Momentum AS Revision Pack

Name: ____________________

Class: ____________________

Date: ____________________

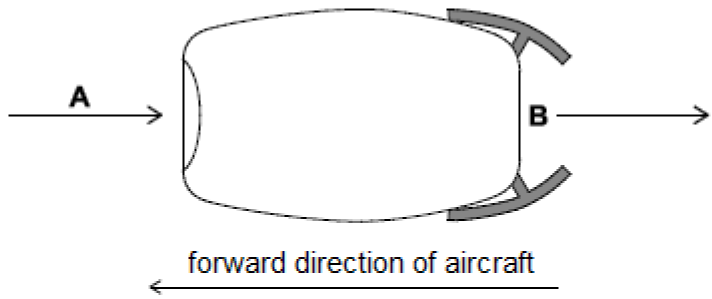
Time: **188 minutes**

Marks: **158 marks**

Comments:

1 **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)

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

____

____

____

____

____

____

____

____

(3)

(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.

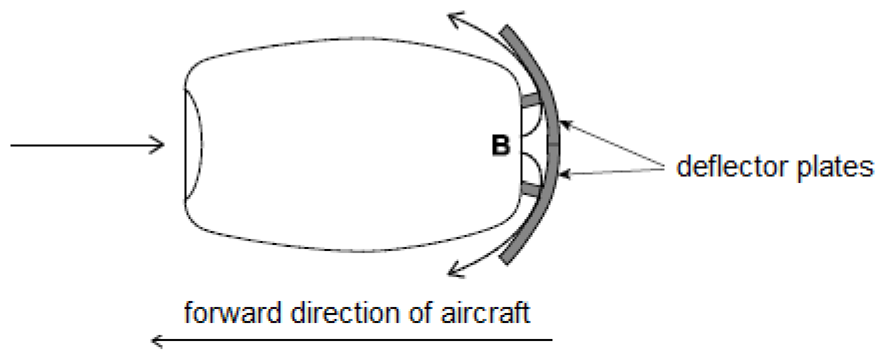
Calculate the force that the air exerts on the engine.

force = ____________________ N

(1)

(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)

(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.

deceleration = ____________________ $m\ s^{-2}$

(1)

(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.

distance = ____________________ m

(2)

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

____

____

____

____

____

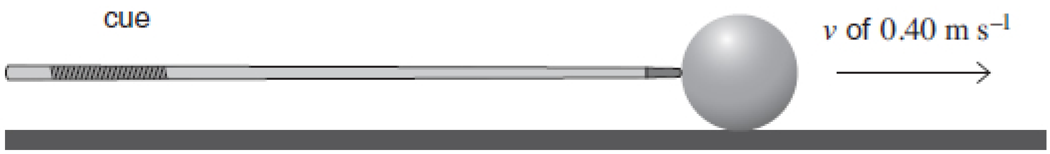
____

____

(2)

(Total 12 marks)

2 The diagram shows a cue striking a stationary snooker ball of mass 140 g. The contact time of the cue with the ball is 12 ms. The ball leaves the cue with a velocity v of 0.40 m s^{-1}



(a) Show that there is an impulse of about 6×10^{-2} N s when the cue is in contact with the snooker ball.

(2)

(b) Calculate the average force exerted by the cue on the snooker ball when they are in contact.

average force ____________________ N

(2)

(Total 4 marks)

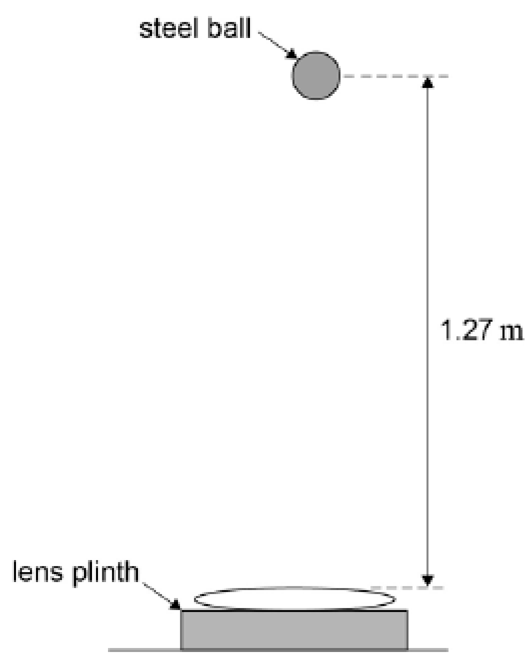
3 Spectacle lenses can be tested by dropping a small steel ball onto the lens, as shown in the figure below, and then checking the lens for damage.

A test requires the following specifications:

diameter of ball = 16 mm

mass of ball = 16 g

height of drop = 1.27 m



(a) Calculate the density of the steel used for the ball.

density = ____________________kg m^{-3}

(3)

(b) In a test the ball bounced back to a height of 0.85 m.

Calculate the speed of the ball just before impact.

speed = ____________________ $m\ s^{-1}$

(2)

(c) Calculate the speed of the ball just after impact.

speed = m ____________________ $m\ s^{-1}$

(2)

(d) Calculate the change in momentum of the ball due to the impact.

momentum = m ____________________ $kg\ m\ s^{-1}$

(2)

(e) The time of contact was 40 ms. Calculate the average force of the ball on the lens during the impact.

average force = ____________________ N

(2)

(f) Explain, with reference to momentum, why the test should also specify the material of the plinth the lens sits on.

