MECHANICS

9709

(March, June, and November series 2020 – 2023 with Marking Scheme)

Momentum

Exercise - 1

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1. Three small smooth spheres A, B and C of equal radii and of masses 4 kg, 2 kg and 3 kg respectively, lie in that order in a straight line on a smooth horizontal plane. Initially, B and C are at rest and A is moving towards B with speed $6\,\text{m}\,\text{s}^{-1}$. After the collison with B, sphere A continues to move in the same direction but with speed $2\,\text{m}\,\text{s}^{-1}$.

(a) Find the speed of B after this collison. [2]

Sphere B collides with C. In this collison these two spheres coalesce to form an object D.

(b) Find the speed of D after this collision. [2]

(c) Show that the total loss of kinetic energy in the system due to the two collisions is 38.4 J. [2]

Question 3: 9709_y20_sp_4

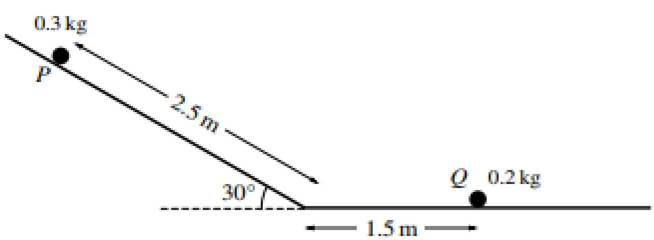
2. On a straight horizontal test track, driverless vehicles (with no passengers) are being tested. A car of mass 1600 kg is towing a trailer of mass 700 kg along the track. The brakes are applied, resulting in a deceleration of $12\,\text{m}\,\text{s}^{-2}$. The braking force acts on the car only. In addition to the braking force there are constant resistance forces of 600 N on the car and of 200 N on the trailer.

(d) After the collision, the van starts to move with speed $5\,\text{m}\,\text{s}^{-1}$ and the car and trailer continue moving in the same direction with speed $2\,\text{m}\,\text{s}^{-1}$.

Find the mass of the van. [3]

Question 6(d): 9709_m20_qp_42

3.



A particle P of mass 0.3 kg, lying on a smooth plane inclined at 30° to the horizontal, is released from rest. P slides down the plane for a distance of 2.5 m and then reaches a horizontal plane. There is no change in speed when P reaches the horizontal plane. A particle Q of mass 0.2 kg lies at rest on the horizontal plane 1.5 m from the end of the inclined plane (see diagram). P collides directly with Q.

(a) It is given that the horizontal plane is smooth and that, after the collision, P continues moving in the same direction, with speed $2\,\text{m}\,\text{s}^{-1}$.

Find the speed of Q after the collision. [5]

(b) It is given instead that the horizontal plane is rough and that when P and Q collide, they coalesce and move with speed $1.2\,\text{m}\,\text{s}^{-1}$.

Find the coefficient of friction between P and the horizontal plane. [5]

Question 7: 9709_s20_qp_41

4. Small smooth spheres A and B, of equal radii and of masses 4 kg and 2 kg respectively, lie on a smooth horizontal plane. Initially B is at rest and A is moving towards B with speed $10\,\text{m s}^{-1}$. After the spheres collide A continues to move in the same direction but with half the speed of B.

(a) Find the speed of B after the collision. [2]

A third small smooth sphere C, of mass 1 kg and with the same radius as A and B, is at rest on the plane. B now collides directly with C. After this collision B continues to move in the same direction but with one third the speed of C.

(b) Show that there is another collision between A and B. [3]

(c) A and B coalesce during this collision.

Find the total loss of kinetic energy in the system due to the three collisions. [5]

Question 4: 9709_s20_qp_42

5. Particles P of mass m kg and Q of mass 0.2 kg are free to move on a smooth horizontal plane. P is projected at a speed of $2\,\text{m s}^{-1}$ towards Q which is stationary. After the collision P and Q move in opposite directions with speeds of $0.5\,\text{m s}^{-1}$ and $1\,\text{m s}^{-1}$ respectively.

Find m. [3]

Question 1: 9709_s20_qp_43

6. A particle B of mass 5 kg is at rest on a smooth horizontal table. A particle A of mass 2.5 kg moves on the table with a speed of $6\,\text{m s}^{-1}$ and collides directly with B. In the collision the two particles coalesce.

(a) Find the speed of the combined particle after the collision. [2]

(b) Find the loss of kinetic energy of the system due to the collision. [3]

Question 1: 9709_w20_qp_41

7. Two particles P and Q, of masses 0.2 kg and 0.5 kg respectively, are at rest on a smooth horizontal plane. P is projected towards Q with speed $2\,\text{m s}^{-1}$.

(a) Write down the momentum of P. [1]

(b) After the collision P continues to move in the same direction with speed $0.3\,\text{m s}^{-1}$.

Find the speed of Q after the collision. [2]

Question 1: 9709_w20_qp_42

8. Two small smooth spheres A and B, of equal radii and of masses 4 kg and m kg respectively, lie on a smooth horizontal plane. Initially, sphere B is at rest and A is moving towards B with speed $6\,\text{m s}^{-1}$. After the collision A moves with speed $1.5\,\text{m s}^{-1}$ and B moves with speed $3\,\text{m s}^{-1}$.

Find the two possible values of the loss of kinetic energy due to the collision. [6]

Question 4: 9709_w20_qp_43

9. Two particles P and Q of masses 0.2 kg and 0.3 kg respectively are free to move in a horizontal straight line on a smooth horizontal plane. P is projected towards Q with speed $0.5\ \mathrm{m\,s^{-1}}$. At the same instant Q is projected towards P with speed $1\ \mathrm{m\,s^{-1}}$. Q comes to rest in the resulting collision.

Find the speed of P after the collision. [3]

Question 1: 9709_m21_qp_42

10. Three particles P, Q and R, of masses 0.1 kg, 0.2 kg and 0.5 kg respectively, are at rest in a straight line on a smooth horizontal plane. Particle P is projected towards Q at a speed of $5\ \mathrm{m\,s^{-1}}$. After P and Q collide, P rebounds with speed $1\ \mathrm{m\,s^{-1}}$.

(a) Find the speed of Q immediately after the collision with P. [3]

Q now collides with R. Immediately after the collision with Q, R begins to move with speed $V\ \mathrm{m\,s^{-1}}$.

(b) Given that there is no subsequent collision between P and Q, find the greatest possible value of V. [3]

Question 3: 9709_s21_qp_41

11. A particle A is projected vertically upwards from level ground with an initial speed of $30\ \mathrm{m\,s^{-1}}$. At the same instant a particle B is released from rest 15 m vertically above A. The mass of one of the particles is twice the mass of the other particle. During the subsequent motion A and B collide and coalesce to form particle C.

Find the difference between the two possible times at which C hits the ground. [8]

Question 6: 9709_s21_qp_42

12 Particles P of mass 0.4 kg and Q of mass 0.5 kg are free to move on a smooth horizontal plane. P and Q are moving directly towards each other with speeds $2.5\ \mathrm{m\,s^{-1}}$ and $1.5\ \mathrm{m\,s^{-1}}$ respectively. After P and Q collide, the speed of Q is twice the speed of P.

