MOMENTUM

1 A rocket is stationary on the launchpad. At time t = 0, the rocket engines are switched on and exhaust gases are ejected from the nozzles of the engines. The rocket accelerates upwards.

Fig. 1.1 shows how the acceleration of the rocket varies between time t = 0 and time $t = t_f$.

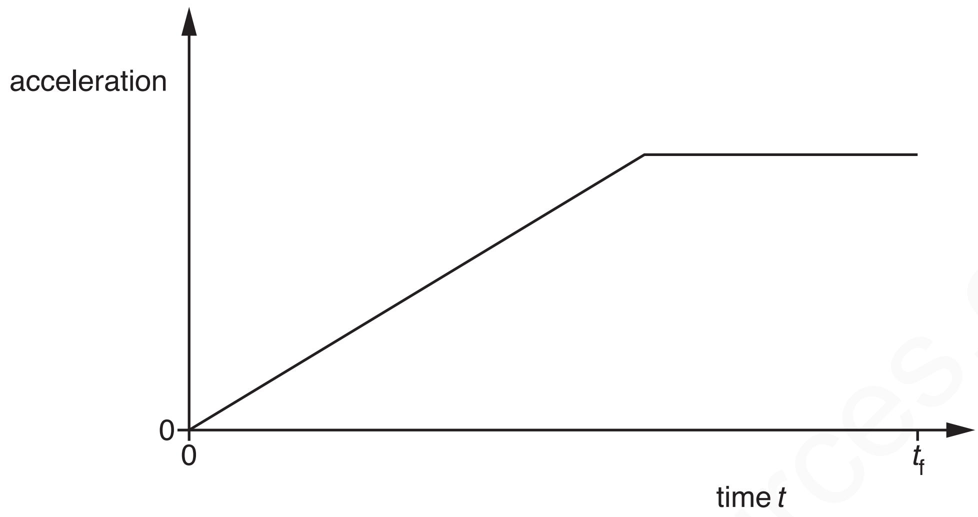

Fig. 1.1

(a) Define *acceleration*.

....

.... [1]

(b) On Fig. 1.2, sketch a graph to show how the speed of the rocket varies between time t = 0 and time $t = t_f$.

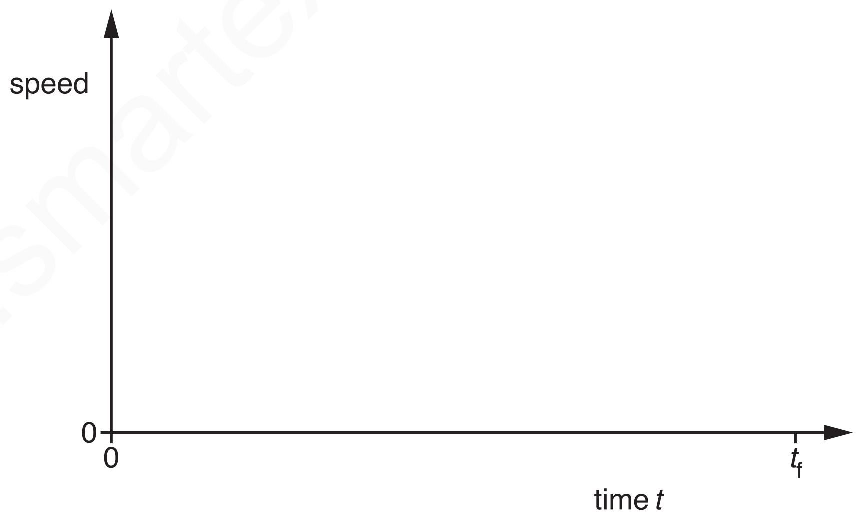

Fig. 1.2

[3]

(c) Some time later, the rocket is far from the Earth. The effect of the Earth's gravity on the motion of the rocket is insignificant. As the rocket accelerates, its momentum increases.

(i) State the principle of the conservation of momentum.

....

....

.... [2]

(ii) Explain how the principle of the conservation of momentum applies to the accelerating rocket and the exhaust gases.

