Q1. For the two physical quantities, impulse and force, which one of the following is correct?

A Impulse is a scalar and force is a scalar.

B Impulse is a scalar and force is a vector.

C Impulse is a vector and force is a scalar.

D impulse is a vector and force is a vector.

(Total 1 mark)

Q2. The rate of change of momentum of a body falling freely under gravity is equal to its

A weight.

B power.

C kinetic energy.

D potential energy.

(Total 1 mark)

Q3.
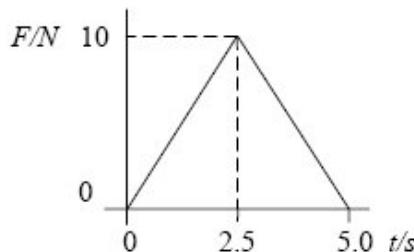
A force, F, varies with time, t, as shown by the graph and is applied to a body initially at rest on a smooth surface. What is the momentum of the body after 5.0 s?

A zero.

B 12.5 N s.

C 25 N s.

D 50 N s.

(Total 1 mark)

Q4.   A particle of mass m strikes a rigid wall perpendicularly from the left with velocity v.
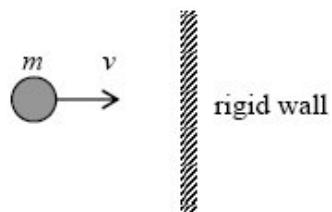

If the collision is perfectly elastic, the change in momentum of the particle which occurs as a result of the collision is

A $2mv$ to the right.

B $2mv$ to the left.

C mv to the left.

D   zero.

(Total 1 mark)

Q5. The graph shows how the force acting on a body changes with time.
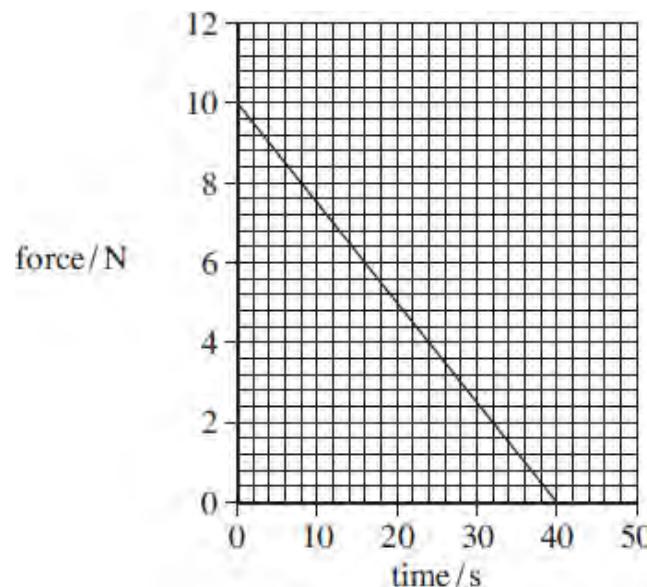
The body has a mass of 0.25 kg and is initially at rest. What is the speed of the body after 40 s assuming no other forces are acting?

    A 200 ms^{-1}

    B 400 ms^{-1}

    C 800 ms^{-1}

    D 1600 ms^{-1}

(Total 1 mark)

Q6. Which line, **A** to **D**, in the table shows correctly whether the moment of a force, and momentum, are scalar or vector quantities?

	moment of force	momentum
A	scalar	scalar
B	scalar	vector
C	vector	scalar
D	vector	vector

(Total 1 mark)

Q7. Which one of the following statements is correct?

The force acting on an object is equivalent to

A   its change of momentum.

B   the impulse it receives per second.

C   the energy it gains per second.

D   its acceleration per metre.