Find the two possible values of the speed of P after the collision. [4]

Question 1: 9709_s21_qp_43

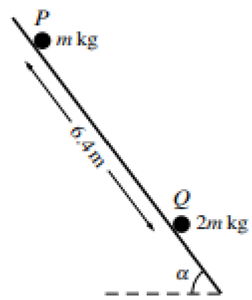
13. Two small smooth spheres A and B, of equal radii and of masses km kg and m kg respectively, where $k > 1$, are free to move on a smooth horizontal plane. A is moving towards B with speed $6\ \mathrm{m\,s^{-1}}$ and B is moving towards A with speed $2\ \mathrm{m\,s^{-1}}$. After the collision A and B coalesce and move with speed $4\ \mathrm{m\,s^{-1}}$.

(a) Find k. [3]

(b) Find, in terms of m, the loss of kinetic energy due to the collision. [2]

Question 2: 9709_w21_qp_41

14.



Particles P and Q have masses m kg and $2m$ kg respectively. The particles are initially held at rest 6.4 m apart on the same line of greatest slope of a rough plane inclined at an angle α to the horizontal, where $\sin\alpha = 0.8$ (see diagram). Particle P is released from rest and slides down the line of greatest slope. Simultaneously, particle Q is projected up the same line of greatest slope at a speed of $10\,\mathrm{m\,s^{-1}}$. The coefficient of friction between each particle and the plane is 0.6.

(a) Show that the acceleration of Q up the plane is $-11.6\,\mathrm{m\,s^{-2}}$. [4]

(b) Find the time for which the particles are in motion before they collide. [5]

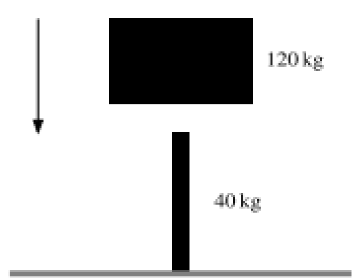
(c) The particles coalesce on impact.

Find the speed of the combined particle immediately after the impact. [4]

Question 7: 9709_w21_qp_42

15.

3



A metal post is driven vertically into the ground by dropping a heavy object onto it from above. The mass of the object is 120 kg and the mass of the post is 40 kg (see diagram). The object hits the post with speed $8\,\mathrm{m\,s^{-1}}$ and remains in contact with it after the impact.

(a) Calculate the speed with which the combined post and object moves immediately after the impact. [2]

(b) There is a constant force resisting the motion of magnitude 4800 N.

Calculate the distance the post is driven into the ground. [3]

Question 1: 9709_w21_qp_43

16. A bead, A, of mass 0.1 kg is threaded on a long straight rigid wire which is inclined at $\sin^{-1}(\frac{7}{25})$ to the horizontal. A is released from rest and moves down the wire. The coefficient of friction between A and the wire is μ. When A has travelled 0.45 m down the wire, its speed is $0.6\,\text{m s}^{-1}$.

(a) Show that $\mu = 0.25$. [6]

Another bead, B, of mass 0.5 kg is also threaded on the wire. At the point where A has travelled 0.45 m down the wire, it hits B which is instantaneously at rest on the wire. A is brought to instantaneous rest in the collision. The coefficient of friction between B and the wire is 0.275.

(b) Find the time from when the collision occurs until A collides with B again. [6]

Question 7: 9709_m22_qp_42

17. Two particles A and B, of masses 0.4 kg and 0.2 kg respectively, are moving down the same line of greatest slope of a smooth plane. The plane is inclined at 30° to the horizontal, and A is higher up the plane than B. When the particles collide, the speeds of A and B are $3\,\text{m s}^{-1}$ and $2\,\text{m s}^{-1}$ respectively. In the collision between the particles, the speed of A is reduced to $2.5\,\text{m s}^{-1}$.

(a) Find the speed of B immediately after the collision. [2]

After the collision, when B has moved 1.6 m down the plane from the point of collision, it hits a barrier and returns back up the same line of greatest slope. B hits the barrier 0.4 s after the collision, and when it hits the barrier, its speed is reduced by 90%. The two particles collide again 0.44 s after their previous collision, and they then coalesce on impact.

(b) Show that the speed of B immediately after it hits the barrier is $0.5\,\text{m s}^{-1}$. Hence find the speed of the combined particle immediately after the second collision between A and B. [7]

Question 7: 9709_s22_qp_41

18. Small smooth spheres A and B, of equal radii and of masses 5 kg and 3 kg respectively, lie on a smooth horizontal plane. Initially B is at rest and A is moving towards B with speed $8.5\,\text{m s}^{-1}$. The spheres collide and after the collision A continues to move in the same direction but with a quarter of the speed of B.

(a) Find the speed of B after the collision. [3]

(b) Find the loss of kinetic energy of the system due to the collision. [2]

Question 1: 9709_s22_qp_42

19. Two particles P and Q, of masses 0.3 kg and 0.2 kg respectively, are at rest on a smooth horizontal plane. P is projected at a speed of $4\,\text{m s}^{-1}$ directly towards Q. After P and Q collide, Q begins to move with a speed of $3\,\text{m s}^{-1}$.

(a) Find the speed of P after the collision. [2]

After the collision, Q moves directly towards a third particle R, of mass m kg, which is at rest on the plane. The two particles Q and R coalesce on impact and move with a speed of $2\,\text{m s}^{-1}$.

(b) Find m. [2]

Question 1: 9709_s22_qp_43

20. Small smooth spheres A and B, of equal radii and of masses 6 kg and 2 kg respectively, lie on a smooth horizontal plane. Initially A is moving towards B with speed $5\,\mathrm{m\,s^{-1}}$ and B is moving towards A with speed $3\,\mathrm{m\,s^{-1}}$. After the spheres collide, both A and B move in the same direction and the difference in the speeds of the spheres is $2\,\mathrm{m\,s^{-1}}$.

Find the loss of kinetic energy of the system due to the collision. [5]

Question 2: 9709_w22_qp_41

21. Three particles A, B and C of masses 0.3 kg, 0.4 kg and m kg respectively lie at rest in a straight line on a smooth horizontal plane. The distance between B and C is 2.1 m. A is projected directly towards B with speed $2\,\mathrm{m\,s^{-1}}$. After A collides with B the speed of A is reduced to $0.6\,\mathrm{m\,s^{-1}}$, still moving in the same direction.

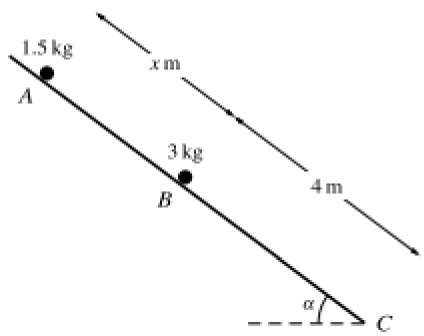
(a) Show that the speed of B after the collision is $1.05\,\mathrm{m\,s^{-1}}$. [2]

After the collision between A and B, B moves directly towards C. Particle B now collides with C. After this collision, the two particles coalesce and have a combined speed of $0.5\,\mathrm{m\,s^{-1}}$.

