1)

(a)		velocity vector tangential to path and drawn from the ball, arrow in correct direction ✓ acceleration vector vertically downwards, arrow drawn and in line with ball ✓	**2**
(b)	(i)	$s = ½\ gt^2$ gives $t = \sqrt{\frac{2y}{g}} = \sqrt{\frac{2\times24}{9.8(1)}}$ ✓ = 2.2(1)s ✓	**4**
	(ii)	$v\ (= s/t)$ = 27/2.2(1) ✓ = 12(.2 m s^{-1}) or 12(.3) ✓ (ecf from (b)(i)) (answer only gets both marks)	
		Total	**6**

2)

(a)	(i)	$v = \frac{s}{t}$ ✓ t = 0.015 (s) or 15 (ms) ✓ 0.68/0.015 ✓ (= 45)	**3**
(a)	(ii)	$\left(a = \frac{\Delta v}{\Delta t} = \frac{45.3}{0.015}\right)$ = 3000 (m s^{-2}) (3022) ✓	**1**
(b)	(i)	$s = (ut) = \frac{1}{2}gt^2$ or $t = \sqrt{\frac{2s}{g}}$ ✓ correct substitution seen = $\sqrt{\frac{2 \times 2.3}{9.81}}$ ✓ 0.68 to 0.69 correct answer to more than one dp seen ✓	**3**
(b)	(ii)	($s = vt$) = 45(.3) × 0.685 or 0.7 ✓ = 30.6 to 32 ✓ (m)	**2**
(b)	(iii)	mention of air resistance or drag ✓ causing **horizontal** deceleration or 'slowing down' ✓	**2**
		Total	**11**

3)

(a)	(i)	$t = \sqrt{\frac{2s}{g}}$ (evidence for correct rearrangement or substitution) ✓ $= \sqrt{\frac{2 \times 67}{9.81}}$ (correct substitution leading to answer) ✓ (= **3.7** (3.696) (s))	**2**
(a)	(ii)	$\left(v = \frac{s}{t} = \frac{150}{3.696}\right)$ = **41** ($m\,s^{-1}$) ✓ 2 sf ✓	**2**
(a)	(iii)	($v = (u +) gt =$) 9.81 × 3.696 ✓ = **36** ✓ ($m\,s^{-1}$)	**2**
(a)	(iv)	$v = \sqrt{40.586^2 + 36.257^2}$ (or correct scale drawing) ✓ = 54 ($m\,s^{-1}$) ✓ ecf from (ii) (iii) [for scale drawing allow range 53 → 56] $\tan\theta = \frac{36.257}{40.586}$ ✓ or correct alternative (angle from horizontal =) **42** (°) or correct alternative angle **and clear indication of direction** ✓ [for scale drawing allow range 40 → 44 ✓ for scale drawing: quality of construction ✓]	**4**
(b)	(i)	($= mgh$ = 22 × 9.81 × 67) = 14000 (14460) (J) ✓	**1**
(b)	(ii)	(G)PE → KE ✓ (KE to) internal/thermal/'heat' (energy) ✓	**2**
		Total	**13**

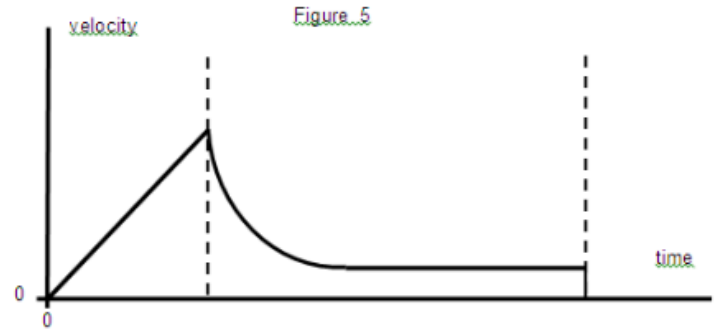
4)