(Total 1 mark)

Q8. The graph shows how the resultant force applied to an object of mass 2.0 kg, initially at rest, varies with time.
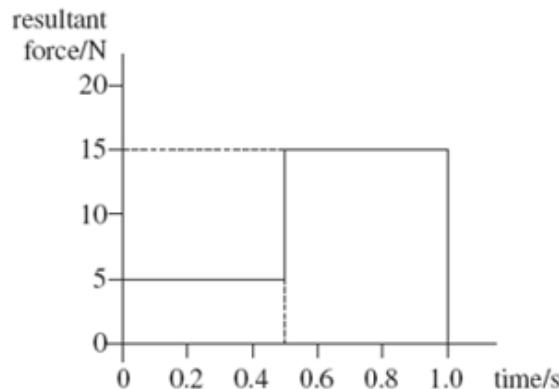
What is the speed of the object after 1.0 s?

A   2.5 ms^{-1}

B   5.0 ms^{-1}

C   7.5 ms^{-1}

D   10 ms^{-1}

(Total 1 mark)

Q9. The graph shows the variation with time, t, of the force, F, acting on a body.
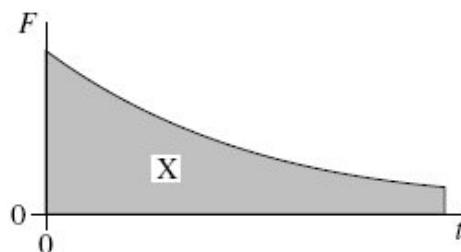
What physical quantity does the area X represent?

A the displacement of the body

B the acceleration of the body

C the change in momentum of the body

D the change in kinetic energy of the body

(Total 1 mark)

Q10. A rail truck X travels along a level track and collides with a stationary truck Y. The two trucks move together at the same velocity after the collision.

Which line, **A** to **D**, in the table states how the total momentum and the total kinetic energy of the trucks change as a result of the impact.

	total momentum	total kinetic energy
A	unchanged	unchanged
B	unchanged	decreases
C	decreases	decreases
D	decreases	unchanged

(Total 1 mark)

Q11.   The graph shows how the force on a glider of mass 2000 kg changes with time as it is launched from a level track using a catapult.
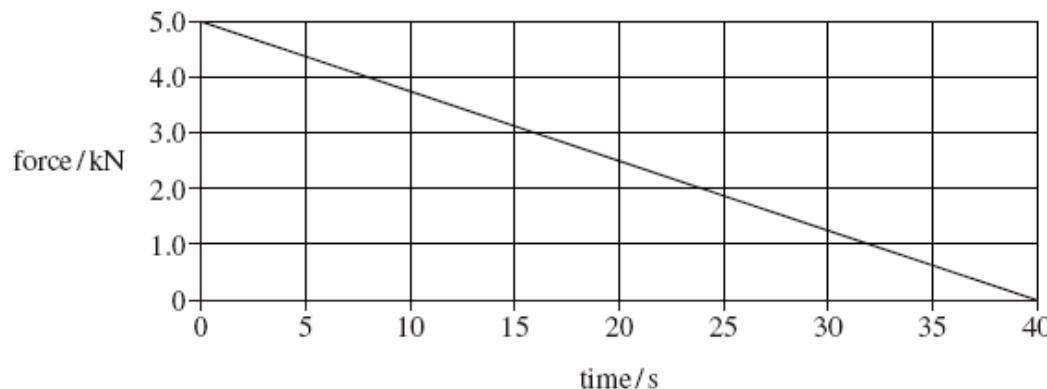
Assuming the glider starts at rest what is its velocity after 40 s?

A   2.5 m s^{-1}

B   10 m s^{-1}

C   50 m s^{-1}

D   100 m s^{-1}

(Total 1 mark)

Q12.   A gas molecule of mass m in a container moves with velocity v. If it makes an elastic collision at right angles to the walls of the container, what is the change in momentum of the molecule?

A   zero

B $\frac{1}{2}mv$

C mv

D $2mv$

(Total 1 mark)

Q13. Water of density 1000 kg m^{-3} flows out of a garden hose of cross-sectional area 7.2 × 10^{-4} m^2 at a rate of 2.0 × 10^{-4} m^3 per second. How much momentum is carried by the water leaving the hose per second?