____

____

____

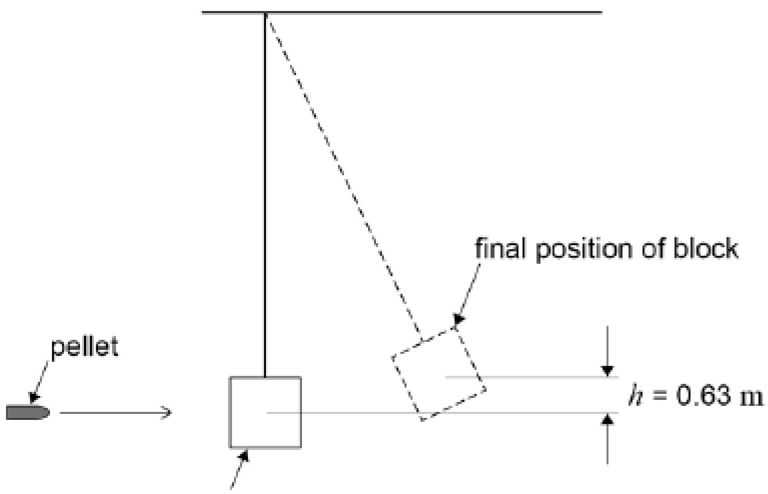
____

(2)

(Total 13 marks)

4 The speed of an air rifle pellet is measured by firing it into a wooden block suspended from a rigid support.

The wooden block can swing freely at the end of a light inextensible string as shown in the figure below.



A pellet of mass 8.80 g strikes a stationary wooden block and is completely embedded in it. The centre of mass of the block rises by 0.63 m. The wooden block has a mass of 450 g.

(a) Determine the speed of the pellet when it strikes the wooden block.

speed = ____________________ m s^{-1}

(4)

(b) The wooden block is replaced by a steel block of the same mass.
The experiment is repeated with the steel block and an identical pellet. The pellet rebounds after striking the block.

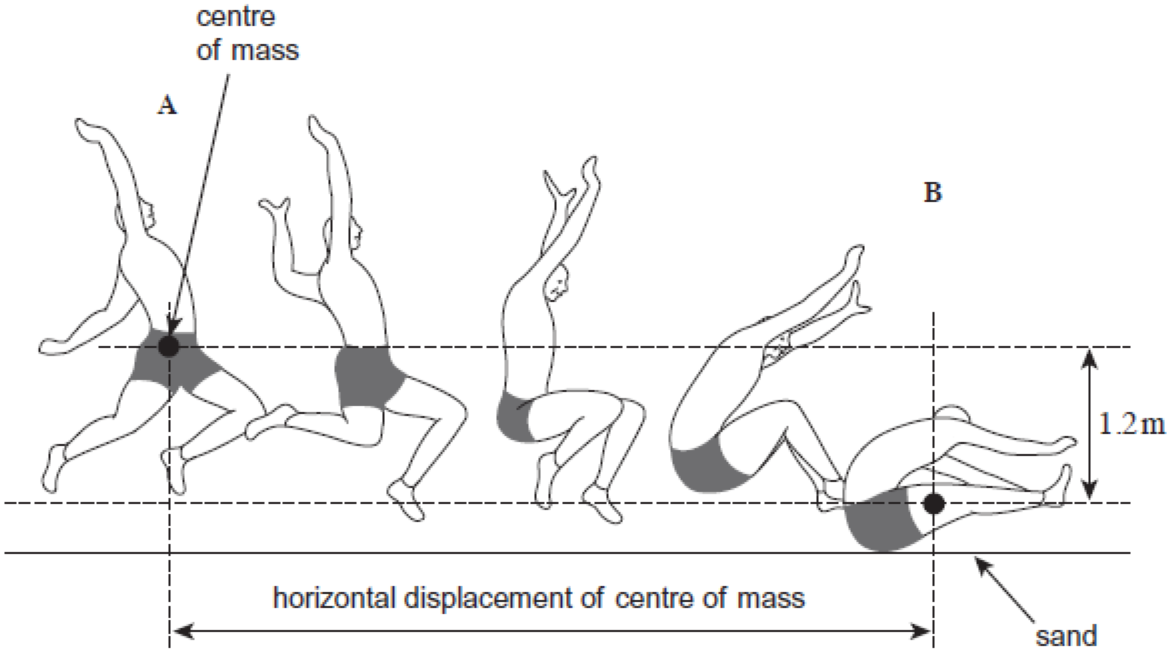
Discuss how the height the steel block reaches compares with the height of 0.63 m reached by the wooden block. In your answer compare the energy and momentum changes that occur in the two experiments.

(4)

(c) Discuss which experiment is likely to give the more accurate value for the velocity of the pellet.

(2)
(Total 10 marks)

5 The motion of a long jumper during a jump is similar to that of a projectile moving under gravity. The figure below shows the path of an athlete above the ground during a long jump from half-way through the jump at position **A**, to position **B** at which contact is made with sand on the ground. The athlete is travelling horizontally at **A**.



(a) During this part of the jump, the centre of mass of the athlete falls 1.2 m.

(i) Calculate the time between positions **A** and **B**.

time ____________________ s

(3)

(ii) The athlete is moving horizontally at **A** with a velocity of 8.5 m s^{-1}. Assume there is noair resistance. Calculate the horizontal displacement of the centre of mass from **A** to **B**.

horizontal displacement ____________________ m

(2)

(b) (i) The athlete in the image above slides horizontally through the sand a distance of 0.35 m before stopping.

Calculate the time taken for the athlete to stop. Assume the horizontal component of the resistive force from the sand is constant.

time ____________________ s

(2)

(ii) The athlete has a mass of 75 kg. Calculate the horizontal component of the resistive force from the sand.