a		vol = $\frac{4}{3}\pi 0.011^3$ = (5.5753) 5.6×10^{-6} (m^3)✓ ($m = \rho V$) (= 8100 × 5.575×10^{-6} =) 0.045 (kg) ✓ ecf from first part **candidate's mass x g** (W = 0.045160 × 9.81 = 0.44302 = 0.44 N) ✓ **any 2sf** ✓	4	Allow use of g = 10 0.36kg , 3.5N from use of diameter rather than radius (max 3 from 4)

b	i	**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 answer is clearly organised, logical and coherent, using appropriate specialist vocabulary correctly. The form and style of writing is appropriate to answer the question. Mentions **all** of the following: • velocity (or speed) increases and then becomes constant (terminal velocity) • acceleration reduces to zero • forces become equal / balanced • weight (allow 'gravity') and drag/friction correctly identified	5-6	

b	i	**For 6 marks: In addition to the above, two of the following:** • drag force increases with speed • (weight /downward force initially) greater than drag/friction etc • resultant force causes acceleration • Resultant force = W – drag • acceleration = gradient • acceleration is maximum (9.81) at the beginning **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. Mentions the **two** following points: • velocity (or speed) increases **OR** velocity (or speed) becomes constant / terminal velocity reached • acceleration decreases **OR** acceleration becomes zero **AND** for 3 marks: mentions **one** more valid point from the 4 above or from the 7 below: for 4 marks: at least two additional points with at least one from the 'Forces' list	3-4	

		• acceleration = gradient • acceleration is maximum (9.81) at the beginning **Forces** • weight greater than drag (before terminal velocity) • there is a resultant force downwards (before terminal velocity) • forces become equal/ balanced / drag = weight • drag force increases with speed. • Resultant force = W – drag **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. **One** valid point from list below For two marks: **Two** valid points **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.** Mention of the points below may influence the mark given within each category: • velocity increases • velocity becomes constant (terminal velocity) • acceleration is maximum (9.81) at the beginning • acceleration decreases (to zero) • weight greater than drag (before terminal velocity)	1-2	Poor QWC may result in award of the lower mark within a band. **Max 3 for mention of deceleration or increasing acceleration** Several serious misconceptions may reduce a 2 mark answer to 1
		• there is a resultant force downwards (before terminal velocity) • forces become equal/ balanced / drag = weight • drag force increases with speed. • resultant force = W – drag • acceleration = gradient valid point explaining why rapid decrease in velocity occurs when ball hits bottom of container. E.g. resultant upward force (decelerates the ball)		

b	ii	Figure 5  straight line with positive gradient from origin to first dotted line ✓ descending line (curved or straight but non-vertical) starting from a point on first dotted line (must not have negative velocity at any point) and the line may then become horizontal ✓ curved line descending from first dotted line which is a continuation of the initial line (the gradient must be decreasing initially (a curve) and the line may then become horizontal **AND** extending up to second dotted line (with positive non-zero velocity) **AND** no **incorrect** continuation of line beyond second time line ✓ **OR** straight line with positive gradient from origin to first dotted line ✓ straight line with positive gradient from origin to first dotted line **AND** ascending curved line with positive gradient decreasing, starting from a point on first dotted line (continuation of first line) ✓ extending up to second dotted line **AND** no **incorrect** continuation of line beyond second time line ✓	3	3rd mark: Allow lines that become straight with a constant negative gradient after a curve. Vertical line at the end is not necessary. End of line must be between start of 'e' in 'time' and end of 'w' in 'when'. Allow correct lines beyond the second time line: continuous zero velocity or falling below x axis and rising back to x axis (bouncing) but not reaching a higher speed than descent

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	3		Some working required for full marks. Correct answer only gets 2
a	ii	*(s= vt)* = 8.5 x 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 x 10^{-2} (s) ✓ (0.0824) allow 0.08 but not 0.080 or 0.1	2		Allow alternative correct approaches
b ii		$a = (v-u)\ /\ t$ OR correct substitution OR a= 103 ✓ (= -8.5) / 8.24 x 10^{-2} = 103.2) $(F = ma =)$ 75 x (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)	3		Or from loss of KE Some working required for full marks. Correct answer only gets 2
		Total	10		

6)

