1. Particle P has mass m kg and particle Q has mass $3m$ kg. The particles are moving in opposite directions along a smooth horizontal plane when they collide directly. Immediately before the collision P has speed $4u$ ms^{-1} and Q has speed ku ms^{-1}, where k is a constant. As a result of the collision the direction of motion of each particle is reversed and the speed of each particle is halved.

(a) Find the value of k.

(4)

(b) Find, in terms of m and u, the magnitude of the impulse exerted on P by Q.

(3)
(Total 7 marks)

2. A particle A of mass 2 kg is moving along a straight horizontal line with speed 12 m s^{-1}. Another particle B of mass m kg is moving along the same straight line, in the opposite direction to A, with speed 8 m s^{-1}. The particles collide. The direction of motion of A is unchanged by the collision. Immediately after the collision, A is moving with speed 3 m s^{-1} and B is moving with speed 4 m s^{-1}. Find

(a) the magnitude of the impulse exerted by B on A in the collision,

(2)

(b) the value of m.

(4)
(Total 6 marks)

3. Two particles A and B have mass 0.4 kg and 0.3 kg respectively. They are moving in opposite directions on a smooth horizontal table and collide directly. Immediately before the collision, the speed of A is 6 m s^{-1} and the speed of B is 2 m s^{-1}. As a result of the collision, the direction of motion of B is reversed and its speed immediately after the collision is 3 m s^{-1}. Find

(a) the speed of A immediately after the collision, stating clearly whether the direction of motion of A is changed by the collision,

(4)

(b) the magnitude of the impulse exerted on *B* in the collision, stating clearly the units in which your answer is given.

(3)
(Total 7 marks)

4. (a) Two particles *A* and *B*, of mass 3 kg and 2 kg respectively, are moving in the same direction on a smooth horizontal table when they collide directly. Immediately before the collision, the speed of *A is* 4 m s^{-1} and the speed of *B* is 1.5 m s^{-1}. In the collision, the particles join to form a single particle *C*.

Find the speed of *C* immediately after the collision.

(3)

(b) Two particles *P* and *Q* have mass 3 kg and *m* kg respectively. They are moving towards each other in opposite directions on a smooth horizontal table. Each particle has speed 4 m s^{-1}, when they collide directly. In this collision, the direction of motion of each particle is reversed. The speed of *P* immediately after the collision is 2 m s^{-1} and the speed of *Q* is 1 m s^{-1}. Find

(i) the value of *m*,

(3)

(ii) the magnitude of the impulse exerted on *Q* in the collision.

(2)
(Total 8 marks)

5. Two small steel balls *A* and *B* have mass 0.6 kg and 0.2 kg respectively. They are moving towards each other in opposite directions on a smooth horizontal table when they collide directly. Immediately before the collision, the speed of *A* is 8 m s^{-1} and the speed of *B* is 2 m s^{-1}. Immediately after the collision, the direction of motion of *A* is unchanged and the speed of *B* is twice the speed of *A*. Find

(a) the speed of *A* immediately after the collision,

(5)

(b) the magnitude of the impulse exerted on *B* in the collision.

(3)
(Total 8 marks)

6. A particle P of mass 1.5 kg is moving along a straight horizontal line with speed 3 m s^{-1}. Another particle Q of mass 2.5 kg is moving, in the opposite direction, along the same straight line with speed 4 m s^{-1}. The particles collide. Immediately after the collision the direction of motion of P is reversed and its speed is 2.5 m s^{-1}.

(a) Calculate the speed of Q immediately after the impact.

(3)

(b) State whether or not the direction of motion of Q is changed by the collision.

(1)

(c) Calculate the magnitude of the impulse exerted by Q on P, giving the units of your answer.

(3)
(Total 7 marks)

7. A stone S is sliding on ice. The stone is moving along a straight horizontal line ABC, where AB = 24 m and AC = 30 m. The stone is subject to a constant resistance to motion of magnitude 0.3 N. At A the speed of S is 20 m s^{-1}, and at B the speed of S is 16 m s^{-1}. Calculate

(a) the deceleration of S,

(2)

(b) the speed of S at C.

(3)

(c) Show that the mass of S is 0.1 kg.

(2)

At C, the stone S hits a vertical wall, rebounds from the wall and then slides back along the line CA. The magnitude of the impulse of the wall on S is 2.4 Ns and the stone continues to move against a constant resistance of 0.3 N.

(d) Calculate the time between the instant that S rebounds from the wall and the instant that S comes to rest.