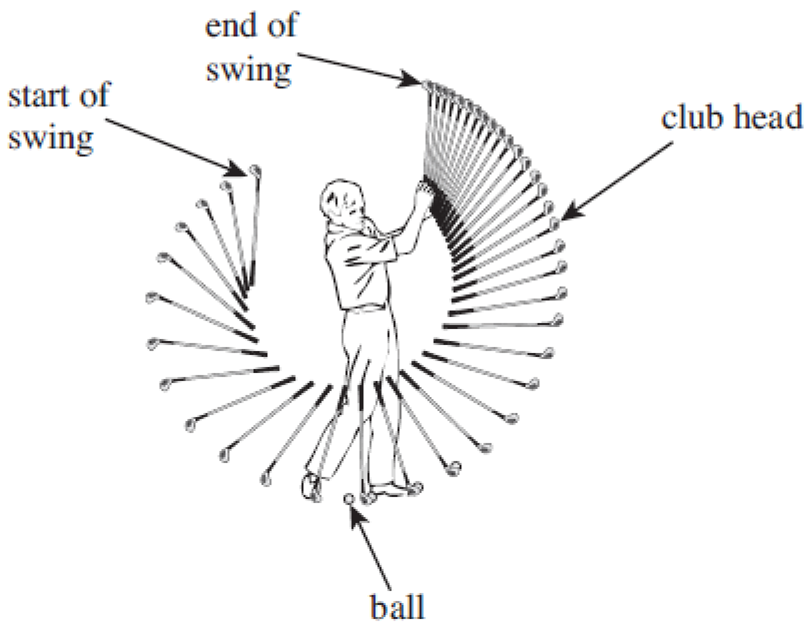
horizontal component of resistive force ____________________ N

(3)

(Total 10 marks)

6 When hitting golf balls long distances, golfers *follow through* with the swing. Doing this increases the time for which the club head is in contact with the ball.

The figure below is a stroboscopic photograph of a golf swing. The images were taken at equal time intervals.



(a) Sketch, on the axes below, how the speed of the club head varies with time over the whole swing.

(2)

(b) Explain in terms of the impulse acting on the ball the advantage to the golfer of following through with the swing.

___

___

___

___

(2)

(c) The club head is in contact with the ball for a time of 180 μs. The mass of the club head is 0.17 kg and that of the ball is 0.045 kg. At the moment of contact the ball is at rest and the club head is moving with a speed of 35 ms^{-1}. The ball moves off with an initial speed of 58 ms^{-1}.

(i) Calculate the average force acting on the ball while the club head is in contact with it.

average force on ball ____________________ N

(2)

(ii) Deduce the average force acting on the club head due to its collision with the ball.

average force on club head ____________________ N

(1)

(iii) Explain why it is not possible to transfer all the kinetic energy of the club head to the ball.

____

____

____

____

____

____

(2)

(Total 9 marks)

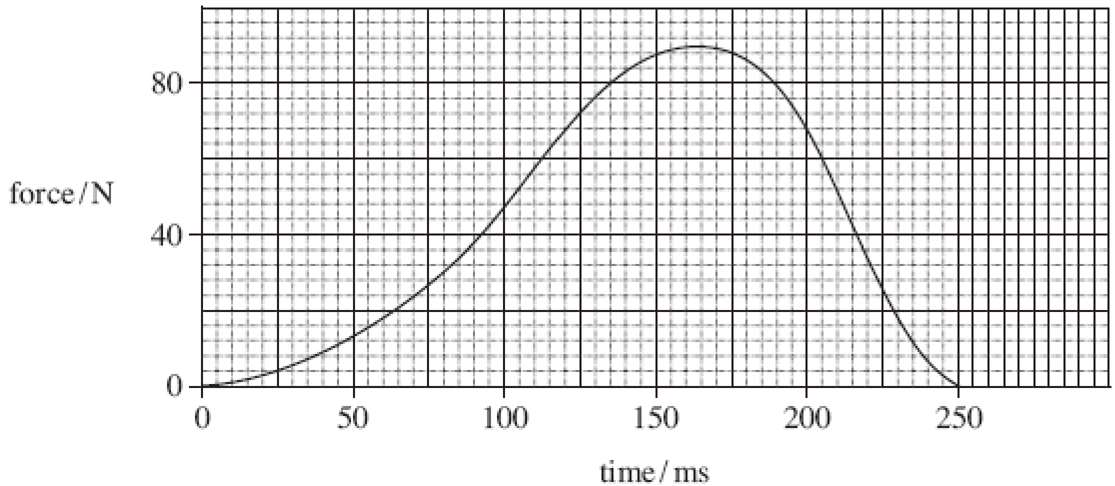
7 (a) State, in words, how the force acting on a body is related to the change in momentum of the body.

____

____

(1)

(b) A football of mass 0.42 kg is moving horizontally at 10 m s^{-1} towards a footballer's boot, which then kicks it. The figure below shows how the force between the boot and the ball varies with time while they are in contact.



(i) What is the significance of the area enclosed by the line on a force–time graph and the time axis when a force acts on a body for a short time?

____

(1)

(ii) Estimate the impulse that acts on the ball, stating an appropriate unit.

answer = ______________________

(4)

(iii) Calculate the speed of the ball after it has been kicked, assuming that it returns along the same horizontal line it followed when approaching the boot. Express your answer to an appropriate number of significant figures.

answer = ______________________m s^{-1}

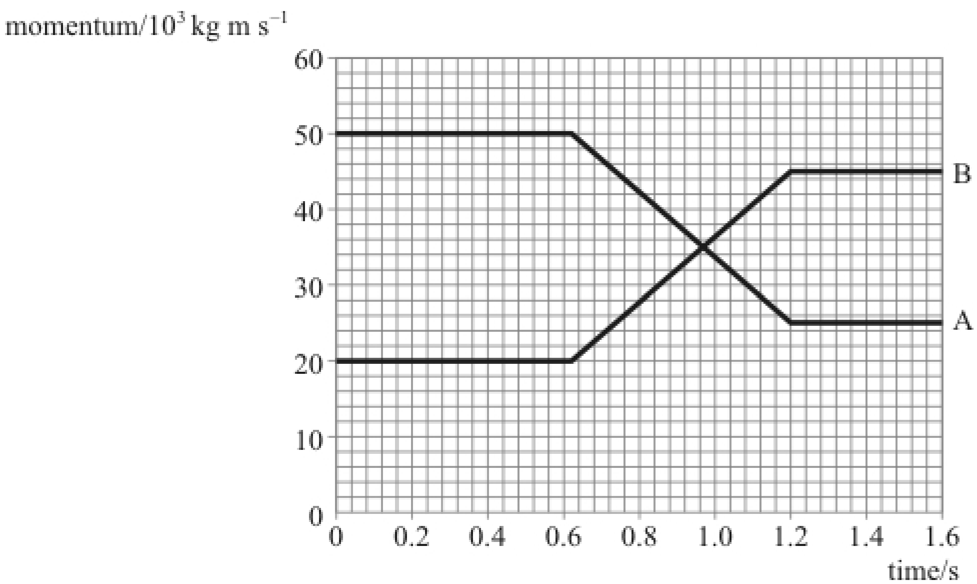
(4)

(c) Discuss the consequences if the ball had approached the boot at a higher speed but still received the same impulse.