1	a		$(Ep = mg\Delta h)$ = 65 × 9.81× 54 ✓ = 3.44×10^4 = 3.4×10^4 (J) ✓ (34433)	2	max 1 if g =10 used (35100 J) Correct answer gains both marks
1	b		$v = \sqrt{\frac{2Ep}{m}}$ OR $v = \sqrt{\frac{2\times34433}{65}}$ ✓ = 33 (32.55 ms^{-1}) ✓ ecf 1(a) OR correct use of $v^2 = 2\,g\,s$	2	allow 32 (32.3) for the use of 34000 allow 32.6 don't penalise g=10 (32.863)
1	c		$(s = 1/2\,gt^2$ or other kinematics equation) $t = \sqrt{\frac{2s}{g}}$ OR $t = \sqrt{\frac{2\times54}{9.81}}$ ✓ = 3.318 = 3.3 (s) ✓ ecf from 1(b) if speed used	2	With use of g= 9.8 or 9.81or 10 and/or various suvat equations, expect range 3.2 to 3.4 s. No penalty for using g= 10 here.
1	d		(all G)PE (lost) is transferred to KE no (GP)E transferred to 'heat' / 'thermal' / internal energy **OR** ✓ (therefore) $mg\Delta h = \frac{1}{2}mv^2$ ✓ mass cancels ✓	3	Must imply that all GPE is transferred to KE. E.g. accept 'loss of GPE is gain in KE' but not: 'loses GPE and gains KE. Accept 'm's crossed out
			total	9	

7)

(a)	(i)	(u = 0, s = 0.16 m, a = 9.8(1) $m\,s^{-2}$) (rearranging $s = ut + ½\,at^2$ with u = 0 gives) $t^2 = \frac{2s}{a}$ or $v^2 = u^2 + 2gs$ or $0.16 = 1/2 \times 9.81\,t^2$ or $t_o = \sqrt{\frac{(2\times0.16)}{9.8(1)}}$ ✓ = **0.1804 or 0.1806 or 0.181** etc ✓ (s) **2 sf only** ✓	**5**
	(ii)	($v_o = u + at_o$ =) 0 + 9.81 × 0.18 ecf 3 (a) (i) or $v^2 = 2 \times 9.81 \times 0.16$ ✓ = 1.8 or 1.77 ($m\,s^{-1}$) ✓	

(b) **QWC**	the mark scheme for this part of the question includes an overall assessment for the Quality of Written Communication **descriptor**	 **mark range**
good - excellent	The candidate provides a correct description of the motion of the ball including its **deceleration in the fluid decreasing** and **becoming zero** (or attaining constant velocity). They should give a comprehensive and coherent explanation which includes nearly all the necessary principles in a logical order. In their explanation, the candidate should refer to the forces including their **directions** acting on the ball, why the **resistive force decreases** and why the acceleration becomes zero.	**5 - 6**
modest - adequate	The description should refer to the ball decelerating in the fluid until it becomes zero or attains **constant velocity**. Their explanation should be fairly coherent although it may not be comprehensive and may focus only on the forces acting when the ball attains constant velocity – **balanced forces** - or on the reason for the initial deceleration.	**3 - 4**
poor - limited	The candidate knows that the ball **decelerates** (acceleration with direction) or is acted on by an **upward** force (as well as the force of gravity). Their explanation of why the ball attains constant velocity may be absent. May be sketchy and lacks key considerations. They may not appreciate that the two forces are equal and opposite when the ball is moving at constant velocity.	**1 – 2**
incorrect, inappropriate or no response	No answer at all or answer refers to unrelated, incorrect or inappropriate physics.	**0**
	The explanation expected in a competent answer should include a coherent selection of the following physics ideas. The ball decelerates/slows down in the fluid ✓ if acceleration is used the direction must be specified • because a force due to fluid friction/resistance/viscosity acts (upwards) on the ball ✓ • (and) the force due to the fluid is greater than the weight of the ball ✓ • resistive force is upwards ✓ • resistive force decreases ✓ The deceleration decreases (to zero) ✓ • because the force due to fluid friction/resistance/viscosity decreases as the ball's speed decreases ✓ • until it is equal (and opposite) to the weight of the ball ✓ (or the resultant force is zero) • gradient of graph gives the acceleration and the ball moves at constant/terminal velocity/a=0 ✓	
	Total	**11**