A   5.6 × 10^{-5} N s

B   5.6 × 10^{-2} N s

C   0.20 N s

D   0.72 N s

(Total 1 mark)

Q14. A body X moving with a velocity v makes an elastic collision with a stationary body Y of equal mass on a smooth horizontal surface.

Which line, **A** to **D**, in the table gives the velocities of the two bodies after the collision?

	velocity of X	velocity of Y
A	$\dfrac{v}{2}$	$-\dfrac{v}{2}$
B	$-\dfrac{v}{2}$	$\dfrac{v}{2}$
C	v	0
D	0	v

(Total 1 mark)

Q15.   Which row, **A** to **D**, in the table correctly shows the quantities conserved in an inelastic collision?

	mass	momentum	kinetic energy	total energy
A	conserved	not conserved	conserved	conserved
B	not conserved	conserved	conserved	not conserved
C	conserved	conserved	conserved	conserved
D	conserved	conserved	not conserved	conserved

(Total 1 mark)

Q16.   Which of the following is a possible unit for rate of change of momentum?

A   N s

B   N s^{-1}

C   kg ms^{-1}

D   kg ms^{-2}

(Total 1 mark)

Q17. A ball of mass 2.0 kg, initially at rest, is acted on by a force *F* which varies with time *t* as shown by the graph.
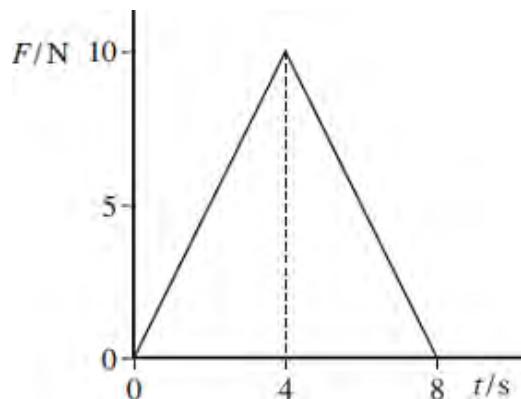
What is the velocity of the ball after 8.0 s?

A 20 ms^{-1}

B 40 ms^{-1}

C 80 ms^{-1}

D 160 ms^{-1}

(Total 1 mark)

Q18. A stationary unstable nucleus of mass M emits an α particle of mass m with kinetic energy E.
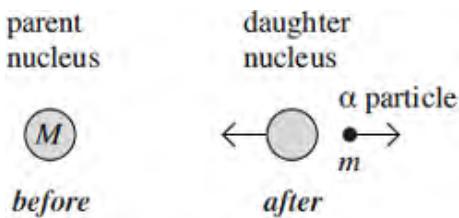
What is the speed of recoil of the daughter nucleus?

A $\dfrac{\sqrt{2mE}}{(M-m)}$

B $\dfrac{\sqrt{2mE}}{M}$

C $\dfrac{(M-m)}{\sqrt{2mE}}$

D $\dfrac{2mE}{(M-m)^2}$

(Total 1 mark)

Q19. A golf club undergoes an *inelastic* collision with a stationary golf ball and gives it an initial velocity of 60 m s⁻¹. The ball is in contact with the club for 15 ms and the mass of the ball is 4.5×10^{-2} kg.

(a) Explain what is meant by an inelastic collision.

....

....

(1)

(b)   Calculate

(i)   the change in momentum of the ball,

....

....

(ii)   the average force the club exerts on the ball.

....

....

....

(4)
(Total 5 marks)

Q20.   In a football match, a player kicks a stationary football of mass 0.44 kg and gives it a speed of 32 m s^{-1}.

(a)   (i)   Calculate the change of momentum of the football.

....

(ii)   The contact time between the football and the footballer's boot was 9.2 m s. Calculate the average force of impact on the football.

....

....

....

(3)

(b)   A video recording showed that the toe of the boot was moving on a circular arc of radius 0.62 m centred on the knee joint when the football was struck. The force of the impact slowed the boot down from a speed of 24 m s⁻¹ to a speed of 15 m s⁻¹.

Figure 1

(i)   Calculate the deceleration of the boot along the line of the impact force when it struck the football.

....

....

....