(3)

(Total 13 marks)

8 The graph shows how the momentum of two colliding railway trucks varies with time. Truck **A** has a mass of 2.0×10^4 kg and truck **B** has a mass of 3.0×10^4 kg. The trucks are travelling in the same direction.



(a) Calculate the change in momentum of

(i) truck **A**,

(ii) truck **B.**

(4)

(b) Complete the following table.

	Initial velocity/m s^{-1}	Final velocity/m s^{-1}	Initial kinetic energy/J	Final kinetic energy/J
truck **A**				
truck **B**				

(4)

(c) State and explain whether the collision of the two trucks is an example of an elastic collision.

____

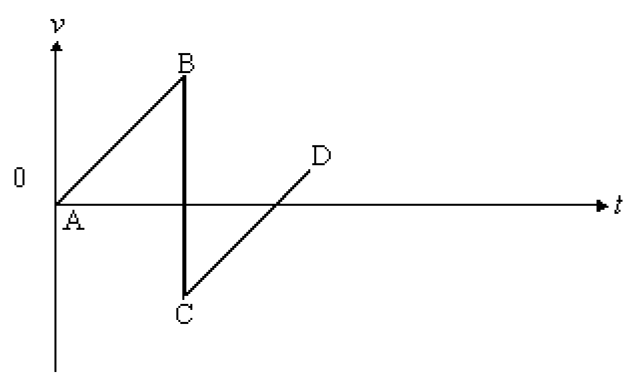
____

____

____

(3)
(Total 11 marks)

9 The diagram shows the velocity-time graph for a vertically bouncing ball, which is released above the ground at A and strikes the floor at B. The effects of air resistance have been neglected.



(a) (i) What does the gradient of a velocity-time graph represent?

____

(ii) Explain why the gradient of the line CD is the same as line AB.

____

____

(iii) What does the area between the line AB and the time axis represent?

____

(iv) State why the velocity at C is negative.

(v) State why the speed at C is less than the speed at B.

(5)

(b) The ball has a mass of 0.15 kg and is dropped from an initial height of 1.2 m. After impact the ball rebounds to a height of 0.75 m.

Calculate

(i) the speed of the ball immediately before impact,

(ii) the speed of the ball immediately after impact,

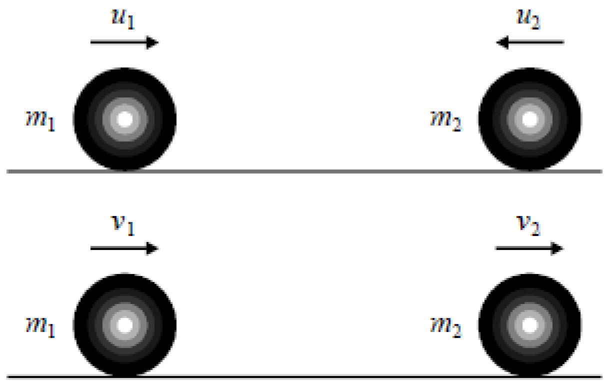
(iii) the change in momentum of the ball as a result of the impact,

(iv) the magnitude of the resultant average force acting on the ball during impact if it is in contact with the floor for 0.10 s.

(8)

(Total 13 marks)

10 (a) (i) Give an equation showing how the principle of conservation of momentum applies to the colliding snooker balls shown in the diagram.



____

(ii) State the condition under which the principle of conservation of momentum applies.

____

____

(3)

(b) A trolley, A, of mass 0.25 kg and a second trolley, B, of mass 0.50 kg are held in contact on a smooth horizontal surface. A compressed spring inside one of the trolleys is released and they then move apart. The speed of A is 2.2 m s^{-1}.

(i) Calculate the speed of B.

____

____

____

(ii) Calculate a minimum value for the energy stored in the spring when compressed.

____

____

____

(4)

(c) The rotor blades of a helicopter sweep out a cross-sectional area, A. The motion of the blades helps the helicopter to hover by giving a downward velocity, v, to a cylinder of air, density ρ. The cylinder of air has the same cross-sectional area as that swept out by the rotor blades.

Explaining your reasoning,

(i) derive an expression for the mass of air flowing downwards per second, and

(ii) derive an expression for the momentum given per second to this air.

(iii) Hence show that the motion of the air results in an upward force, F, on the helicopter given by

$$F = \rho A v^2.$$

(5)

(d) A loaded helicopter has a mass of 2500 kg. The area swept out by its rotor blades is 180 m^2. If the downward flow of air supports 50% of the weight of the helicopter, what speed must be given to the air by the motion of the rotor blades when the helicopter is hovering? Take the density of air to be 1.3 kg m^{-3}.

(3)

(Total 15 marks)

11 (a) Explain what is meant by the *principle of conservation of momentum*.

(2)

(b) A hose pipe is used to water a garden. The supply delivers water at a rate of 0.31 kg s^{-1} to the nozzle which has a cross-sectional area of 7.3×10^{-5} m^2.

(i) Show that water leaves the nozzle at a speed of about 4 m s^{-1}.
density of water = 1000 kg m^{-3}

(2)

(ii) Before it leaves the hose, the water has a speed of 0.68 m s^{-1}. Calculate the force on the hose.

