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 = $4.5 \times 10^{-2} \times 60$ **(1)**

= 2.7kg m s^{-1} **(1)**

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

= 180 N **(1)**

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

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

4

[5]

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

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

= 1.5(3) × 10^3N **(1)**

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

3

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

(9.78 × 10^2m s^{-2})

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

centripetal acceleration = $\frac{24^2}{0.62}$ = 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 $mg\Delta h = \frac{1}{2} mv^2$ 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 = $\frac{1.68}{9.81}$

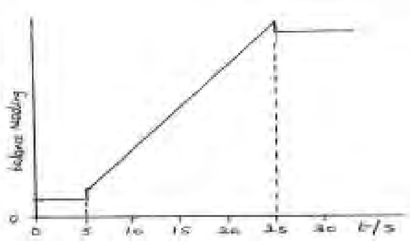
✓ (= 0.17 kg)

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)**

$= 7.2 \times 10^{-23}\text{Ns}$ **(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 $g \sin\theta$ 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 ma e 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 × 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 × 500 × 160^2 **(1)** (= 6.40 × 10^6 J)

final E_k = (½ × 350 × 240^2) + (½ × 150 × 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 × 10^{-3} × 20 = 0.5 (N s) **(1)**
or approximate triangle etc **(1)**
½ × 250 × 10^{-3} × 90 **(1)**]

gives impulse = 11 ± 1 **(1)**

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

4

(iii) use of impulse = Δ(*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 = $\frac{\text{impulse (from graph)}}{\text{mass of ball}}$ – 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]