(6)
(Total 13 marks)

8. A tent peg is driven into soft ground by a blow from a hammer. The tent peg has mass 0.2 kg and the hammer has mass 3 kg. The hammer strikes the peg vertically.

Immediately before the impact, the speed of the hammer is 16 m s^{-1}. It is assumed that, immediately after the impact, the hammer and the peg move together vertically downwards.

(a) Find the common speed of the peg and the hammer immediately after the impact.

(3)

Until the peg and hammer come to rest, the resistance exerted by the ground is assumed to be constant and of magnitude *R* newtons. The hammer and peg are brought to rest 0.05 s after the impact.

(b) Find, to 3 significant figures, the value of *R*.

(5)
(Total 8 marks)

9. A particle *P* of mass 2 kg is moving with speed *u* m s^{-1} in a straight line on a smooth horizontal plane. The particle *P* collides directly with a particle *Q* of mass 4 kg which is at rest on the same horizontal plane. Immediately after the collision, *P* and *Q* are moving in opposite directions and the speed of *P* is one-third the speed of *Q*.

(a) Show that the speed of *P* immediately after the collision is $\frac{1}{5}u$ m s^{-1}.

(4)

After the collision *P* continues to move in the same straight line and is brought to rest by a constant resistive force of magnitude 10 N. The distance between the point of collision and the point where *P* comes to rest is 1.6 m.

(b) Calculate the value of *u*.

(5)
(Total 9 marks)

10. Two trucks *A* and *B*, moving in opposite directions on the same horizontal railway track, collide. The mass of *A* is 600 kg. The mass of *B* is *m* kg. Immediately before the collision, the speed of *A* is 4 m s^{-1} and the speed of *B* is 2 m s^{-1}. Immediately after the collision, the trucks are joined together and move with the same speed 0.5 m s^{-1}. The direction of motion of *A* is unchanged by the collision. Find

(a) the value of *m*,

(4)

(b) the magnitude of the impulse exerted on *A* in the collision.

(3)
(Total 7 marks)

11. A railway truck *S* of mass 2000 kg is travelling due east along a straight horizontal track with constant speed 12 m s^{-1}. The truck *S* collides with a truck *T* which is travelling due west along the same track as *S* with constant speed 6 m s^{-1}. The magnitude of the impulse of *T* on *S* is 28 800 Ns.

(a) Calculate the speed of *S* immediately after the collision.

(3)

(b) State the direction of motion of *S* immediately after the collision.

(1)

Given that, immediately after the collision, the speed of *T* is 3.6 m s^{-1}, and that *T* and *S* are moving in opposite directions,

(c) calculate the mass of *T*.

(4)
(Total 8 marks)

12. Two particles *A* and *B* have mass 0.12 kg and 0.08 kg respectively. They are initially at rest on a smooth horizontal table. Particle *A* is then given an impulse in the direction *AB* so that it moves with speed 3 m s^{-1} directly towards *B*.

(a) Find the magnitude of this impulse, stating clearly the units in which your answer is given.

(2)

Immediately after the particles collide, the speed of *A* is 1.2 m s^{-1}, its direction of motion being unchanged.

(b) Find the speed of *B* immediately after the collision.
(3)

(c) Find the magnitude of the impulse exerted on *A* in the collision.
(2)
(Total 7 marks)

13. A railway truck *P* of mass 2000 kg is moving along a straight horizontal track with speed 10 m s^{-1}. The truck *P* collides with a truck *Q* of mass 3000 kg, which is at rest on the same track. Immediately after the collision *Q* moves with speed 5 m s^{-1}. Calculate

(a) the speed of *P* immediately after the collision,
(3)

(b) the magnitude of the impulse exerted by *P* on *Q* during the collision.
(2)
(Total 5 marks)

14. A post is driven into the ground by means of a blow from a pile-driver. The pile-driver falls from rest from a height of 1.6 m above the top of the post.

(a) Show that the speed of the pile-driver just before it hits the post is 5.6 m s^{-1}.
(2)

The post has mass 6 kg and the pile-driver has mass 78 kg. When the pile-driver hits the top of the post, it is assumed that `there is no rebound and that both then move together with the same speed.

(b) Find the speed of the pile-driver and the post immediately after the pile-driver has hit the post.
(3)

The post is brought to rest by the action of a resistive force from the ground acting for 0.06 s.