(3)

(iii) The water from the hose is sprayed onto a brick wall the base of which is firmly embedded in the ground. Explain why there is no overall effect on the rotation of the Earth.

___

___

___

___

(2)
(Total 9 marks)

12 (a) Starting with the relationship between impulse and the change in momentum, show clearly that the unit, N, is equivalent to kg m s^{-2}.

(2)

(b) A rocket uses a liquid propellant in order to move.
Explain how the ejection of the waste gases in one direction makes the rocket move in the opposite direction.

____

____

____

____

____

____

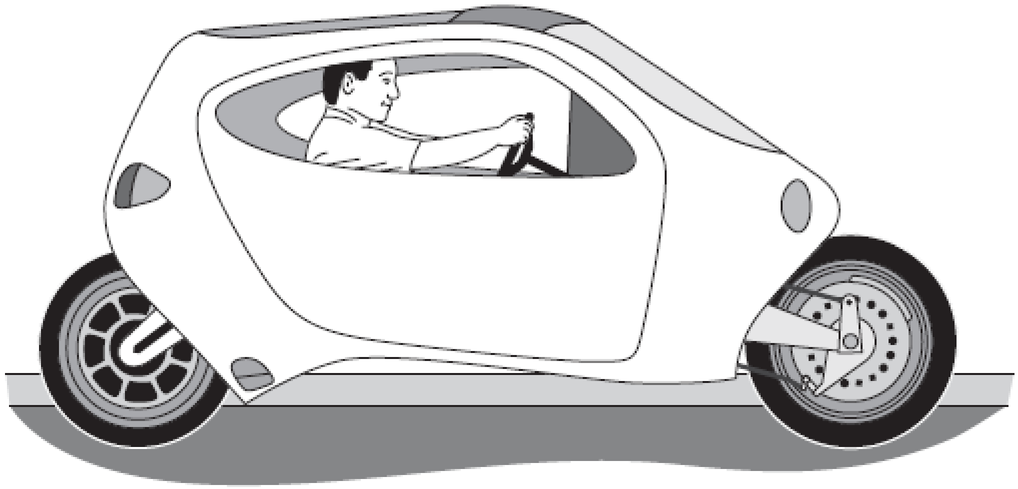
____

(3)

(c) A rocket ejects 1.5×10^4 kg of waste gas per second. The gas is ejected with a speed of 2.4 km s^{-1} relative to the rocket. Show that the average thrust on the rocket is about 40 MN.

(2)
(Total 7 marks)

13 The diagram below shows an electric two-wheeled vehicle and driver.



(a) The vehicle accelerates horizontally from rest to 27.8 m s^{-1} in a time of 4.6 s. The mass of the vehicle is 360 kg and the rider has a mass of 82 kg.

(i) Calculate the average acceleration during the 4.6 s time interval.
Give your answer to an appropriate number of significant figures.

acceleration = ____________________ m s^{-2}

(2)

(ii) Calculate the average horizontal resultant force on the vehicle while it is accelerating.

resultant force = ____________________ N

(2)

(b) State and explain how the horizontal forward force on the vehicle has to change for **constant** acceleration to be maintained from 0 to 27.8 m s^{-1}.

___

___

___

___

___

___

___

___

(3)

(c) The electric motors drive both wheels of the vehicle.

Add labelled force arrows to the diagram to show the horizontal forces acting on the vehicle when it is moving at a constant speed.

(2)

(d) The vehicle now accelerates to a constant speed of 55 m s^{-1}. The useful power output of the motors is 22 kW at this speed.

Calculate the horizontal resistive force acting on the vehicle.

horizontal resistive force = ____________________ N

(2)

(Total 11 marks)

14 A girl kicks a ball along the ground at a wall 2.0 m away. The ball strikes the wall normally at a velocity of 8.0 m s^{-1} and rebounds in the opposite direction with an initial velocity of 6.0 m s^{-1}. The girl, who has not moved, stops the ball a short time later.

(a) Explain why the final displacement of the ball is not 4.0 m.

____

____

____

(1)

(b) Explain why the average velocity of the ball is different from its average speed.

____

____

____

(2)

(c) The ball has a mass of 0.45 kg and is in contact with the wall for 0.10 s. For the period of time the ball is in contact with the wall,

(i) calculate the average acceleration of the ball.

____

____

(ii) calculate the average force acting on the ball.

____

(iii) state the direction of the average force acting on the ball.

____

(5)

(Total 8 marks)

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

____

____

(2)

(ii) Explain briefly how an elastic collision is different from an inelastic collision.

____

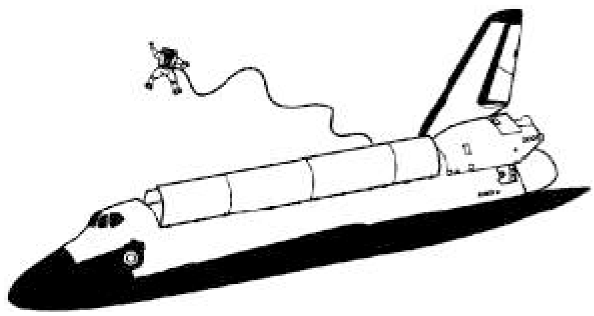
____

(1)

(b) Describe and explain what happens when a moving particle collides elastically with a stationary particle of equal mass.

(3)

(c) The diagram below shows an astronaut undertaking a space-walk. The astronaut is tethered by a rope to a spacecraft of mass 4.0×10^4 kg. The spacecraft is moving at constant velocity.



The astronaut and spacesuit have a total mass of 130 kg. The change in velocity of the astronaut after pushing off is 1.80 m s^{-1}.

(i) Determine the velocity change of the spacecraft.

(2)

(ii) The astronaut pushes for 0.60 s in achieving this speed. Calculate the average power developed by the astronaut. Neglect the change in motion of the spacecraft.

(3)

(iii) The rope eventually becomes taut. Suggest what would happen next.