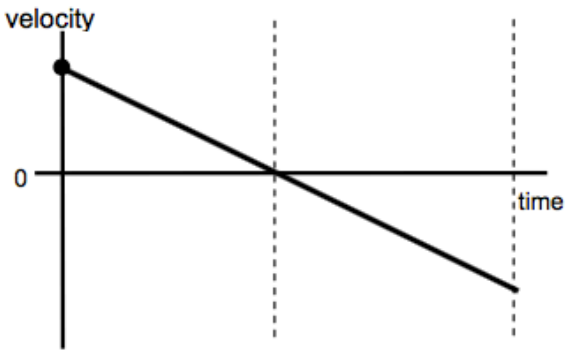
8)

(a)	($\Delta Ep = mg\Delta h$) = **55** × 9.8(1) × 4.2 ✓ = 2300 (J) ✓ (2266.1)	**2**
(b) (i)	(E_k = 3.2/4.2 x 2264 or uses suitable kinematics equation) = 1700(J) ✓ (= 1724.8 = 1720) ecf 4 (a)	**1**
(b) (ii)	($E_k = \frac{1}{2}mv^2$ = 1724.8) $v = \sqrt{\frac{2 \times 1724.8}{55}} = \sqrt{62.72}$ ecf (b) (i) or use of $v^2 = 2as$ ✓ = 7.9 m s^{-1} ✓ (= 7.9196)	**2**
(c)	one arrow, vertical, upward pointing, starts on soles of feet ✓	**1**
(d)	(use of $\alpha = \frac{\Delta v}{\Delta t}$ gives) = $\frac{7.920}{0.26}$ ✓ or ecf 4 (b) (ii)/0.26 = 30 ($m s^{-2}$) ✓ (30.46) **or use** $\alpha = \frac{2s}{t^2}$ of or $\alpha = \frac{v^2}{2s}$ ✓ allow incorrect values of *s* here = 29.6 or 31.4 respectively ✓	**2**

(e)	**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 answer is clearly organised, logical and coherent, using appropriate specialist vocabulary correctly. The form and style of writing is appropriate to answer the question. Candidate must state that: • (elastic potential) energy is transformed to **kinetic or** trampoline does work (on gymnast) • (KE) is transformed into (gravitational) **potential** energy • (the gymnast) must 'jump'/bend knees/do work/'use' chemical energy/supply energy (to increase height) For 6 marks, must also state that (the gymnast) must overcome resistive forces (drag/heat loss/reference to energy 'lost' in trampoline, etc) **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. Candidate must state **one** from: • chemical energy (transferred) to elastic, kinetic or gravitational energy • PE (from trampoline) to KE (of gymnast) • KE (gymnast) to (G)PE (gymnast) **and one** of the following: • work is done by the trampoline (on the gymnast) • that work is done on the trampoline (by the gymnast) • work done against resistive forces • (additional) energy input required (to achieve additional height) **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. Candidate must • give **one** relevant energy gain or loss in the system **or** state that energy is input to reach greater height For two marks, a relevant energy transformation must be given **or** one further marking point from next page	**max 6**

	Further marking points: • (to reach the same height) the gymnast must do work in order to replace the energy wasted as the springs and the trampoline (rubber) unload (contract) • to reach a greater height, the gymnast must do additional work by (bending and) extending her legs (jumping) as the trampoline moves upwards • the additional downward force keeps the trampoline extended for longer, thus increasing the impulse • correct reference to law of energy conservation	
	Total	**14**

9)

