M1. (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 i 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 card's **or** card's 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

[5]

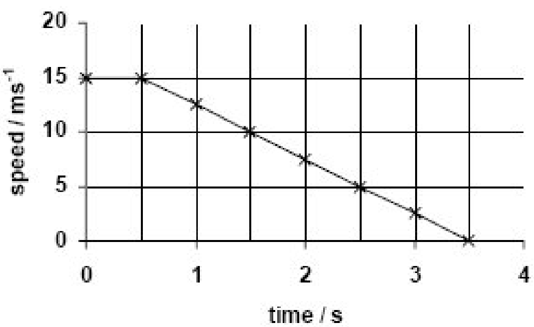
M2. (a) axes labelled correctly with correct units shown **(1)**

suitable scales **(1)**

6 points plotted correctly **(1)**

all points plotted correctly **(1)**

both sections of line drawn correctly **(1)**



5

(b) (i) the gradient (of the slope section) represents the deceleration/ calculates 5 m s^{-2} **(1)**

(deceleration is uniform because) the gradient is constant/ line is straight **(1)**

(ii) distance travelled = area under line (0 to 3.5 s or 0.5 to 3.5 s) **(1)**

(= 15.0 × 0.5) = 7.5 m in first 0.5 s **(1)**

(= 0.5 × 15.0 × 3.0) or s = ½(u + v)t, etc) = 22.5 m
(from 0.5s to 3.5s) **(1)**

(= ½(0.5 + 3.5) × 15 gets all three method marks)
(total distance travelled = 7.5 + 22.5) = 30m **(1)**

6

[11]

M3. (a) (i) car A: travels at constant speed **(1)**

(ii) car B: accelerates for first 5 secs (or up to 18 m s^{-1}) **(1)**
then travels at constant speed **(1)**

3

(b) (i) car A: distance = 5.0 × 16 **(1)**
= 80 m **(1)**

(ii) car B: (distance = area under graph)
distance = [5.0 × ½ (18 + 14)] **(1)**
= 80 m **(1)**

4

(c) car B is initially slower than car A (for first 2.5 s) **(1)**
distance apart therefore increases **(1)**
cars have same speed at 2.5 s**(1)**
after 2.5 s, car B travels faster than car A (or separation decreases) **(1)**

max 3

[10]

M4. (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 $t_0 = \sqrt{\frac{(2 \times 0.16)}{9.8(1)}}$ **(1)** = **0.1804 or 0.1806 or 0.181** etc **(1)**

(s) **2 sf only (1)**

(ii) ($v_0 = u + at_0 =$) 0 + 9.81 × 0.18 ecf (a) (i) or $v^2 = 2 \times 9.81 \times 0.16$ **(1)**
= 1.8 or 1.77 (m s^{-1}) **(1)**

5

(b) the mark scheme for this part of the question includes an overall assessment for the Quality of Written Communication

QWC	**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 **(1)** if acceleration is used the direction must be specified

- because a force due to fluid friction/resistance/viscosity acts (upwards) on the ball **(1)**
- (and) the force due to the fluid is greater than the weight of the ball **(1)**
- resistive force is upwards **(1)**
- resistive force decreases **(1)**

The deceleration decreases (to zero) **(1)**

- because the force due to fluid friction/resistance/viscosity decreases as the ball's speed decreases **(1)**
- until it is equal (and opposite) to the weight of the ball **(1)** (or the resultant force is zero)
- gradient of graph gives the acceleration and the ball moves at constant/terminal velocity/a = 0 **(1)**

[11]

M5. (a) (i) $v = \frac{s}{t}$ **(1)**

t = 0.015 (s) or 15 (ms) **(1)**

0.68/0.015 **(1)** (= 45)

3

(ii) $\left(a = \frac{\Delta v}{\Delta t} = \frac{45.3}{0.015}\right)$ = 3000 (m s^{-2}) (3022) **(1)**

1

(b) (i) $s = (ut) = \frac{1}{2}gt^2$ or $t = \sqrt{\frac{2s}{g}}$ **(1)**

correct substitution seen = $\sqrt{\frac{2 \times 2.3}{9.81}}$ **(1)**

0.68 to 0.69 correct answer to more than one dp seen **(1)**

3

(ii) ($s = vt$) = 45(.3) × 0.685 or 0.7 **(1)**

= 30.6 to 32 **(1)** (m)

2

(iii) mention of air resistance or drag **(1)**

causing **horizontal** deceleration or 'slowing down' **(1)**

2

[11]

M6. (a) (i) $t = \sqrt{\frac{2s}{g}}$ (evidence for correct rearrangement or substitution) **(1)**

$= \sqrt{\frac{2 \times 67}{9.81}}$ (correct substitution leading to answer) **(1)**

(= **3.7** (3.696) (s))

2

(ii) $\left(v = \frac{s}{t} = \frac{150}{3.696}\right)$ = **41** (m s^{-1}) **(1)** 2sf **(1)**

2

(iii) $(v = (u+)gt =) 9.81 \times 3.696$ **(1)** = **36** **(1)** (m s^{-1})