(b) Find m. [2]

Question 6: 9709_w22_qp_42

22.



Particles of masses 1.5 kg and 3 kg lie on a plane which is inclined at an angle of α to the horizontal, where $\tan\alpha = \frac{3}{4}$. The section of the plane from A to B is smooth and the section of the plane from B to C is rough. The 1.5 kg particle is held at rest at A and the 3 kg particle is in limiting equilibrium at B. The distance AB is x m and the distance BC is 4 m (see diagram).

(a) Show that the coefficient of friction between the particle at B and the plane is 0.75. [3]

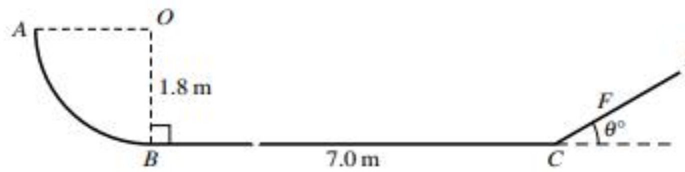
The 1.5 kg particle is released from rest. In the subsequent motion the two particles collide and coalesce. The time taken for the combined particle to travel from B to C is 2 s. The coefficient of friction between the combined particle and the plane is still 0.75.

(b) Find x. [6]

(c) Find the total loss of energy of the particles from the time the 1.5 kg particle is released until the combined particle reaches C. [3]

Question 7: 9709_w22_qp_41

23.



The diagram shows a smooth track which lies in a vertical plane. The section AB is a quarter circle of radius 1.8 m with centre O. The section BC is a horizontal straight line of length 7.0 m and OB is perpendicular to BC. The section CFE is a straight line inclined at an angle of $\theta°$ above the horizontal.

A particle P of mass 0.5 kg is released from rest at A. Particle P collides with a particle Q of mass 0.1 kg which is at rest at B. Immediately after the collision, the speed of P is $4\,\text{m s}^{-1}$ in the direction BC. You should assume that P is moving horizontally when it collides with Q.

(a) Show that the speed of Q immediately after the collision is $10\,\text{m s}^{-1}$. [4]

When Q reaches C, it collides with a particle R of mass 0.4 kg which is at rest at C. The two particles coalesce. The combined particle comes instantaneously to rest at F. You should assume that there is no instantaneous change in speed as the combined particle leaves C, nor when it passes through C again as it returns down the slope.

(b) Given that the distance CF is 0.4 m, find the value of θ. [4]

(c) Find the distance from B at which P collides with the combined particle. [5]

Question 7: 9709_m23_qp_42

24. Two particles P and Q, of masses m kg and 0.3 kg respectively, are at rest on a smooth horizontal plane. P is projected at a speed of $5\,\text{m s}^{-1}$ directly towards Q. After P and Q collide, P moves with a speed of $2\,\text{m s}^{-1}$ in the same direction as it was originally moving.

(a) Find, in terms of m, the speed of Q after the collision. [2]

After this collision, Q moves directly towards a third particle R, of mass 0.6 kg, which is at rest on the plane. Q is brought to rest in the collision with R, and R begins to move with a speed of $1.5\,\text{m s}^{-1}$.

(b) Find the value of m. [2]

Question 1: 9709_s23_qp_41

25. Two particles A and B, of masses 3.2 kg and 2.4 kg respectively, lie on a smooth horizontal table. A moves towards B with a speed of $v\,\text{m s}^{-1}$ and collides with B, which is moving towards A with a speed of $6\,\text{m s}^{-1}$. In the collision the two particles come to rest.

(a) Find the value of v. [2]

(b) Find the loss of kinetic energy of the system due to the collision. [2]

Question 2: 9709_s23_qp_42

26. Two particles P and Q, of masses 0.1 kg and 0.4 kg respectively, are free to move on a smooth horizontal plane. Particle P is projected with speed $4\,\text{m s}^{-1}$ towards Q which is stationary. After P and Q collide, the speeds of P and Q are equal.

Find the two possible values of the speed of P after the collision. [3]

Question 1: 9709_s23_qp_43

MARKING SCHEME

1.

Answer	Marks	Partial Marks	Guidance
Conservation of momentum $4 \times 6\ [+0] = 4 \times 2 + 2v$	1	**M1**	For applying conservation of momentum
$v = 8\,[\text{m s}^{-1}]$	1	**A1**	
	2		
$2 \times$ their (8) $[+0] = 2v + 3v$	1	**M1**	For applying conservation of momentum
$v = 3.2\,[\text{m s}^{-1}]$	1	**A1**	
	2		
Kinetic energy (KE) initial $= \frac{1}{2} \times 4 \times 6^2$ KE final $= \frac{1}{2} \times 4 \times 2^2 + \frac{1}{2} \times 5 \times 3.2^2$	1	**M1**	For use of $\frac{1}{2} \times m \times v^2$, when either initial or final calculation correct using their value from **(b)**
Loss of KE $= 72 - 33.6 = 38.4$ [J]	1	**A1**	AG For all correct
	2		

2.

$[2300 \times 8 + m \times 0 = 2300 \times 2 + m \times 5]$	**M1**	For applying the conservation of momentum equation to the system of car, trailer and van, where m = mass of the van
	A1	Correct equation
$m = 2760$ kg	**A1**	
	3	

3.

$0.3g\sin 30 = 0.3a$ $(a = 5)$ (**M1** for applying Newton's second law parallel to the plane)	**M1**
$v^2 = 0 + 2 \times 2.5 \times a$	**M1**
$v = 5$	**A1**
$0.3 \times 5 + 0 = 0.3 \times 2 + 0.2\,w$	**M1**
Velocity of $Q = 4.5\ \text{ms}^{-1}$	**A1**
	5

Answer	Marks
$0.3\times z+0=0.5\times 1.2$	M1
Velocity of P before collision $z=2$	A1
Friction force on P after reaches horizontal plane $F=\mu\times 0.3\,g$	B1
$\mu\times 0.3g\times 1.5=\frac{1}{2}\times 0.3\times 5^2-\frac{1}{2}\times 0.3\times 2^2$	M1
Coefficient $\mu=0.7$	A1
Alternative method for question 7(b)	
$0.3\times z+0=0.5\times 1.2$	M1
Velocity of P before collision $z=2$	A1
Friction force on P after reaches horizontal plane $F=\mu\times 0.3\,g$	B1
$a=(5^2-2^2)/(2\times 1.5)=7$, $F=0.3\times 7$	M1
Coefficient $\mu=0.7$	A1
	5

4.

$4\times 10\,[+0]=4\times 0.5v+2v$	M1
$v_A=5$ and $v_B=10$	A1
	2
Conservation of momentum B, C $2\times 10\,[+0]=2\times v+3v$	M1
$v=4$	A1
$v_A>v_B$, hence another collision	A1
	3
Conservation of momentum A, B	M1
$4\times their5+2\times their4=4v+2v$ $\quad v=\frac{14}{3}$ (ms^{-1})	A1
KE initial $=\frac{1}{2}\times 4\times 10^2$	M1
KE final $=\frac{1}{2}\times 6\times their(\frac{14}{3})^2+\frac{1}{2}\times 1\times their12^2$	A1
Loss of KE $=200-\frac{412}{3}=\frac{188}{3}$	A1
	5

5.