(ii)   Calculate the centripetal acceleration of the boot just before impact.

....

....

....

(iii) Discuss briefly the radial force on the knee joint before impact and during the impact.

....

....

....

....

....

....

....

....

(4)
(Total 7 marks)

Q21. (a) State, in words, the relationship between the force acting on a body and the momentum of the body.

....

....

....

(1)

(b)   A container rests on a top-pan balance, which measures mass in kg. A funnel above the
      container holds some sand. The sand falls at a constant rate of 0.300 kg s^{-1} into the
      container, having fallen through an average vertical height of 1.60 m.
      This arrangement is shown in the figure below.
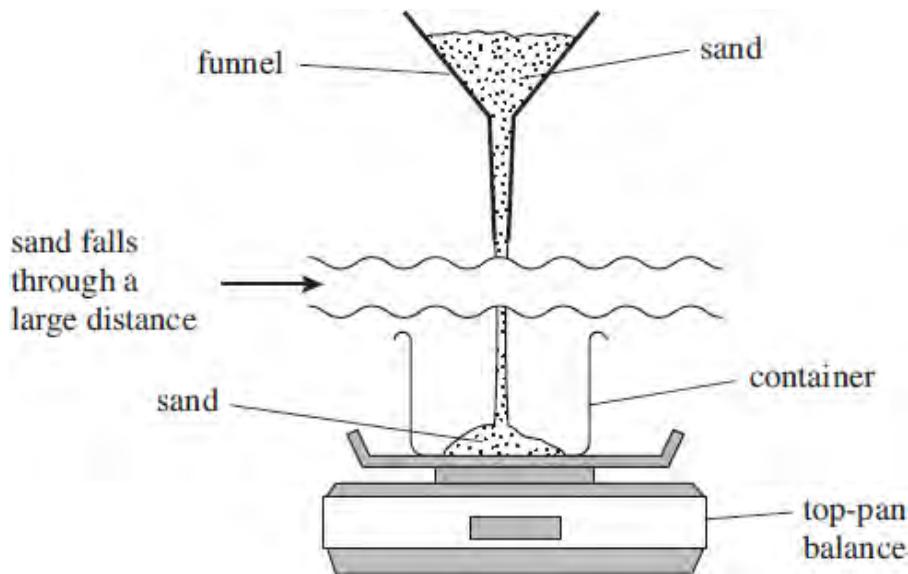
(b)   (i)   Show that the velocity of the sand as it lands in the container is 5.6 ms^{-1}.

(1)

      (ii)   Calculate the magnitude of the momentum of the sand that lands in the container in
             each second.

                                  answer = ... Ns

(1)

(iii) The mass of the container is 0.650 kg. Show that the reading of the balance, 10.0 s after the sand starts landing continuously in the container, will be 3.82 kg. You may assume that the sand comes to rest without rebounding when it lands in the container.

(3)

(c) It takes 20.0 s for all of the sand to fall into the container.
On the axes below, sketch a graph to show how the reading of the balance will change over a 30.0 s period, where t = 5.0 s is the time at which the sand starts to land in the container. No further calculations are required and values need not be shown on the vertical axis of the graph.
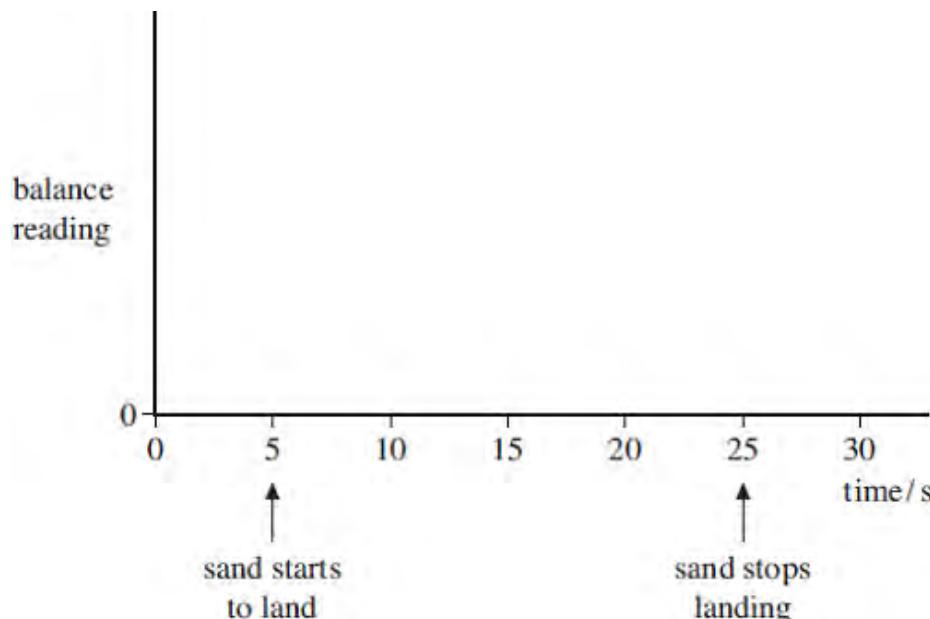
(3)
(Total 9 marks)