(2)

(Total 13 marks)

Mark schemes

1 (a) (momentum of air) increases ✓

words implying increase

1

(b) (rate of change of momentum so) force acting on the air (Newton 2) ✓

1

it/air exerts force (on engine) of the same/equal magnitude/size ✓

1

but opposite in direction (Newton 3) ✓

allow backwards and forwards to indicate opposite

1

(c) *(use of $F = \Delta mv/t$)*

F = 210 × 570 = 120 000 (N) (119 700) ✓

1

(d) momentum/velocity is a vector OR momentum/velocity has direction ✓

1

there is a change (in the air's) direction ✓

1

(e) *(use of $F = ma$)*

a = (−) 190 000/7.0 × 10^4 = 2.7 (2.71) (m s^{-2}) ✓

1

(f) *(use of $v^2 = u^2 + 2as$)*

CE from 01.5

accept range 850 − 860

if forget to square u or double a score 1 mark

1

$0 = 68^2 - 2 \times 2.7 \times s$ ✓

$s = 68^2/(2 \times 2.7) = 860$ (m) (856)

accept alternatives using $s = ut + 1/2at^2$ OR average speed – first mark for time calculation AND correct substitution

1

(g) rate of intake of air decreases (as plane slows) OR volume/mass /amount of air (passing through engine) per second decreases ✓

allow argument in terms of (air) resistance

(air) resistance decreases as speed of aircraft decreases for 1 mark

1

(as) smaller rate of change of momentum OR momentum change ✓

NOT FRICTION

1

[12]

2 (a) $F\Delta t = \Delta p$ (or stated in words)
$\Delta p = 0.14 \times 0.4$ or 0.056

Accept use of $F = ma$ with / in $F\Delta t$

Accept $4.67 \times 12 \times 10^{-3} = 0.056$

2

(b) $0.056 / 12 \times 10^{-3}$ or $0.06 / 12 \times 10^{-3}$
4.7 (4.67) (N)

Condone power of 10 error in t for C1 mark

Allow 1 sf answer of 5 (N) for 0.06 (kg m s^{-1})

2

[4]

3 (a) m = 16 g = 0.016 kg r = 0.008 m

Use of $V = 4 / 3\, \pi\, r^3$ to give $V = 4 / 3\, \pi\, (0.008)^3$

= 2.1 × 10 − 6 m^3✓

The first mark is for calculating the volume

1

Use of density = m / V to give density = $0.016 / 2.1 \times 10^{-6}$✓

The second mark is for substituting into the density equation using the correct units

1

Density = 7.4×10^3 kg m^{-3} ✓

The final mark is for the answer.

1

(b) Use of $v^2 = u^2 + 2as$ to give $v^2 = 2\,(9.81)\,(1.27)$ ✓

(allow use of $mg\Delta h = ½\, mv^2$)

$v^2 = 25$ (24.9)

The first mark is for using the equation

1

v = 5.0 (m s^{-1}) ✓

The second for the final answer

1

(c) Use of v2 = u2 + 2as to give $0 = u^2 + 2\,(-9.81)\,(0.85)$ ✓

The first mark is for using the equation

1

$u^2 = 17$ (16.7)

u = 4.1 m s^{-1} ✓

The second for the final answer

1

(d) Change in momentum = $mv + mu$ = 0.016 × 5 + 0.016 × 4.1✓

The first mark is for using the equation

1

= 0.15 (0.146) $kg\ m\ s^{-1}$ ✓

The second for the final answer

1

(e) Use of Force = change in momentum / time taken

= 0.15 / 40 × 10^{-3}✓

The first mark is for using the equation

1

= 3.6 N ✓

The second for the final answer

1

(f) Impact time can be increased if the plinth material is not stiff✓

Alternative

A softer plinth would decrease the change in momentum of the ball (or reduce the height of rebound) ✓

1

Increased impact time would reduce the force of the impact. ✓

Smaller change in momentum would reduce the force of impact ✓

1

[13]

4 (a) Max GPE of block = Mgh = 0.46 × 9.81 × 0.63 = 2.84 J ✓

The first mark is for working out the GPE of the block

1

Initial KE of block = ½ Mv^2 = 2.84 J

Initial speed of block v^2 = (2 × 2.84) / 0.46

v = 3.51 ms^{-1} ✓

The second mark is for working out the speed of the block initially

1

momentum lost by pellet = momentum gained by block

= Mv = 0.46 × 3.51 = 1.61 kg m s^{-1} ✓

The third mark is for working out the momentum of the block (and therefore pellet)

1

Speed of pellet = 1.58 / m = 1.58 / 8.8 × 10^{-3} = 180 ms^{-1} (183) ✓

The final mark is for the speed of the pellet

1

At each step the mark is for the method rather than the calculated answer

Allow one consequential error in the final answer

(b) As pellet rebounds, change in momentum of pellet greater and therefore the change in momentum of the block is greater ✓

Ignore any discussion of air resistance

1

Initial speed of block is greater ✓

1

(Mass stays the same)

Initial KE of block greater ✓

1

Therefore height reached by steel block is greater than with wooden block ✓

1

(c) Calculation of steel method will need to assume that collision is elastic so that change of momentum can be calculated ✓

1

This is unlikely due to deformation of bullet, production of sound etc. ✓

1

And therefore steel method unlikely to produce accurate results.

[10]

5

(a) (i) use of $\left(s = \frac{1}{2}gt^2\right)$ OR $t^2 = 2s / g$ ✓

t = $\sqrt{\frac{2 \times 1.2}{9.81}}$ ✓

= 0.49 (0.4946 s) ✓ allow 0.5 do not allow 0.50

Some working required for full marks. Correct answer only gets 2

3

(ii) ($s = vt$)

= 8.5 × 0.4946 ✓ ecf ai

= 4.2 m ✓ (4.20) ecf from ai

2

(b) (i) $\left(s = \frac{1}{2}(u + v)\,t\right)$

$t = \frac{2s}{u(+v)}$ or correct sub into equation above ✓

$= \frac{2 \times 0.35}{8.5}$ = 8.2 × 10^{-2} (s) ✓ (0.0824) allow 0.08 but not 0.080 or 0.1

Allow alternative correct approaches

2

(ii) *a = (v − u) / t* OR correct substitution OR a = 103 ✓
(= −8.5) / 8.24 × 10^{-2} = 103.2)

(*F* = *ma* =) 75 × (103.2) ✓ ecf from bi for incorrect acceleration due to arithmetic error only, not a physics error (e.g. do not allow a = 8.5. Use of g gets zero for the question.