Use of conservation of momentum	**M1**
$m \times 2 + 0 = m \times (-0.5) + 0.2 \times 1$	**A1**
$m = 0.08$	**A1**
	3

6.

$6 \times 2.5 = 2.5v + 5v$	**M1**	Apply conservation of momentum, 3 terms implied
$v = 2\ \text{ms}^{-1}$	**A1**	
	2	
Use KE = ½ mv^2 either before or after collision	**M1**	Allow this for either particle
KE(before) = $0.5 \times 2.5 \times 6^2$ KE(after) = $0.5 \times 7.5 \times 2^2$	**A1 FT**	Both correct FT on v
Loss of KE = 30 J	**A1**	
	3	

7.

Momentum = $0.2 \times 2 = 0.4\ \text{kg ms}^{-1}$	**B1**	
	1	
$0.4 = 0.2 \times 0.3 + 0.5v$	**M1**	Apply conservation of momentum, 3 terms
$v = 0.68\ \text{ms}^{-1}$	**A1 FT**	FT on answer in **1(a)**
	2	

8.

For using conservation of momentum (either case)	**M1**	
$6 \times 4 = 3m + 4 \times 1.5$ **or** $6 \times 4 = 3m - 4 \times 1.5$	**A1**	
$m = 6$ **and** $m = 10$	**A1**	
KE_A initial = $½ \times 4 \times 6^2$ (72 J) or KE_A after = $½ \times 4 \times 1.5^2$ (4.5 J) or KE_B after = $½ \times 6 \times 3^2$ (27 J) or KE_B after = $½ \times 10 \times 3^2$ (45 J)	**B1 FT**	KE = $½ \times m \times v^2$ FT $4.5m$ for KE_B
KE loss = $[½ \times 4 \times 6^2 - ½ \times 4 \times 1.5^2 - ½ \times 6 \times 3^2]$ or $[½ \times 4 \times 6^2 - ½ \times 4 \times 1.5^2 - ½ \times 10 \times 3^2]$	**M1**	Uses KE loss = KE before – KE after
Loss of KE = 40.5 J or 22.5 J	**A1**	
	6	

9.

±0.2 × 0.5 or ±0.3 × 1	**B1**	For initial momentum for either particle. Allow kg or g.
$0.2 \times 0.5 + 0.3 \times (-1) = 0.2 \times v + 0$	**M1**	For conservation of momentum. Dimensions correct. Allow if 3 relevant momentum terms are seen regardless of sign.
Speed = 1 m s^{-1}	**A1**	Allow if final answer given as $v = 1$ or speed = 1 from an equation whose solution is $v = -1$
	3	

10.

Use of conservation of momentum, 3 terms	**M1**	Correct dimensions
$0.1 \times 5 + 0 = 0.1 \times (-1) + 0.2 \times (\pm v)$	**A1**	
$v = 3$ m s^{-1}	**A1**	A0 for $v = -3$
	3	
$0.2 \times \textit{their}\, 3 + 0 = 0.2 \times u + 0.5V$	**M1**	Use of conservation of momentum, 3 terms, correct dimensions. Allow $u = 0$ used or if Q and R coalesce
$u \geqslant -1$	**B1**	Allow $u = -1$. Allow equality for finding greatest value of V. Condition for no collision with P, may be a statement.
Greatest $V = 1.6$	**A1 FT**	FT on *their* 3 from **3(a)** if $u = -1$ used.
	3	

11.

Answer	Marks	Guidance
$s_A = \pm(30t - 5t^2)$ or $s_B = \pm 5t^2$	**B1**	Use of constant acceleration equations to find expressions for displacements of *A* or *B*.
$s_A + s_B = 15$ leading to $15 = 30t$ leading to $t = 0.5$	**B1**	Use $s_A + s_B = 15$ to find time at which particles collide.
$t = 0.5$ leading to $v_A = \pm 25$ and $v_B = \pm 5$	**B1**	Find speed of particles at $t = 0.5$ before collision.
$t = 0.5$ leading to $h_A = \pm\left(30 \times 0.5 - \frac{1}{2} g \times 0.5^2\right) = \pm 13.75$	**B1**	Find position of *A* or *B* at which collision occurs at $t = 0.5$ Alternatively allow $h_B = \pm 1.25$ as displacement of *B*
$25 \times (2m) - 5(m) = (3m)v \rightarrow v_1 = 15$ $25(m) - 5 \times (2m) = (3m)v \rightarrow v_2 = 5$	**M1**	Use of conservation of momentum, either case, using *their* v_A and $v_B \neq 0$ or 30, with 3 terms.
	A1	Both values of v correct

Answer	Marks	Guidance
Particle C_1 $-13.75 = 15t - 5t^2$ Particle C_2 $-13.75 = 5t - 5t^2$	**M1**	Use of $s = ut + \frac{1}{2}at^2$ OE to find *t*, using either *their* numerical v_1 or numerical v_2 from a relevant conservation of momentum equation.
$t_{C_1}, t_{C_2} = 3.74, 2.23$ leading to $T = 1 + \sqrt{5} - \sqrt{3} = 1.50$	**A1**	Find $T = t_{C_1} - t_{C_2}$ from $t_{C_1} = 3.736$ and $t_{C_2} = 2.232$
	8	Subscripts 1 and 2 refer to the two cases.
Alternative method for the final two marks		
$0 = 15 - gt_1$, $0 = 5 - gt_2 \rightarrow t_1 = 1.5$, $t_2 = 0.5$ Total heights $h_1 = 13.75 + 11.25 = 25$ Or $h_2 = 13.75 + 1.25 = 15$ $25 = 5T_1^2$ and $15 = 5T_2^2 \rightarrow T_1 = \sqrt{5}$, $T_2 = \sqrt{3}$	**M1**	Use of $v = u - gt$ to find time to highest point for either case and use of $v^2 = u^2 - 2gs$ to find total height reached for either case, using either *their* numerical v_1 or numerical v_2 from a relevant conservation of momentum equation. Use $s = 0 + \frac{1}{2}gT^2$ to find time to reach ground (either case).
$T = 1.5 + \sqrt{5} - (0.5 + \sqrt{3}) = 1 + \sqrt{5} - \sqrt{3} = 1.50$	**A1**	Find difference in total times $T = (t_1 + T_1) - (t_2 + T_2)$

12.

0.4 × 2.5 – 0.5 × 1.5	**M1**	Attempt momentum before impact.
0.4 × 2.5 – 0.5 × 1.5 = 0.4*v* + 0.5 × 2*v*	**M1**	Use of conservation of momentum, either case.
0.4 × 2.5 – 0.5 × 1.5 = 0.4*v* + 0.5 × 2*v* or 0.4 × 2.5 – 0.5 × 1.5 = –0.4*v* + 0.5 × 2*v*	**A1**	One correct equation
Speed is 0.179 m s^{-1} or 0.417 m s^{-1}	**A1**	Both values
	4	

13.