Q22. (a) State **two** quantities that are conserved in an elastic collision.

quantity 1: ....

quantity 2: ....

(2)

(b)   A gas molecule makes an elastic collision with the walls of a gas cylinder. The molecule is travelling at 450 m s^{-1} at right angles towards the wall before the collision.

(i)   What is the magnitude and direction of its velocity after the collision?

....

....

(ii)   Calculate the change in momentum of the molecule during the collision if it has a mass of 8.0 × 10^{-26} kg.

....

....

....

....

(4)

(c)   Use Newton's laws of motion to explain how the molecules of a gas exert a force on the wall of a container.

You may be awarded additional marks to those shown in brackets for the quality of written communication in your answer.

....

....

....

....

....

....

(4)
(Total 10 marks)

Q23. The diagram represents part of an experiment that is being used to estimate the speed of an air gun pellet.
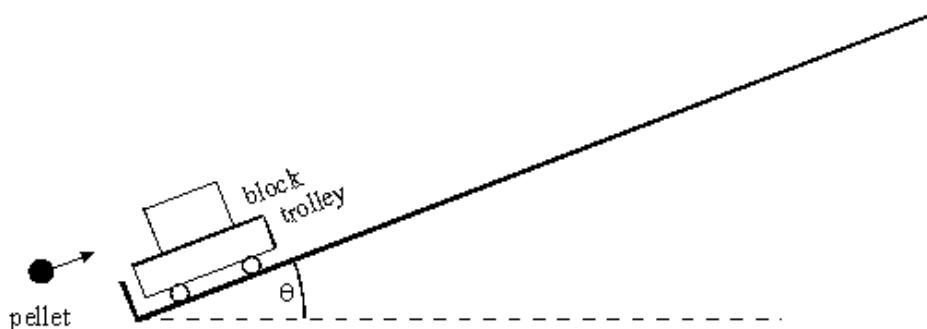
The pellet which is moving parallel to the track, strikes the block, embedding itself. The trolley and the block then move along the track, rising a vertical height, *h*.

(a) Using energy considerations explain how the speed of the trolley and block immediately after it has been struck by the pellet, may be determined from measurements of *h*. Assume frictional forces are negligible.

....

....

....

....

....

....

....

(3)

(b) The following data is collected from the experiment

mass of trolley and block	0.50 kg
mass of pellet	0.0020 kg
speed of trolley and block immediately after impact	0.40 m s^{-1}

Calculate

(i) the momentum of the trolley and block immediately after impact,

....

....

(ii) the speed of the pellet just before impact.

....

....

....

(4)

(c)   (i)   State what is meant by an inelastic collision.

....

....

....

(ii)   Use the data from part (b) to show that the collision between the pellet and block is inelastic.

....

....

....

(4)
(Total 11 marks)

Q24.   Deep space probes often carry modules which may be ejected from them by an explosion.