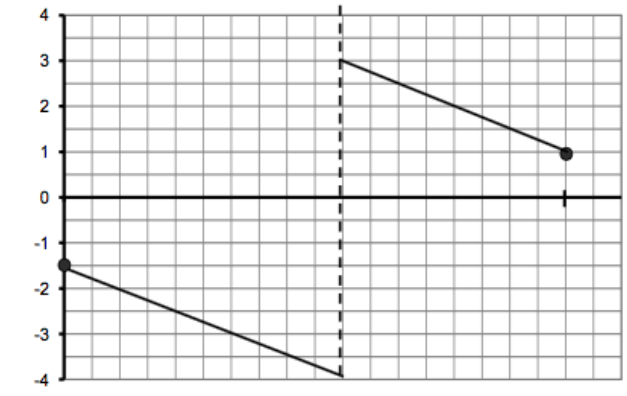
a	i	gradient (allow 'slope'/'**steepness of the line**') ✓	**1**
a	ii	 single straight line sloping down from X to t_2 ✓ passes through zero at t_1 ✓ increases to a maximum negative value at t_2 (ignore all lines beyond t_2) **or** allow line from zero at t_1 to a positive velocity at t_2 greater than the initial velocity ✓	**3**
b	i	**ball** exerts **force on ground and** ground exerts force (on ball)/reaction ✓ and **these** forces are **equal** and **opposite** ✓	**2**
(b)	ii	recognise that the downward force is the weight of the ball (accept gravity) ✓ recognition that the upward/reaction force (on the ball) is greater than the downward force on the ball ✓	**2**
		Total	**8**

10)

a	correct substitution in ($v^2 = u^2 + 2as$) **or** correct rearrangement $g = \frac{v^2}{2s}$ **or** $\frac{3.10^2}{2 \times 0.50}$ ✓ = 9.6 (9.61 m s^{-1}) ✓	**2**
b	$g = W/m$ **or** $W = mg$ (= ma) **and** weight is proportional to mass/doubling the mass doubles the weight/'masses cancel'/the factor of two cancels (so g remains the same) ✓	**1**
c	ball's acceleration will decrease/be less than cards **or** cards acceleration will be unaffected/nearly constant ✓ air resistance affects cards less **or** card is more streamlined **or** card does less work against air resistance ✓ **alternative** timing/(velocity/speed/acceleration) uncertain/(inaccurate /imprecise/less reliable) ✓ indication that full width of ball may not pass through gate/difficulty in determining 'length' of ball passing through gate ✓	**2**
	Total	**5**

11)

1a	Velocity and speed correct ✓ Distance and displacement correct ✓ velocity: vector ✓; speed: scalar ✓; distance: scalar ✓; displacement: vector ✓		2	
1bi	$v^2 = u^2 + 2as$ $v = \sqrt{u^2 + 2as}$ ✓ $v = \sqrt{1.5^2 + 2 \times 9.81 \times 0.65}$ ✓ = (-)3.9 (m s^{-1}) ✓two or more sig fig needed (- 3.87337 m s^{-1})	1st mark for equation rearranged to make v the subject (note sq' root may be implied by a later calculation) penalise the use of g = 10 m s^2 only on this question 2nd mark for substituting numbers into any valid equation 3rd mark for answer Alt' approach is gainKE=lossPE Missing out u gives zero marks Answer only gains one mark [Note it is possible to achieve the correct answer by a wrong calculation]	3	

1bii	 first line descends from X to the dotted line at t_A or up to one division sooner ✓ (allow line to curve) first line is straight and descends from X to v = -4 (m s^{-1}) ✓(allow tolerance one division) second line has same gradient as the first , straight and descends to v = 1(m s^{-1}) ✓ (tolerance ½ division) A steep line may join the two straight lines but its width must be less than 2 divisions		3	
1c	$s = ut + 1/2at^2$ $t = \sqrt{\frac{2s}{a}}$ OR correct substitution seen into either equation $t = \sqrt{\frac{2\times1.2}{9.81}}$ ✓ = 0.49 (s) ✓ (0.4946 s) $v = s/t$ = 5.0 / 0.49 = 10 (m s^{-1}) ✓ (10.2 m s^{-1}) (allow CE from their time)	working must be shown for the first mark but not the subsequent marks. [Note it is possible to achieve the correct answer by a wrong calculation]	3	