....

....

....

.... [2]

[Total: 8]

MARKING SCHEME:

(a)	change of velocity per unit time **OR** $\frac{v-u}{t}$	**B1**
(b)	line starts at origin **and** is asymptotic to *x*-axis	**B1**
	increasing gradient initially **and** no decrease	**B1**
	constant **and** clearly positive gradient finally	**B1**
(c)(i)	no external forces **OR** isolated system	**B1**
	sum of momenta / (total) momentum remains constant	**B1**
(c)(ii)	rocket gains (upward) momentum	**B1**
	(ejected) gas gains equal (quantity of) momentum in opposite direction **OR** momentum of gas decreases by equal amount	**B1**

2 Fig. 2.1 shows a model fire engine. Its brakes are applied.

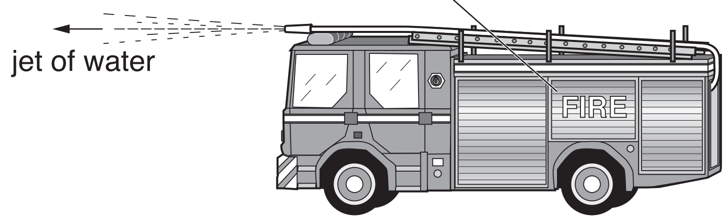

Fig. 2.1

0.80 kg of water is emitted in the jet every 6.0 s at a velocity of 0.72 m / s relative to the model.

(a) Calculate the change in momentum of the water that is ejected in 6.0 s.

momentum = ... [2]

(b) Calculate the magnitude of the force acting on the model because of the jet of water.

force = ... [2]

(c) The brakes of the model are released.

State and explain the direction of the acceleration of the model.

Statement ....

Explanation ....

....
[2]

(d) In **(c)** the model contains a water tank, which is initially full.

State and explain any change in the magnitude of the initial acceleration if the brakes are first released when the tank is nearly empty.

Statement ....

Explanation ....

....

....
[3]

[Total: 9]

MARKING SCHEME:

(a)	(Δ) p=mv in any form OR ((Δ)p=) mv OR 0.8 × 0.72	**C1**
	(Δp=) 0.58 kg m/s	**A1**
(b)	Ft= Δp in any form OR (F=) Δp/t OR 0.58/6	**B1**
	(F=) 0.096 N accept rounding if 0.096 seen	**B1**

(c)	Statement: (acceleration is) to right/backward	**B1**
	Explanation: force (from water OR on model) to right /backwards OR acceleration in same direction as force (from water OR on model)	**B1**
(d)	(acceleration) more (when empty)	**B1**
	mass less (and force is constant)	**B1**
	meaningful reference to F=ma / Newton's 2nd law / change in momentum	**B1**

3 **(a)** State what is meant by *the principle of conservation of energy*.

....

....[1]

(b) Fig. 3.1 shows a girl throwing a heavy ball.

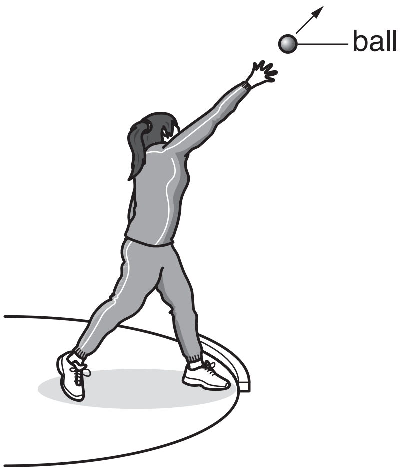

Fig. 3.1

(i) State the energy changes that take place from when the girl begins to exert a force on the ball until the ball hits the ground and stops moving.

....

....

....

....

....[2]

(ii) The mass of the ball is 4.0 kg. The girl exerts a force on the ball for 0.60 s. The speed of the ball increases from 0 m / s to 12 m / s before it leaves the girl's hand.