A space probe of total mass 500 kg is travelling in a straight line through free space at 160 m s^{-1} when it ejects a capsule of mass 150 kg explosively, releasing energy. Immediately after the explosion the probe, now of mass 350 kg, continues to travel in the original straight line but travels at 240 m s^{-1}, as shown in the figure below.

160 m s^{-1} 240 m s^{-1}

500 kg   150 kg   350 kg

probe   capsule   probe

before explosion   after explosion
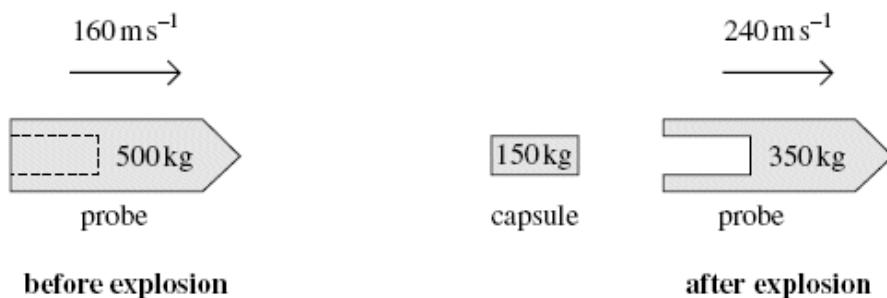
(a) Discuss how the principles of conservation of momentum and conservation of energy apply in this instance.

The quality of your written communication will be assessed in this question.

....

....

....

....

....

....

....

....

....

....

....

....

....

(6)

(b) (i) Calculate the magnitude of the velocity of the capsule immediately after the explosion and state its direction of movement.

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

direction of movement ....

(3)

(ii) Determine the total amount of energy given to the probe and capsule by the explosion.

answer = ... J

(4)
(Total 13 marks)

Q25. (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.
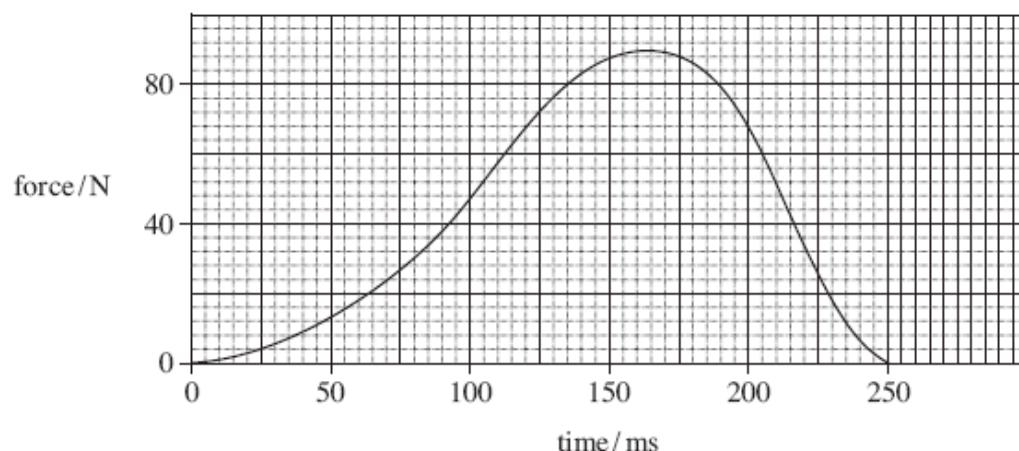
(i) What is the significance of the area enclosed by the line on a force–time graph and the time axis when a force acts on a body for a short time?

....