By modelling this force as constant throughout this time,

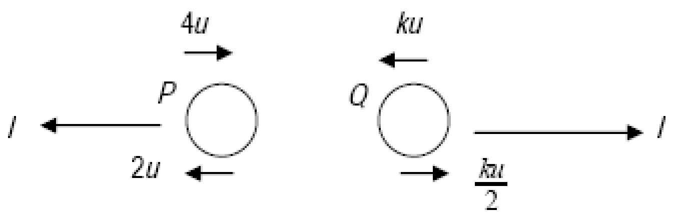
(c) find the magnitude of the resistive force,

(4)

(d) find, to 2 significant figures, the distance travelled by the post and the pile-driver before they come to rest.

(4)
(Total 13 marks)

1. (a)



$4mu - 3mku = -2mu + 3mk\dfrac{u}{2}$ M1 A1

$k = \dfrac{4}{3}$ M1 A1cso 4

(b) For P, $I = m\,(2u - -4u)$ M1 A1

$= 6mu$ A1 3

OR

For Q, $I = 3m\;(\dfrac{ku}{2} - -ku)$ (M1 A1)

[7]

2. (a) $I = 2\times12 - 2\times3 = 18$ (N s) M1 A1 2

(b) LM $2\times12 - 8m = 2\times3 + 4m$ M1 A1

Solving to $m = 1.5$ DM1 A1 4

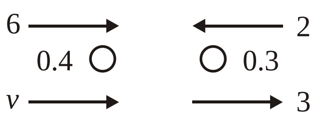
<u>Alternative</u>

$I = m(4-(-8)) = 18$ M1 A1

Solving to $m = 1.5$ DM1 A1

[6]

3. (a)



CLM: $0.4 \times 6 - 0.3 \times 2 = 0.4 \times v + 0.3 \times 3$ M1 A1

$\Rightarrow v = (+)\ 2.25$ m s^{-1} A1

('+' $\Rightarrow$) direction unchanged A1 ft 4

M1 for 4 term equation dimensionally correct (± g).
A1 correct
A1 answer must be positive
A1 f.t. - accept correct answer from correct working without justification; if working is incorrect
allow f.t. from a clear diagram with answer consistent with their statement; also allow A1 if their ans is +ve and they say direction unchanged.

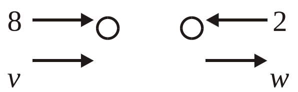
	(b)	$I = 0.3 \times (2 + 3) = 1.5$, Ns (o.e.)	M1 A1 B1	3
		M1 - need (one mass) × (sum or difference of the two speeds associated with the mass chosen)		
		A1 - answer must be positive		
		B1 allow o.e. e.g. kg m s^{-1}		

[7]

4.	(a)	CLM: $3 \times 4 + 2 \times 1.5 = 5 \text{ x } v$	M1 A1	
		$\Rightarrow v =$ <u>3 m s^{-1}</u>	A1	3
	(b) (i)	CLM: $3 \times 4 - m \times 4 = -3 \times 2 + m \text{ (x 1)}$	M1 A1	
		$\Rightarrow m =$ <u>3.6</u>	A1	3
	(ii)	$I = 3.6(4 + 1)$ [or $3(4 + 2)$]	M1	
		= <u>18 Ns</u>	M1 A1	2

[8]

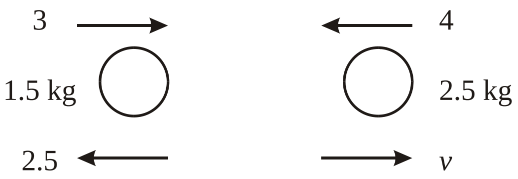
5.



	CLM: $0.6 \times 8 - 0.2 \times 2 = 0.6 \times v + 0.2 \times w$	M1A1 ↓	
	Using $w = 2v$ to form equn in v/w only	M1 ↓	
	Solve to get $v =$ <u>4.4 m s^{-1}</u>	M1A1	5
(b)	Impulse on $B = 0.2(2 + 8.8)$	M1 A1ft	
	= <u>2.16 Ns</u>	A1	3

[8]

6.