= 7700 N ✓ (7741) ecf (see above)

Or from loss of KE

Some working required for full marks. Correct answer only gets 2

3

[10]

6 (a) smooth curve with a maximum value shown

B1

condone non-zero at start and finish

gradient fairly constant or slight increase for half time

B1

falls gradually on second half of swing

B1

oscillations score zero

2 max

(b) impulse is product of force and time

B1

clear reference to impulse

prolonging the time (of contact) increases momentum / velocity

B1

being force time product needed for first mark

2

(c) (i) use of $F=mv/t$ $= 0.045 \times 58 / 180 \times 10^{-6}$

C1

use of 35 can gain first mark

or $a = 58 / 180 = 3.2 \times 10^5$ (ignore power for first mark) 1.45×10^4 (N)

A1

2

(ii) $(-)1.45 \times 10^4$ (N)

B1

numerically equal to c(i)

1

(iii) club head has inertia

C1

do not credit reference to friction

club head only slows slightly on impact

A1

club head still has kinetic energy / collision not elastic increase in internal energy / 'heat' / temperature of ball / club head

treat references to sound neutrally

2 max

[9]

7 (a) force = rate of change of momentum **(1)**

1

(b) (i) area under graph represents impulse **or change in** momentum **(1)**

1

(ii) suitable method to estimate area under graph **(1)(1)**

[eg counting squares: 20 to 23 squares **(1)**
each of area $25 \times 10^{-3} \times 20 = 0.5$ (N s) **(1)**
or approximate triangle etc **(1)**
$\frac{1}{2} \times 250 \times 10^{-3} \times 90$ **(1)**]

gives impulse = 11 ± 1 **(1)**

N s (or kg m s^{-1}) **(1)**

4

(iii) use of impulse = $\Delta(mv)$ **(1)**

$\Delta p = mv - (-mu) = m(v + u)$ **or** $11 = 0.42\ (v + 10)$ **(1)**

giving $0.42\ v = 6.8$ and $v = 16$ (m s^{-1}) (impulse = 12 gives 19 m s^{-1}) **(1)**

answer to **2 sf** only **(1)**

4

(c) final speed would be lower **(1)**

any **two** of the following points **(1)(1)**

- initial momentum would be greater [**or** greater *u* must be reversed]
- change in momentum [or velocity] is the same [**or** larger *F* acts for shorter *t*]
- initial and final momenta are (usually) in opposite directions
- initial and final momenta may be in same direction if initial speed is sufficiently high

[alternatively]

final speed = $\dfrac{\text{impulse (from graph)}}{\text{mass of ball}}$ – initial speed **(1)**

gives final speed $v = (26 \pm 3)$ – initial speed *u* **(1)**

consequence is

- *v* is in opposite direction to *u* when $u < 26$
- *v* is in same direction as *u* when $u > 26$
- *v* is zero (ball stationary) when $u = 26$

any one of these bullet points **(1)**

3

[13]

8 (a) (i) (change in momentum of A) = – **(1)** 25×10^3 **(1)**
kg m s^{-1} (or N s) **(1)**

(ii) (change in momentum of B) = 25×10^3 kg m s^{-1} **(1)**

4

(b)

	initial vel/m s^{-1}	final vel/m s^{-1}	initial k.e./J	final k.e./J
truck A	2.5	1.25	62500	15600
truck B	0.67	1.5	6730	33750
	(1)	**(1)**	**(1)**	**(1)**

4

(c) not elastic **(1)**
because kinetic energy not conserved **(1)**
kinetic energy is greater before the collision (or less after) **(1)**
[or justified by correct calculation]

3

[11]

9 (a) (i) acceleration **(1)**

(ii) both represent acceleration of free fall
[or same acceleration] **(1)**

(iii) height/distance ball is dropped from above the ground
[or displacement] **(1)**

(iv) moving in the opposite direction **(1)**

(v) kinetic energy is lost in the collision
[or inelastic collision] **(1)**

5

(b) (i) $v^2 = 2 \times 9.81 \times 1.2$ **(1)**
$v = 4.9\ \text{m s}^{-1}$ **(1)** ($4.85\ \text{m s}^{-1}$)

(ii) $u^2 = 2 \times 9.81 \times 0.75$ **(1)**
$u = 3.8\ \text{m s}^{-1}$ **(1)** ($3.84\ \text{m s}^{-1}$)

(iii) change in momentum = $0.15 \times 3.84 - 0.15 \times 4.85$ **(1)**
$= -1.3\ \text{kg m s}^{-1}$ **(1)** ($1.25\ \text{kg m s}^{-1}$)

(allow C.E. from (b) (i) and (b)(ii))

(iv) $F = \frac{1.3}{0.10}$ **(1)**
$= 13\ \text{N}$ **(1)**

(allow C.E. from (b)(iii))

8

[13]

10 (a) (i) equation showing momentum before = momentum after **(1)**
correct use of sign **(1)**

(ii) no <u>external</u> forces (on any system of colliding bodies) **(1)**

3

(b) (i) (by conservation of momentum $m_1\upsilon_1 + m_2\upsilon_2 = 0$)

$0.25 \times 2.2 = (–)0.50\upsilon_2$ **(1)**
$\upsilon_2 = (–)1.1(0)\text{ms}^{–1}$ **(1)**

(ii) = total k.e. = $\frac{1}{2} \times 0.25 \times 2.2^2 + \frac{1}{2} \times 0.5 \times 1.1^2$ **(1)**