Answer	Marks	Guidance
Attempt at use of conservation of momentum	M1	4 terms implied, i.e. *m* and *km* included before and after collision. Velocity after collision is the same for *m* and *km*.
$km \times 6 - m \times 2 = (km + m) \times 4$	A1	
$k = 3$	A1	
	3	
KE initial = $\frac{1}{2} \times km \times 6^2 + \frac{1}{2} \times m \times (-2)^2$ KE after = $\frac{1}{2} \times (km + m) \times 4^2$	M1	Attempt at any of the three possible KE terms, unsimplified. *k* need not be substituted here.
Loss of KE = $24m$ J	A1 FT	KE loss = $56m - 32m$ FT on *their* k, KE loss $= (10k - 6)m$, $k > 0.6$.
	2	

14.

For *Q*: $-2mg \sin \alpha - F = 2ma \quad [-16m - 7.2m = 2ma]$ $R = 2mg \cos \alpha \quad [= 12m]$	M1	Apply Newton's 2nd law along or perpendicular to the plane to particle *Q*. Must use values for α or sin α or cos α.
	A1	Both correct.
$F = 0.6 \times 2mg \cos \alpha = 0.6 \times 0.6 \times 20m$ [$= 7.2m$] [$2(m)a = -2(m)g\,(0.8) - 0.6 \times 2(m)g\,(0.6)$]	M1	Using $F = 0.6R$ where R is a component of $2mg$ only
Acceleration of *Q* up the plane while moving up the plane is $a = -11.6$ ms^{-2}	A1	**AG**
	4	
For *P*: $mg \sin \alpha - 0.6R = ma$, leading to $8m - 3.6m = ma$ [$R = mg \cos \alpha = 6m,\ a = 4.4$ ms^{-2}]	M1	Apply Newton's 2nd law to attempt to find the acceleration of particle *P*. Must use values for α or sin α.
Q comes to rest when $10 - 11.6T_1 = 0$, $\left[T_1 = \frac{25}{29} = 0.862\right]$	M1	For using constant acceleration equations to attempt to determine when $v_Q = 0$.
For *P* $\quad s_{P(\text{down})} = \frac{1}{2} \times 4.4 \times T_1^2 \quad [=1.635]$ For *Q* $\quad s_{Q(\text{up})} = 10T_1 + \frac{1}{2} \times (-11.6) \times T_1^2 \quad [=4.31]$	M1	Use constant acceleration equations to attempt to find either $s_{P(\text{down})}$ or $s_{Q(\text{up})}$ at time T_1.
$d = 6.4 - s_{P(down)} - s_{Q(up)} \quad [=0.455]$ and to find T_2 $[=0.12]$ by using $d = s_{P2} - s_{Q2} = (4.4T_1) \times T_2$ [s_{P2} and s_{Q2} are distances travelled by *P* and *Q* in time T_2]	M1	For attempting to find the extra distance $d\,[=0.455]$ needed to reach 6.4 m and using $u_P = 4.4T_1$ at T_1 to find T_2 as $d = (4.4T_1)T_2 + \frac{1}{2} \times 4.4T_2^2 - \frac{1}{2} \times 4.4T_2^2$.
Time before collision = $[t = T_1 + T_2 = 0.862 + 0.12 =]\,0.982$	A1	$t = 0.98194357\ldots$

Alternative method for Question 7(b)		
For P: $mg\sin\alpha - 0.6R = ma$, leading to $8m - 3.6m = ma$ $[R = mg\cos\alpha = 6m, a = 4.4 \text{ ms}^{-2}]$	**M1**	Apply Newton's 2nd law to attempt to find the acceleration of particle P. Must use values for α or $\sin\alpha$
Q comes to rest when $10 - 11.6T_1 = 0$, $\left[T_1 = \frac{25}{29} = 0.862\right]$	**M1**	For using constant acceleration equations to attempt to determine when $v_Q = 0$
For P $s_{P(\text{down})} = \frac{1}{2} \times 4.4 \times t^2$ For Q $s_{Q(\text{up})} = 10T_1 + \frac{1}{2} \times (-11.6)T_1^2 - \frac{1}{2} \times 4.4(t - T_1)^2$	**M1**	Use constant acceleration equations to attempt to find either $s_{P(\text{down})}$ or $s_{Q(\text{up})}$ at time t where t is the total time before collision.
$\frac{1}{2} \times 4.4t^2 + 10T_1 + \frac{1}{2} \times (-11.6)T_1^2 - \frac{1}{2} \times 4.4(t - T_1)^2 = 6.4$	**M1**	For using $s_{P(\text{down})} + s_{Q(\text{up})} = 6.4$ and solving for t
Time before collision is $t = 0.982$ s	**A1**	$t = 0.98194357\ldots$
	5	
Special case for those who do not take into account the fact that Q comes to rest and then changes its direction		
For P: $mg\sin\alpha - 0.6R = ma$, leading to $8m - 3.6m = ma$ $[R = mg\cos\alpha = 6m, a = 4.4 \text{ ms}^{-2}]$	**M1**	Apply Newton's 2nd law to attempt to find the acceleration of particle P. Must use values for α or $\sin\alpha$.
For P $s_{p(\text{down})} = (\pm)\frac{1}{2} \times 4.4t^2$ For Q $s_{q(\text{up})} = (\pm)\ 10t + \frac{1}{2} \times (-11.6)t^2$	**M1**	For using constant acceleration equations to attempt to find either $s_{p(\text{down})}$ or $s_{q(\text{up})}$.
$s_p + s_q = 6.4$ leading to $\frac{1}{2} \times 4.4t^2 + 10t + \frac{1}{2} \times (-11.6)t^2 = 6.4$	**M1**	For applying $(\pm)\ s_p + (\pm)\ s_q = 6.4$ using their expressions for s_p and s_q to set up and solve a 3-term quadratic equation in t to obtain at least 1 solution.

Time that particles are in motion before collision $= t = 1$ s	**A1**	Must reject $t = 16/9$ **Maximum mark 4 out of 5**
	4	
$u_{p(\text{down})} = 0 + 4.4 \times 0.982\ [= 4.3208]$	**B1 FT**	Allow ±4.4. FT on *their* 4.4 and *their* 0.982
$u_{q(\text{down})} = 4.4 \times 0.12\ [= 0.528]$	**B1 FT**	Allow ±4.4. FT on *their* 4.4 and *their* 0.12
$\pm m \times 4.3208 \pm 2m \times 0.528 = \pm(m + 2m)v$ [Correct equation is $m \times 4.3208 + 2m \times 0.528 = \pm(m + 2m)v$]	**M1**	Apply conservation of momentum, 4 terms, using *their* u_p and u_q values with m and $2m$ respectively. Velocity of P and Q after impact must be equal.
Speed of combined particle immediately after impact $= v = 1.79 \text{ ms}^{-1}$	**A1**	Must be positive
Special case for those who do not take into account the fact that Q comes to rest and then changes its direction		
$u_{p(\text{down})} = 0 + 4.4 \times 1\ [= 4.4]$	**B1 FT**	Allow ±4.4, FT on *their* 1 and *their* 4.4
$u_{q(\text{up})} = 10 - 11.6 \times 1\ [= -1.6]$ so $u_{q(\text{down})} = 1.6$	**B1 FT**	Allow $\pm(10 - 11.6 \times 1)$, FT on *their* 1
$\pm m \times 4.4 \pm 2m \times 1.6 = \pm(m + 2m)v$	**M1**	Apply conservation of momentum, 4 terms, using their u_p and u_q values with m and $2m$ respectively. Velocity of P and Q after impact must be equal.
Speed of combined particle immediately after impact $= v = 2.53 \text{ ms}^{-1}$	**A1**	Allow $v = \frac{38}{15}$. Must be positive.
	4	

15.

