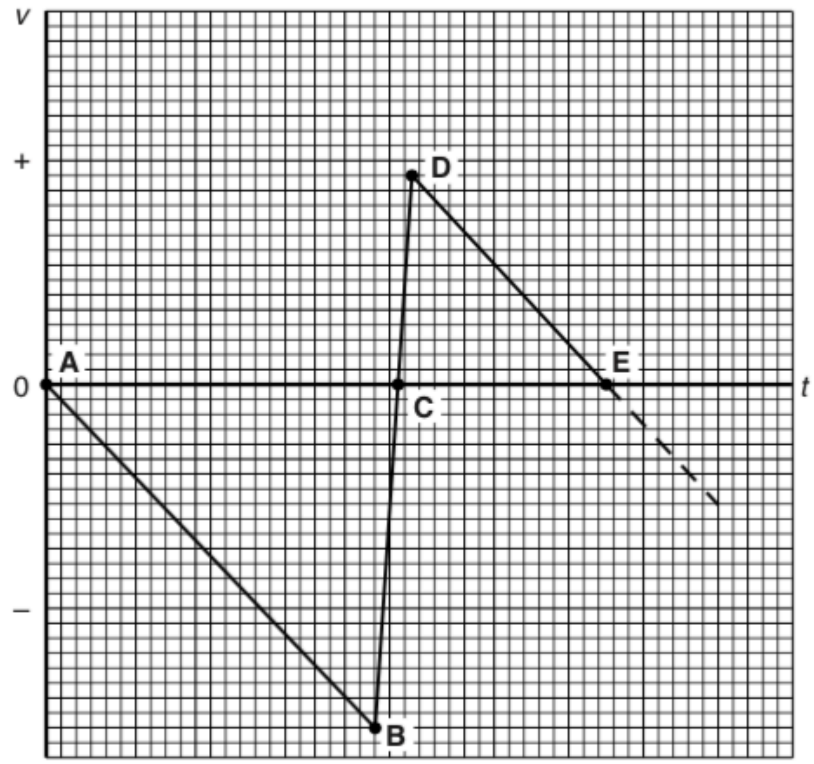

Fig. 1.1

(a) **(i)** Explain why the gradient of the line **DE** is the same as the gradient of the line **AB**.

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

....

.... **[1]**

(ii) Explain why the area of triangle **ABC** is not the same as the area of triangle **CDE**.

....

....

....

.... **[2]**

(b) The ball, of mass 0.13 kg, was dropped from an initial height of 1.7 m. It remained in contact with the ground for 75 ms while experiencing a mean upward force of 16 N.

Calculate

(i) the speed of the ball immediately before impact with the ground

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

(ii) the speed of the ball immediately at **D**

speed = ... $m s^{-1}$ **[2]**

(iii) the maximum height reached after the first bounce.

height = ... m **[1]**

5)

(a) State Newton's first law of motion.

....

....

.... **[1]**

(b) Newton's third law suggests that forces always occur in pairs when two objects interact.

(i) State **two** ways in which the forces in such a pair are identical.

....

....

.... **[2]**

(ii) State **two** ways in which these forces are different.

....

....

.... **[2]**

(c) Fig. 2.1 shows a fireman using a hosepipe held at 55° to the horizontal. The cross-sectional area of the hosepipe nozzle is $3.3 \times 10^{-4}\,m^2$. Water is ejected from the nozzle at $25\,m\,s^{-1}$.

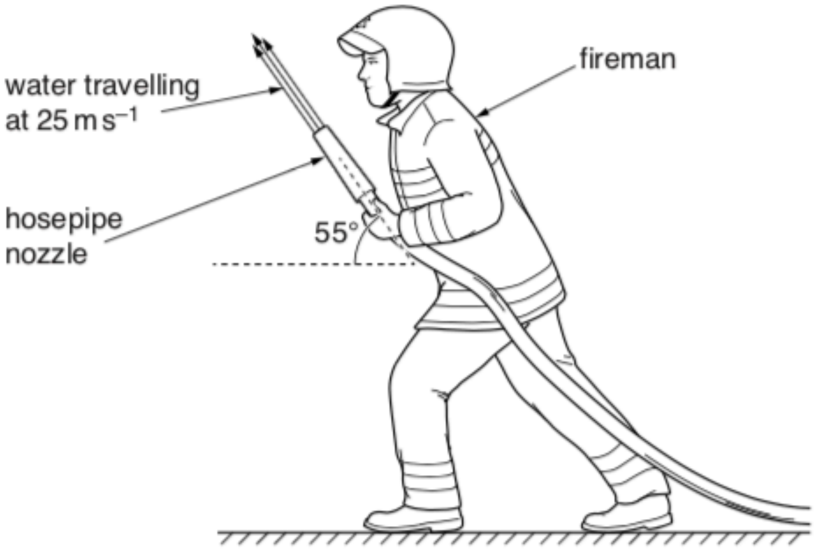

Fig. 2.1

(i) Show that the rate at which water is ejected from the nozzle is about $8.3\,kg\,s^{-1}$.

density of water = $1.0 \times 10^3\,kg\,m^{-3}$

[1]

(ii) The mass of the fireman is 92 kg. Determine the vertical component of the force exerted by the ground on the fireman's feet.

force = ... N **[3]**

6)

An alpha-particle is moving in a straight line directly towards a **stationary** strontium nucleus. The alpha-particle and the strontium nucleus are both positively charged particles. The alpha-particle has kinetic energy of 5.2 MeV when it is at a large distance away from the strontium nucleus. The mass of the alpha-particle is 6.6×10^{-27} kg.

(a) Show that the speed of the alpha-particle is about $2 \times 10^{7}\,\text{m}\,\text{s}^{-1}$.

[2]

(b) Use Newton's laws to describe and explain the motion of the **strontium** nucleus as the alpha-particle approaches the strontium nucleus.

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

[3]

(c) Fig. 1 shows the alpha-particle and the strontium nucleus at an instant in time. The alpha-particle is now **stationary** and the strontium nucleus is moving with a speed *V*.

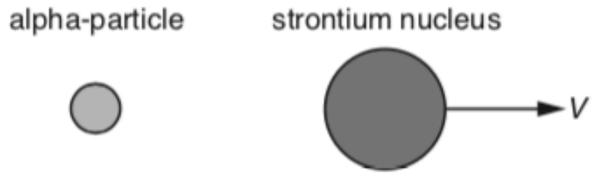

Fig. 1

The mass of the strontium nucleus is 1.3×10^{-25} kg.
Calculate the speed *V* of the strontium nucleus.

V = ... m s^{-1} **[2]**

(d) The alpha-particle 'bounces' back after its interaction with the strontium nucleus. The final speed of the alpha-particle is the same as its initial speed of approach. The average force experienced by the alpha-particle during the interaction is 4.8 N.
Estimate the time *t* of the interaction between the alpha-particle and the strontium nucleus.

t = ... s **[2]**