Calculate:

1. the momentum of the ball on leaving the girl's hand

momentum = ...[2]

2. the average resultant force exerted on the ball.

average resultant force = ...[2]

[Total: 7]

(a)	Energy cannot be created or destroyed OR energy can only be transferred from one form to another OR total energy remains constant	**B1**
(b)(i)	Chemical (energy) to kinetic (energy) AND / OR potential (energy)	**B1**
	Any **one** of: Kinetic (energy) to potential (energy) OR gravitational (energy) Potential (energy) OR gravitational (energy) to kinetic (energy) Kinetic (energy) to thermal (energy) OR heat (energy)	**B1**
(b)(ii)1	(momentum =) mv OR 4.0×12	**C1**
	48 kg m/s or N s	**A1**
(b)(ii)2	(average force =) momentum change / time OR $m(v - u) / t$ OR $(mv - mu) / t$ OR $F = ma$ AND $a = (v - u) / t$ OR 48 / 0.60	**C1**
	80 N	**A1**

4 **(a)** The velocity of an object of mass m increases from u to v.

State, in terms of m, u and v, the change of momentum of the object.

....[1]

(b) In a game of tennis, a player hits a stationary ball with his racquet.

(i) The racquet is in contact with the ball for 6.0 ms. The average force on the ball during this time is 400 N.

Calculate the impulse on the tennis ball.

impulse = ...[2]

(ii) The mass of the ball is 0.056 kg.

Calculate the speed with which the ball leaves the racquet.

speed = ...[2]

(iii) State the energy transfer that takes place:

1. as the ball changes shape during the contact between the racquet and the ball

....

....

2. as the ball leaves the racquet.

....

....
[2]

[Total: 7]

MARKING SCHEME:

.(a)	*mv* – *mu* or *mu* – *mv* in any form	**B1**
(b)(i)	(impulse =) *Ft* in any form	**C1**
	(impulse =) 2.4 N s	**A1**
`(b)(ii)	*Ft* = *mv* – *mu* in any form OR *(v – u =) Ft / m*	**C1**
	43 m / s	**A1**
(b)(iii)	1 kinetic energy (of racquet) to elastic / strain energy (in ball or strings)	**B1**
	2. elastic / strain energy (in ball or strings) to kinetic energy (of ball)	**B1**

5 **(a)** Complete Fig. 2.1 by writing in the right-hand column the name of the quantity given by the product in the left-hand column.

product	quantity
mass × acceleration	
force × time	

[2]

Fig. 2.1

(b) Fig. 2.2 shows a man hitting a ball with a golf club.

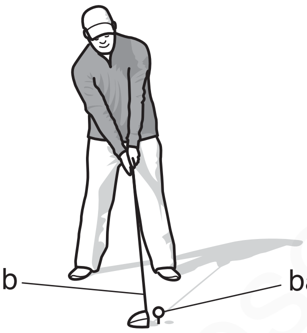

Fig. 2.2

The ball has a mass of 0.046 kg. The golf club is in contact with the ball for 5.0×10^{-4} s and the ball leaves the golf club at a speed of 65 m/s.

(i) Calculate:

1. the momentum of the ball as it leaves the golf club

momentum = ...[2]

2. the average resultant force acting on the ball while it is in contact with the golf club.

average force = ...[2]

(ii) While the golf club is in contact with the ball, the ball becomes compressed and changes shape.

State the type of energy stored in the ball during its contact with the golf club.

....[1]

[Total: 7]

MARKING SCHEME:

(a)	1st box: force	**B1**
	2nd box: impulse	**B1**
(b)(i)	**1** $(p =)\ mv$ **or** 0.046×65	**C1**
	3.0 kg m/s **or** 3.0 N s	**A1**
	2 $(F =)\ m(v - u) / t$ **or** $3.0 / 0.00050$ **or** $a = (v - u) / t$ **and** $F = ma$ **or** $0.046 \times 65 / 0.00050$ **or** $0.046 \times 130\,000$	**C1**
	6000 N **or** 6000 N	**A1**
(b)(ii)	elastic (energy) **or** strain (energy)	**B1**