$120 \times 8 = 120v + 40v$	**M1**	Applying conservation of momentum.
$v = 6\ \text{ms}^{-1}$	**A1**	
	2	
$1600 - 4800 = 160a$ leading to $a = -20$	**M1**	Applying Newton's 2nd law to the system.
$0 = 6^2 + 2 \times (-20) \times s$	**M1**	Use of constant acceleration equations such as $v^2 = u^2 + 2as$.
Distance travelled by post = 0.9 m	**A1**	
Alternative method for question 1(b)		
Initial KE = $\frac{1}{2} \times 160 \times 6^2$	**M1**	Use of KE = $\frac{1}{2}mv^2$ for combined mass.
$\frac{1}{2} \times 160 \times 6^2 + 160 \times 10 \times s = 4800s$	**M1**	Forms work/energy equation.
Distance travelled by post = 0.9 m	**A1**	
	3	

16.

a)

$0.6^2 = 0 + 2a \times 0.45$	**M1**	Use of constant acceleration equations to find a.
$a = 0.4$	**A1**	
$R = 0.1g \times \cos\alpha = 0.1g \times \frac{24}{25} = 0.1g \times \cos 16.3° \left[R = \frac{24}{25} = 0.96\right]$	**B1**	Must use a value for $\cos\alpha$.
$0.1g \times \frac{7}{25} - F = 0.1 \times 0.4$ $[0.28 - F = 0.04 \rightarrow F = 0.24]$	**M1**	Newton's second law, 3 terms.
$F = \mu \times 0.1g \times \frac{24}{25} \left[F = \frac{24\mu}{25} = 0.96\mu\right]$	**M1**	Use of $F = \mu R$, where R is a component of $0.1g$
$\mu = 0.25$	**A1**	**AG** Must be from exact working $\mu = 0.25$ only

Alternative scheme for question 7(a)		
Attempt PE loss or KE gain	**M1**	Use of either PE = mgh or KE = ½ mv^2
PE loss $= 0.1 \times g \times 0.45 \sin 16.3 = 0.1 \times g \times 0.45 \times \frac{7}{25}$ $\left[= \frac{63}{500} = 0.126\right]$ KE gain $= \frac{1}{2} \times 0.1 \times 0.6^2$ $\left[= \frac{9}{500} = 0.018\right]$	**A1**	Both correct.
$R = 0.1g \times \cos\alpha = 0.1g \times \frac{24}{25} = 0.1g \times \cos 16.3°$ $\left[R = \frac{24}{25} = 0.96\right]$	**B1**	Must use a value for cosα.
$0.1 \times g \times 0.45 \times \frac{7}{25} = \frac{1}{2} \times 0.1 \times 0.6^2 + F \times 0.45$ $\left[\frac{63}{500} = \frac{9}{500} + \mu \times \frac{54}{125}\right]$ or $[0.126 = 0.018 + \mu \times 0.432]$	**M1**	Use of work-energy equation as PE loss = KE gain + WD against friction
$F = \mu \times 0.1g \times \frac{24}{25}$ $\left[F = \frac{24\mu}{25} = 0.96\mu\right]$	**M1**	Use of $F = \mu R$, where R is a component of $0.1g$
$\mu = 0.25$	**A1**	**AG** Must be from exact working $\mu = 0.25$ only
	6	

b)

$0.1 \times 0.6 = 0.5v$	**M1**	Use of conservation of momentum, 2 terms.
$v = 0.12$	**A1**	
For B $0.5g \times \frac{7}{25} - 0.275 \times 0.5g \times \frac{24}{25} = 0.5a$ [leading to $a = 0.16$]	**B1**	Apply Newton's second law for particle B, 3 terms. Allow correct unsimplified expression in a only.
$s_A = 0 + \frac{1}{2} \times 0.4t^2$ $s_B = 0.12t + \frac{1}{2} \times 0.16t^2$	***M1**	Attempt an expression for either s_A or s_B. Must see $u_A = 0$ and $u_B \neq 0$ but u_B must have been found from a momentum equation.
For both s_A and s_B and attempt to solve $s_A = s_B$ to find t	**DM1**	Must be from 3 terms leading to a 2-term quadratic. If energy used in **7(a)** then must find $a = 0.4$ for A. *Their* working must be leading to a positive t value.
Required time is $t = 1$ s	**A1**	
	6	

17.

$0.4\times3+0.2\times2=0.4\times2.5+0.2v$	M1	Use of conservation of momentum with 4 terms. Allow sign errors.
$v=3\text{ ms}^{-1}$	A1	Allow M1A0 if g included with the masses.
	2	
For A $\pm0.4g\sin30°=0.4a$ or for B $\pm0.2g\sin30°=0.2a$ or $\pm mg\sin30°=ma$	M1	For either. Allow sin/cos mix.
$a=\pm5$ or $\pm g\sin30°$	A1	Allow $g\sin30°$ without working for M1A1
For B when hits barrier $v^2=3^2+2\times5\times1.6$ $[\Rightarrow v=5]$ OR $v=u+at\Rightarrow v=3+5\times0.4$ $[\Rightarrow v=5]$	M1	Using *their* $a\neq\pm g$ and *their* v from part **(a)** OR: use of $s=\frac{u+v}{2}t$ $1.6=\frac{3+v}{2}\times0.4[\Rightarrow v=5]$ OR $\frac{1}{2}\times0.2\times v^2-\frac{1}{2}\times0.2\times3^2=0.2\times1.6\times g\sin30$
Speed after hitting barrier = 0.1 × 5 = 0.5	A1	**AG**
$v_A=2.5+5\times0.44$ [= 4.7] $v_B=-0.5+5\times0.04$ [= −0.3] or $v_B=0.5+(-5)\times0.04$ [= 0.3]	*M1	Use of $v=u+at$ for either with correct t-value, with initial speeds ±2.5 or ±0.5 *their* $\pm a\neq\pm g$
$0.4\times4.7+0.2\times(-0.3)=0.6\,v_{comb}$	DM1	Use of $v=u+at$ for BOTH with correct t-values, initial speeds $\pm2.5,\pm0.5$ and $\pm$ *their* acceleration (same for both) and use of conservation of momentum with correct number of terms. Allow sign errors.
$v_{comb}=3.03\text{ ms}^{-1}$	A1	Allow $v=\frac{91}{30}=3\frac{1}{30}$ Allow DM1A0 if g included with the masses.
	7	

18.