= 0.91J **(1)**

4

(c) (i) mass of air per second = $\rho A \upsilon$ **(1)**
correct justification, incl ref to time **(1)**

(ii) momentum per second (= $M\upsilon = \upsilon^2 A\rho$) = $\upsilon^2 A\rho$ **(1)**

(iii) force = rate of change of momentum (hence given result) **(1)**
upward force on helicopter equals (from Newton third law)
downward force on air **(1)**

5

(d) $\upsilon^2 A\rho = \frac{mg}{2}$ (for 50% support) **(1)**

$\upsilon^2 \times 180 \times 1.3 = \frac{2500 \times 9.81}{2}$ **(1)**

gives $\upsilon = 7.2\text{ms}^{–1}$ **(1)** (or 7.3, g taken as 10)
if not 50% of weight, max 1 / 3 provided all correct otherwise (gives 10.2)

3

[15]

11 (a) **total** momentum of system constant/**total** momentum before =

B1

total momentum after
isolated system/no external force

B1

2

(b) (i) clear explanation of method

B1

correct numerical working leading to 4.25 m s^{-1}

B1

2

(ii) F = 0.31 × a speed

C1

use of speed difference [4.25 – 0.68]

C1

= 1.11 N [ecf]

A1

3

(iii) states that two momenta/forces related to hose and wall are equal in size/appreciates reaction force

B1

transmitted by hose to Earth
and in opposite direction

B1

2

[9]

12

(a) $F = \frac{\Delta(mv)}{t}$ or $Ft = mv - mu$ etc.

M1

substitute units

A1

2

(b) conservation of momentum mentioned

B1

ejected gas has momentum or velocity in one direction

B1

rocket must have equal momentum in the opposite direction

B1

3

or force = rate of change of momentum

(B1)

ejected gas has momentum or velocity in one direction

(B1)

rocket must have equal and opposite force

(B1)

(c) equation seen ($F = m/t \times v$ but not $F = ma$)

B1

substitution into any sensible equation leading to
3.6×10^7 (N)

B1

2

[7]

13 (a) (i) *(a =(v-u) / t)*

= 27.8 (−0) / 4.6 = 6.04 ✓

= <u>6.0</u> (ms^{-1}) ✓

no need to see working for the mark

2 sig fig mark stands alone

2

(ii) (*F = ma*)

= (360 + 82) × 6.0(4) ✓ (allow CE from (i))

= 2700 (N) ✓ (2670 N or 2652 N)

F = 442 × (i)

1 mark may be gained if mass of rider is ignored giving answer 2200N from 2175N

2

(b) (forward force would have to) increase ✓

air resistance / drag increases (with speed) ✓

<u>driving / forward</u> force must be greater than resistive / drag force ✓

no mark for wind resistance

(so that) <u>resultant / net</u> force stayed the same / otherwise the <u>resultant / net</u> force would decrease ✓

4max3

(c) horizontal force arrows on both wheels towards the right starting where tyre meets road or on the axle labelled driving force or equivalent ✓

ignore the actual lengths of any arrows

ignore any arrows simply labelled 'friction'

a horizontal arrow to the left starting anywhere on the vehicle labelled drag / air resistance

no mark for wind resistance, resistance or friction force

the base of an arrow is where the force is applied

2

(d) ($F = P / v$)
= 22 000 / 55 ✓ Condone 22 / 55 for this mark
= 400 ✓ (N)

2

[11]

14 (a) displacement is a vector **(1)**
ball travels in opposite directions **(1)**

max 1

(b) velocity is rate of change of displacement
average speed is rate of change of distance
velocity is a vector [or speed is a scalar)
velocity changes direction

any two **(1) (1)**

2

(c) (i) $a = \frac{(-6.0 - 8.0)}{0.10}$ **(1)**

= (–)140.m s^{-1} **(1)**

(allow C.E. for incorrect values of Δv)

(ii) F = 0.45 × (–) 140 = (–) 63N **(1)**
(allow C.E for value of *a)*

(iii) away from wall **(1)**
at right angles to wall **(1)**
[or back to girl **(1) (1)**]
[or opposite to direction of velocity at impact **(1) (1)**]

5

[8]

15 (a) (i) momentum before (a collision) = momentum after (a collision)
or
there is no change in momentum (when bodies collide)

C1

reasonably rigorous statement including
reference to total momentum etc. **and**
lack of external force or in a closed system or isolated system

A1

(2)

(ii) in an elastic collision the (total) KE remains constant
or
in an inelastic collision the (total) KE is reduced (not just changed)

B1

(1)

(b) the incident particle stops (loses all its momentum or KE)

M1

the stationary particle moves off with the **same** velocity (speed) as the incident particle (gains **same** momentum or KE as incident particle had)

M1

no other possibility would conserve both momentum and KE
or
original total momentum = mv = final momentum
and original KE = $\frac{1}{2}mv^2$ = final KE

A1

(3)

(c) (i) $130 \times 1.8 = 4.0 \times 10^4\ v$
or clear appreciation that momentum = mv

C1

e.g. an incorrect momentum equation
$5.9\ (5.85) \times 10^{-3}$ m s^{-1} (in opposite direction to that of the astronaut)

A1

(2)

(ii) energy change / time

C1

energy change of astronaut = 211 J

C1

or

power = Fv

C1

force = 390 N from $F = ma$

(need to use $v = 1.8 / 2$ to obtain average power 350 W)

C1

power = total energy / time = 211 / 0.6 = 350 – 352 W

A1

(3)

(iii) any two sensible comments

e.g. momentum of astronaut and spacecraft reduced to zero
rope stores elastic energy
momentum of astronaut becomes equal and opposite to original
astronaut and spacecraft move toward one another
the astronaut and spacecraft are ‘reunited’
taut rope produces a force toward the spacecraft
velocity of astronaut and of spacecraft will be reversed
rope acting like a spring

not astronaut pulled along at a constant speed

B2

(2)

[13]