(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)

M1. D

[1]

M2. A

[1]

M3. C

[1]

M4. B

[1]

M5. C

[1]

M6. D

[1]

M7. B

[1]

M8. B

[1]

M9. C

[1]

M10. B

[1]

M11. C

[1]

M12. D

[1]

M13. B

[1]

M14. D

[1]

M15. D

[1]

M16. D

[1]

M17. A

[1]

M18. A

[1]

M19. (a) *kinetic* energy is not conserved **(1)**

(or velocity of approach equals velocity of separation)

1

(b) (i) (use of $p = mv$ gives) p = 4.5 × 10⁻² × 60 **(1)**

$$= 2.7 \text{kg m s}^{-1} \textbf{(1)}$$

(ii) (use of $F = \dfrac{\Delta(mv)}{\Delta t}$ gives) $F = \dfrac{2.7}{15 \times 10^{-3}}$ **(1)**

= 180 N **(1)**

[or $a = \dfrac{v-u}{t} = \dfrac{60}{15 \times 10^{-3}} = 400$ (m s⁻¹) **(1)**

$F = ma = 4.5 \times 10^{-2} \times 4000 = 180 \text{N}$ **(1)**

4

[5]

M20 (a) (i) change of momentum (0 44 × 32) 14(1) kg m ¹ **(1)**

(ii) (use of $F = \dfrac{\Delta(mv)}{\Delta t}$ gives) $F = \dfrac{14.1}{9.2 \times 10^{-3}}$ **(1)**

= 1.5(3) × 10³N **(1)**

(allow C.E. for value of Δ(mv) from (i)

3

(b) (i) deceleration = $\dfrac{24-15}{9.2 \times 10^{-3}} = 9.8 \times 10^2 \text{m s}^{-2}$ **(1)**

(9.78 × 10²m s⁻²)

(ii)   (use of $a = \dfrac{v^2}{r}$ gives)

centripetal acceleration = $\dfrac{24^2}{0.62}$ = 9.3 × 10^{2}m s^{-2} **(1)**

(9.29 × 10^2 m s^{-2})

(iii)   before impact: radial pull on knee joint due to centripetal
acceleration of boot **(1)**
during impact: radial pull reduced **(1)**

4

[7]

M21.   (a)   force is equal to (**or** proportional to) rate of <u>change of</u> momentum ✓

[**or** impulse = force × time = <u>change of</u> momentum]

[Answer should **not** be in symbols unless all the symbols are explained]

1

(b)   (i)   use of $mg\Delta h$ = ½ mv^2 gives v = $\sqrt{2gh}$ = $\sqrt{2 \times 9.81 \times 1.6}$ ✓ (= 5.60 m s^{-1})

1

(ii)   momentum per second (= 0.30 × 5.60) = 1.68 (Ns) ✓

1

(iii)   mass of sand falling in 10s = (0.30 × 10) (= 3.00 kg) ✓

force due to arriving sand = momentum arriving per second = 1.68(N)

equivalent mass reading = $\dfrac{1.68}{9.81}$

✓   (= 0.17 kg)

so balance reading is 3.00 + 0.65 + 0.17 ✓ (= 3.82 kg)

3

(c)   horizontal lines up to 5 s and beyond 25 s ✓

line of constant positive gradient between 5 s and 25 s ✓
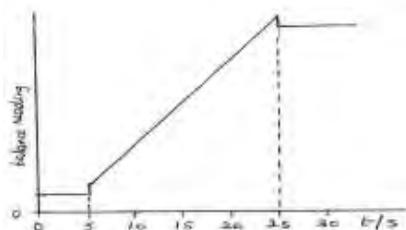
(near) vertical steps up at 5 s and down at 25 s ✓

3

[9]

M22.   (a)   momentum **(1)**

kinetic energy **(1)**

2

(b)   (i)   450ms⁻¹ **(1)**

in the opposite direction **(1)**

(ii) $\Delta p = 8.0 \times 10^{-26} \times 900$ **(1)**

$= 7.2 \times 10^{-23}$Ns **(1)**

4

(c)   force is exerted on molecule by wall **(1)**
to change its momentum **(1)**
molecule must exert an equal but opposite force on wall **(1)**
in accordance with Newton's second or third law **(1)**

4

[10]

M23.   (a)   kinetic energy changes to potential energy **(1)**
potential energy calculated by measuring *h* **(1)**
equate kinetic energy to potential energy to find speed **(1)**
        [or use *h* to find *s* **(1)**
        use *g* sin*θ* for *a* **(1)**
        use $v^2 = u^2 + 2as$ **(1)**]
        [or use *h* to find *s* **(1)**
        time to travel *s* and calculate v_{av} **(1)**
        $v = 2v_{av}$ **(1)**]