Conservation of momentum	M1	3 terms; allow M1 if speed of A after collision is $\frac{1}{4}\times8.5$. Allow $5\times8.5=5X+3Y$ where $\lvert X\rvert$ and $\lvert Y\rvert$ are different which may be seen by later work. If $\lvert X\rvert$ and $\lvert Y\rvert$ are subsequently used as being equal then M0.
$5\times8.5=5\times0.25v+3v$	A1	OE e.g. $5\times8.5=5V+3\times4V$
Speed of B $=10\text{ms}^{-1}$	A1	Do not award if 10 from using mgv, maximum 2/3 −10 is A0 as speed required not velocity
	3	
KE before $=\frac{1}{2}\times5\times8.5^2\,[=180.625]$ KE after $=\frac{1}{2}\times5\times2.5^2+\frac{1}{2}\times3\times10^2\,[=15.625+150=165.625]$	1	Attempt at any of the 3 terms for KE, using their 10ms^{-1} Not $\frac{1}{2}\times(5+3)\times8.5^2$, not $\frac{1}{2}\times(5+3)\times2.5^2$ not $\frac{1}{2}\times(5+3)\times10^2$ unless $\lvert X\rvert=\lvert Y\rvert$ seen
KE loss $[=180.625-165.625]=15$ J	A1	Accept −15, AWRT ±15.0
	2	

19.

$0.3\times4+0=0.3v+0.2\times3$	**M1**	For attempt at use of conservation of momentum
Speed = 2 ms^{-1}	**A1**	
	2	
$0.2\times3+0=(0.2+m)\times2$	**M1**	For attempt at use of conservation of momentum
$m=0.1$	**A1**	
	2	

20.

Use conservation of momentum $6\times5+2\times(-3)=6v_A+2v_B$	***M1**	4 dimensionally correct terms. Allow sign errors, v_A and v_B must be different.
Use $v_B=v_A+2$ or $v_A=v_B-2$ with their momentum equation and solve for v_A or v_B	**DM1**	Allow $v_B=v_A\pm2$ or $v_A=v_B\pm2$.
$v_A=2.5$ or $v_B=4.5$	**A1**	
Attempt at initial KE, or final KE, or change in KE for A, or change in KE for B Initial KE $=\frac{1}{2}\times6\times5^2+\frac{1}{2}\times2\times(-3)^2\,[=84]$ Final KE $=\frac{1}{2}\times6\times(their2.5)^2+\frac{1}{2}\times2\times(their4.5)^2$ Change in KE for $A=\pm\left(\frac{1}{2}\times6\times5^2-\frac{1}{2}\times6\times(their2.5)^2\right)$ Change in KE for $B=\pm\left(\frac{1}{2}\times2\times(-3)^2-\frac{1}{2}\times2\times(their4.5)^2\right)$	**M1**	Allow use or their v_A and/or v_B. Allow if 2 KE equations seen.
Loss of KE = 45 J	**A1**	Allow –45 J. Allow if mgv used in momentum equation.
	5	

21.

$0.3\times2[+0]=0.3\times0.6+0.4\times v$	**M1**	For use of conservation of momentum. Must be 3 terms. Allow sign errors.
Speed of B = 1.05 ms^{-1}	**A1**	AG Allow M1 A0 if g included with the masses.
	2	
$0.4\times1.05[+0]=(0.4+m)\times0.5$	**M1**	For use of conservation of momentum. Must be 3 terms. Allow sign errors.
$m=0.44$ or $\frac{11}{25}$	**A1**	Allow M1 A0 if g included with the masses.
	2	

22.

$R = 3g\cos\alpha = 3\times10\times0.8$	**B1**	
$F = 3g\sin\alpha = 3\times10\times0.6$	**M1**	Resolving parallel to plane.
$\mu = \frac{18}{24} = 0.75$ **or** $\mu = \frac{3g\sin\alpha}{3g\cos\alpha} = \tan\alpha = 0.75$	**A1**	Uses $\mu = \frac{F}{R}$ AG.
	3	
$a = g\sin\alpha$ or PE loss $= 1.5gx\sin\alpha$ for *AB* **and** $a = 0$ for *BC* $4.5g\times\sin\alpha - 0.75\times4.5g\cos\alpha = 4.5a$ leading to $a = 0$	**B1**	Accelerations for *AB* and *BC*.
$v_1^2 = 2\times g\sin\alpha\times x$] **or** [$1.5g\times x\sin\alpha = 0.5\times1.5\times v_1^2$	**M1**	Uses '*suvat*' or PE loss = KE gain for *AB*.
$v_1^2 = 20x\sin\alpha = 12x$ leading to $v_1 = \sqrt{12x}$	**A1**	
$1.5\times\sqrt{12x} + 0 = 4.5\times v_2$ leading to $v_2 = \frac{1}{3}\sqrt{12x}$	**M1**	Conservation of momentum.
$4 = \frac{2}{3}\times\sqrt{12x}$	**M1**	Use of $s = vt$ on *BC* since $a = 0$.
$x = 3$	**A1**	

Alternative Method for 7(b)		
$a = g\sin\alpha$ or PE loss $= 1.5gx\sin\alpha$ for *AB* **and** $a = 0$ for *BC* $4.5g\times\sin\alpha - 0.75\times4.5g\cos\alpha = 4.5a$ leading to $a = 0$	**B1**	Accelerations for *AB* and *BC*.
$4 = 2v_2$ leading to $v_2 = 2$	**M1**	Uses $s = vt$ on *BC* since $a = 0$.
$1.5\times v_1 + 0 = 4.5\times2$	**M1**	Conservation of momentum.
$v_1 = 6$	**A1**	Velocity before collision.
$6^2 = 2\times g\sin\alpha\times x$ **or** $1.5g\times x\sin\alpha = 0.5\times1.5\times6^2$	**M1**	Uses *suvat* or PE loss = KE gain for *AB*.
$x = 3$	**A1**	
	6	
KE = $0.5\times4.5\times2^2 = 9$J	**B1**	KE gain for *AC*.
PE loss = $15\times(4+3)\times\frac{3}{5} + 30\times4\times\frac{3}{5} = 135$J	**M1**	Evaluates PE loss for *AC*.
Loss of energy = 126 J	**A1**	
	3	

23.