2

(iv) $v = \sqrt{40.586^2 + 36.257^2}$ (or correct scale drawing) **(1)**

= 54 (m s^{-1}) **(1)**

ecf from (ii) (iii) [for scale drawing allow range 53 → 56]

$\tan\theta = \frac{36.257}{40.586}$ **(1)** or correct alternative

(angle from horizontal =) **42** (°) or correct alternative angle
and clear indication of direction (1)

[for scale drawing allow range 40 → 44 **(1)**
for scale drawing: quality of construction **(1)**]

4

(b) (i) (= mgh = 22 × 9.81 × 67) = 14000 (14460) (J) **(1)**

1

(ii) (G)PE → KE **(1)**

(KE to) internal/thermal/'heat' (energy) **(1)**

2

[13]

M7. (a) velocity vector tangential to path and drawn from the ball, arrow in correct direction **(1)**

acceleration vector vertically downwards, arrow drawn and in line with ball **(1)**

2

(b) (i) $s = \frac{1}{2} gt^2$ gives $t = \sqrt{\frac{2y}{g}} = \sqrt{\frac{2 \times 24}{9.8(1)}}$ **(1)** = 2.2(1) s **(1)**

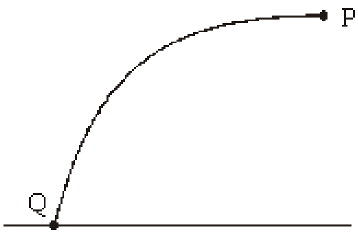
(ii) v (= s/t) = 27/2.2(1) **(1)** = 12(.2 m s^{-1}) or 12(.3) **(1)** (ecf from (b)(i))

(answer only gets both marks)

4

[6]

M8. (a) (i)



(1)

(ii) no **horizontal** force acting **(1)**
(hence) no (horizontal) acceleration **(1)**
[or correct application of Newton's First law]

3

(b) (i) (use of $v^2 = u^2 + 2as$ gives) $32^2 = (0) + 2 \times 9.81 \times s$ **(1)**

$s = \frac{1024}{19.62}$ **(1)** (= 52.2 m)

(ii) (use of $s = ½\, at^2$ gives) $52 = ½\ 9.81 \times t^2$ **(1)**

$t = \sqrt{\left(\frac{104}{9.81}\right)}$ = 3.3 s **(1)** (3.26 s)

[or use of $v = u + at$ gives $32 = (0) + 9.81 \times t$ **(1)**

$t = \frac{32}{9.81}$ = 3.3 s **(1)** **(**3.26 s)]

(iii) (use of $x = vt$ gives) × (= QR) = 95 × 3.26 **(1)**
= 310 m **(1)**

(use of t = 3.3 gives x = 313.5 m)
(allow C.E. for value of t from (ii**)**

6

(c) maximum height is greater **(1)**
because vertical acceleration is less **(1)**
[or longer to accelerate]

2

[11]

M9. (a) potential energy to kinetic energy **(1)**
mention of thermal energy and friction **(1)**

2

(b) (use of ½ $mv^2 = mgh$ gives) ½ $v_h^2 = 9.81 \times 1.5$ **(1)**

$v_h = 5.4(2)\text{ms}^{-1}$ **(1)**

(assumption) energy converted to thermal energy is negligible **(1)**

3

(c) component of weight down the slope causes acceleration **(1)**
this component decreases as skateboard moves further down the slope **(1)** air resistance/friction increases (with speed) **(1)**

2

(d) (i) distance (= 0.42 × 5.4) = 2.3m **(1)**
(2.27m)
(allow C.E. for value of v_h from (b))

(ii) v_v 9 8 × 0 42 **(1)**
= 4.1(l) m s^{-1} **(1)**

(iii) $v^2 = 4.1^2 + 5.4^2$ **(1)**
v = 6.8 m s^{-1} **(1)**
(6.78 m s^{-1})
(allow C.E. for value of v_h from (b))

5

[12]

M10. (a) suitable calculation using a pair of values of *x* and corresponding *t* to give an average of 2.2 m s^{-1} (± 0.05 m s^{-1}) **(1)**
valid reason given **(1)**
(e.g. larger values are more reliable/accurate
or use of differences eliminates zero errors)

2

(b) (i) column D (y/t (cm s^{-1})
186
210
233
259
284
307

all values correct to 3 s.f. **(1)**

(ii) graph: chosen graph gives a straight line (e.g. y/t against t) **(1)**
axes labelled correctly **(1)**
suitable scale chosen **(1)**
minimum of four points correctly plotted **(1)**
best straight line **(1)**

(iii) u (y intercept) 162 cm $^{-1}$ (± 4 cm $^{-1}$) **(1)**
gradient = 495 (cm s^{-2}) (± 25 cm s^{-2}) **(1)**
k = gradient (= 495 cm s^{-2}) **(1)**

9

(c) (i) u : initial vertical component of velocity **(1)**

(ii) k : = ½ g **(1)**

2

(d) $v^2 = u^2 + 2.2^2$ **(1)**

gives $v = (1.62^2 + 2.2^2)^{1/2} = 2.7$ m s^{-1} (± 0.1 m s^{-1}) **(1)**

2

[15]