3

(b)   (i) $p(= mv) = 0.5(0) \times 0.4(0) = 0.2(0)$ **(1)** N s(or kg m s⁻¹) **(1)**

      (ii)   (use of $m_p v_p = m_t v_t$ gives) $0.002(0) \, v = 0.2(0)$ **(1)**
            $v = 100$ m s⁻¹ **(1)**

4

(c)   (i)   kinetic energy is not conserved **(1)**

      (ii)   initial kinetic energy = $\frac{1}{2} \times 0.002 \times 100^2 = 10$ (J) **(1)**

            final kinetic energy = $\frac{1}{2} \times 0.5 \times 0.4^2 = 0.040$ (J) **(1)**

            hence change in kinetic energy **(1)**

            (allow C.E. for value of *v* from (b))

4

[11]

M24.   (a)   **The candidate's writing should be legible and the spelling, punctuation and grammar should be sufficiently accurate for the meaning to be clear.**

The candidate's answer will be assessed holistically. The answer will be assigned to one of three levels according to the following criteria.

High Level (Good to excellent): 5 or 6 marks

The information conveyed by the an wer i clearly organi ed, logical and coherent, using appropriate specialist vocabulary correctly. The form and style of writing is appropriate to answer the question.

The candidate states that momentum is conserved, supported by reasoning to explain why the conditions required for momentum conservation are satisfied in this case.

The candidate also gives a statement that total energy is conserved, giving detailed consideration of the energy conversions which take place, described in the correct sequence, when there is an explosion on a body that is already moving.

Intermediate Level (Modest to adequate): 3 or 4 marks

The information conveyed by the answer may be less well organised and not fully coherent. There is less use of specialist vocabulary, or specialist vocabulary may be used incorrectly. The form and style of writing is less appropriate.

The candidate states that momentum is conserved, but the reasoning is much more limited.

and/or

There is a statement that (total) energy is conserved, with basic

Low Level (Poor to limited): 1 or 2 marks

The information conveyed by the answer is poorly organised and may not be relevant or coherent. There is little correct use of specialist vocabulary. The form and style of writing may be only partly appropriate.

The candidate indicates that either momentum or energy is conserved, or that both are conserved. There are very limited attempts to explain either of them.

The explanation expected in a competent answer should include a coherent selection of the following points concerning the physical principles involved and their consequences in this case.

Momentum

- momentum is conserved because there are no external forces acting on the overall system (probe plus capsule) – or because it's free space

- they are moving in free space and are therefore so far from large mae that gravitational force are negligible

- during the explosion, there are equal and opposite forces acting between the probe and the capsule

- these are internal forces that act within the overall system

- because momentum has to be conserved, and it is a vector, the capsule must move along the original line of movement after the explosion

Energy

- total energy is always conserved in any physical process because energy can be neither created nor destroyed

- however, energy may be converted from one form to another

- the probe is already moving and has kinetic energy

- in the explosion, some chemical energy is converted into kinetic energy (and some energy is lost in heating the surroundings)

- the system of probe and capsule has more kinetic energy than the probe had originally, because some kinetic energy is released by the explosion

max 6

(b) (i) conservation of momentum gives (500×160)
        $= 150\,v + (350 \times 240)$ **(1)**

   from which $v = (-)26(.7)$ (m s^{-1}) **(1)**

   direction: opposite horizontal direction to larger fragment
   [**or** to the left, **or** backwards] **(1)**

3

(ii)   initial $E_k = ½ \times 500 \times 160^2$ **(1)** (= 6.40×10^6 J)

final $E_k = (½ \times 350 \times 240^2) + (½ \times 150 \times 26.7^2)$ **(1)** (= 1.01×10^7 J)

energy released by explosion = final E_k − initial E_k **(1)**

= 3.7×10^6 (J) **(1)**

4

[13]

M25.   (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)**
       $½ \times 250 \times 10^{-3} \times 90$ **(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 ± 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]