Attempt to use conservation of energy $\left[\frac{1}{2}\times 0.5v^2 = 0.5g\times 1.8\right]$ or $\left[\frac{1}{2}\times mv^2 = mg\times 1.8\right]$	M1	2 terms, dimensionally correct. Do not allow from use of constant acceleration.
$v = 6$	A1	Do not allow from use of constant acceleration.
Attempt at conservation of momentum $[0.5\times 6(+0) = 0.5\times 4 + 0.1w]$	M1	3 terms; allow sign errors; allow *their* $v = 6$ or just v; allow if using mgv (consistently in all terms).
Speed of Q $(=w)$=10 ms^{-1}	A1	AG Do not allow from use of constant acceleration. Do not allow if using mgv. Use of constant acceleration gets M0 A0 M1 A0 maximum.
	4	**SC Assuming elastic collision** **M1A1** $0.5g\times 1.8 = \frac{1}{2}\times 0.1w^2 + \frac{1}{2}\times 0.5\times 4^2$ **M1** For attempt at conservation of energy, 3 terms; allow sign errors. **B1** Speed of Q $(=w)$=10 ms^{-1}

Attempt at conservation of momentum $[0.1\times 10 = (0.1+0.4)\times z\ (\Rightarrow z = 2)]$	*M1	3 terms, allow sign errors, allow if using mgv.
Attempt to use conservation of energy $\left[\frac{1}{2}\times(0.1+0.4)\times(\mathit{their}\,2)^2 = (0.1+0.4)gh\ \ (\Rightarrow h = 0.2)\right]$	*DM1	Dependent on previous M mark. 4 terms, dimensionally correct. Do not allow from use of constant acceleration. $\mathit{their}\,2 \neq 10$.
Use trigonometry to get an equation in θ and solve for θ $\left[\theta = \sin^{-1}\left(\frac{\mathit{their}\,0.2}{0.4}\right)\right]$	DM1	Dependent on previous 2 M marks. Using *their* h and 0.4 . Allow sin/cos mix.
$\theta = 30$	A1	Do not allow if using mgv.
Alternative method for Question 7(b): Using constant acceleration		
Attempt at conservation of momentum $[0.1\times 10 = 0.5\times z\ (\Rightarrow z = 2)]$	*M1	2 terms, allow sign errors, allow if using mgv.
Attempt at use of constant acceleration $\left[0^2 = (\mathit{their}\,2)^2 \pm 2\times a\times 0.4\ \ (\Rightarrow a = \mp 5)\right]$	*DM1	Dependent on previous M mark. Uses constant acceleration with $u = \mathit{their}\,2$ and $s = 0.4$ to get an equation in a; $\mathit{their}\,2 \neq 10$.
Use N2L to get an equation in θ leading to a positive value of θ and solve for θ $[(0.5)\lvert \mathit{their}\,a\rvert = (0.5)g\sin\theta]$	DM1	Dependent on previous 2 M marks. Using *their* a; May have m for 0.5 . Allow sin/cos mix.
$\theta = 30$	A1	Do not allow if using mgv.
	4	

Q takes 0.7s to travel from B to C	**B1**	
$0.4 = \frac{(their\,2)+0}{2}t \Rightarrow t = 0.4$	**B1FT**	SOI FT *their* 2 from (b), $t = \frac{0.8}{their\,2}$. For use of $s = \left(\frac{u+v}{2}\right)t$ to get a time up the slope. Allow for total time on slope from $0 = (their\,2)t - \frac{1}{2}(their\,a)t^2 \Rightarrow t = 0.8$.
Distance between P moved is $(0.7+0.8)\times 4 (=6)$	**B1**	Allow 1 m from point C.
Set up equation in t using $4t$, $(their\,2)t$ and *their* 6 and solve for t $[4t + (their\,2)t = (their\,1) \text{OR} (their\,6) + 4t + (their\,2)t = 7]$	**M1**	Must have considered all parts of motion to find times from relevant equations.
Distance from B = $6\frac{2}{3}$ m	**A1**	

Alternative method for last 3 marks of Question 7(c)		
[Time for P =]$\frac{b}{4}$ **and** [Time for QR =]$\frac{7-b}{2}$ OR [Time for P =]$\frac{7-c}{4}$ **and** [Time for QR =]$\frac{c}{2}$	**B1**	Where b is distance from B OR Where c is distance from C.
Attempt to form an equation from use of total time and solve for b (or c) $\left[\frac{7-b}{2} + 0.7 + 0.4 + 0.4 = \frac{b}{4}\left[\Rightarrow b = 6\frac{2}{3}\right]\right.$ $\left. OR \frac{c}{2} + 0.7 + 0.4 + 0.4 = \frac{7-c}{4}\left[\Rightarrow c = \frac{1}{3}\right]\right]$	**M1**	Where b is distance from B OR Where c is distance from C. Must have considered all parts of motion to find times from relevant equations.
Distance from B = $6\frac{2}{3}$ m	**A1**	
	5	

24.

$m \times 5 + 0 = m \times 2 + 0.3v$	**M1**	Attempt at conservation of momentum; 3 non-zero terms (with *m* appearing in two terms); allow sign errors.
Speed $= 10m$ (m s^{-1})	**A1**	M1A0 if using *g* in momentum terms. $v = -10m$ is A0.
	2	
$0.3 \times 10m + 0 = 0 + 0.6 \times 1.5$ [$3m = 0.9$]	**M1**	Attempt at conservation of momentum between *Q* and *R* (so must be using correct masses of 0.3 and 0.6) to form a linear equation in *m* using their answer from **(a)**; 2 non-zero terms; allow sign errors.
$m = 0.3$	**A1FT**	FT $\dfrac{3}{\textit{their} \text{ +ve coefficient of } m \text{ from } \mathbf{(a)}}$ Condone including kg in answer.
	2	

25.

$\pm[3.2v + 2.4 \times (-6)] = 0$	**M1**	Attempt at conservation of momentum; 2 non-zero terms; allow sign errors.
$v = 4.5$	**A1**	M1A0 for use of *mgv*. $v = -4.5$ is A0.
	2	

KE $= \pm\frac{1}{2} \times 3.2 \times (\textit{their } 4.5)^2$ OR $\pm\frac{1}{2} \times 2.4 \times 6^2$	**M1**	Attempt at either KE term, using *their v*. Do not allow $\frac{1}{2} \times 3.2 \times (\textit{their } 4.5 \pm 6)^2$, or $\frac{1}{2} \times 2.4 \times (\textit{their } 4.5 \pm 6)^2$, or $\frac{1}{2} \times (3.2 + 2.4) \times (\textit{their } 4.5 \pm 6)^2$, or $\frac{1}{2} \times 3.2 \times (\textit{their } 4.5 - 0)^2$, or $\frac{1}{2} \times 2.4 \times (6 - 0)^2$.
$\text{KE}_{\text{loss}} = 75.6$ J	**A1**	Allow −75.6. Note $\frac{1}{2} \times (3.2 + 2.4) \times 6^2$ or $\frac{1}{2} \times (3.2 + 2.4) \times (\textit{their } 4.5)^2$ is M1A0.
	2	

26.

For attempt at use of conservation of momentum in one case	**M1**	$0.1 \times 4 + 0 = 0.4v + 0.1v$ or $0.1 \times 4 + 0 = 0.4v + 0.1(-v)$ OE. Must have correct number of terms. Allow sign errors.
Speed = 0.8 [ms^{-1}] or $\frac{4}{5}$	**A1**	Must be positive. Allow Max M1A1A0 if *g* included with the masses.
Speed = $\frac{4}{3}$ [ms^{-1}] Allow 1.33	**A1**	Must be positive.
	3	