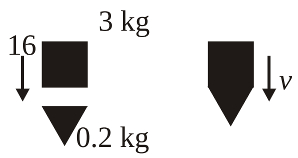
(a)	CLM: $1.5 \times 3 - 2.5 \times 4 = -1.5 \times 2.5 + 2.5 \times v$	M1 A1	
	$\Rightarrow$ v = <u>– 0.7 m s^{-1}</u> <u>so speed = 0.7 m s^{-1}</u>	A1	3
(b)	Direction of Q unchanged	A1ft	1
(c)	Impulse = 1.5 (3 + 2.5)	M1	
	= <u>8.25, Ns</u>	A1, B1	3

[7]

7.	(a)	$16^2 = 20^2 - 2 \times a \times 24 \Rightarrow a = \underline{3 \text{ m s}^{-2}}$	M1 A1	2
	(b)	$v^2 = 20^2 - 2 \times 3 \times 30$	M1 A1ft	
		$v = \sqrt{220}$ or 14.8 m s^{-1}	A1	3
	(c)	$0.3 = m \times 3 \Rightarrow m = 0.1$ kg (*)	M1 A1	2
	(d)	$0.1(w + \sqrt{220}) = 2.4$	M1 A1ft	
		$w = 9.17$	A1 ↓	
		$0 = 9{,}17 - 3 \times t$	M1 A1ft	
		$t \approx \underline{3.06 \text{ s}}$	A1	6

[13]

8. (a)

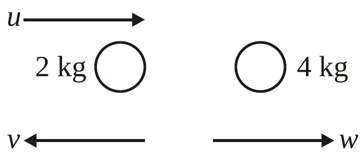


		CLM: $3 \times 16 = 3.2 \times v$	M1 A1	
		$\Rightarrow v = \underline{15 \text{ m s}^{-1}}$	A1	3
	(b)	Impulse-momentum: $(R - 3.2g)0.05 = 3.2 \times 15$	M1 A1 A1ft ↓	
		$\Rightarrow R = 960 + 3.2g \approx \underline{991}$	M1 A1	5
		Or: deceleration: $0 = 15 + 0.05a \Rightarrow a = -300 \text{ m s}^{-2}$ Hence $3.2g - R = 3.2 \times -300$	M1 A1 A1ft ↓	
		$\Rightarrow R = 960 + 3.2g \approx \underline{991}$	M1 A1	5

[13]

Final M1 needs a three term equation.

9. (a)



		CLM: $2u = -2v + 4w$	M1 A1 ↓	
		Using $w = 3v$ ($\Rightarrow 2u = -2v + 12v$) and solve	M1	
		$\Rightarrow v = \frac{1}{5}u$ (*)	A1 cso	4

(b) $10 = 2a \Rightarrow a = 5 \text{ m s}^{-2}$ B1

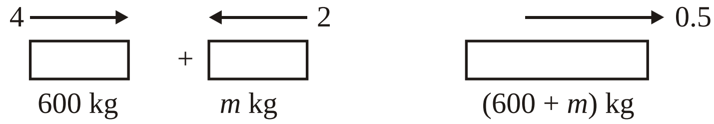
$0 = \frac{1}{25}u^2 - 2 \times 5 \times 1.6$ M1 A1f.t.

↓

$\rightarrow u = \underline{20 \text{ m s}^{-1}}$ M1 A1 5

[9]

10.



(a) CLM: $600 \times 4 - m \times 2 = (600 + m) \times 0.5$ M1 A1

↓

$\Rightarrow m = \underline{840 \text{ kg}}$ M1 A1 4

(b) $I = 600\ (4 - 0.5)$ M1 → M1

$= \underline{2100 \text{ Ns}}$ A1 3

[7]

11.

(a) $28800 = 2000\ (12 - v)$ M1 A1

$v = -2.4 \text{ ms}^{-1}$ Speed = $\underline{2.4 \text{ ms}^{-1}}$ A1 3

(b) due west / ←/reversed direction (o.e.) A1 ft 1

(c) T: $28800 = m(6 + 3.6)$ M1 A1

$\Rightarrow m = \underline{3000 \text{ kg}}$ M1 A1 4

OR $2000 \times 12 - 6 \times m = -2000 \times 2.4 + m \times 3.6$ M1 A1

$\Rightarrow m = 3000 \text{ kg}$ M1 A1

[8]

12. (a) $I = 0.12 \times 3 = \underline{0.36, \text{ Ns}}$ B1, B1 2

(b) $0.12 \times 3 = 0.12 \times 1.2 + 0.08 \times v$ M1 A1

$\Rightarrow v = \underline{2.7 \text{ m s}^{-1}}$ A1 3

(c) $I = 0.12 \times (3 - 1.2)$ <u>or</u> 0.08×2.7 M1

$= \underline{0.216 \text{ Ns}}$ A1 2

[7]

13.	(a)	CLM: $2000 \times 10 = 2000v + 3000 \times 5$	M1, A1	
		$v = 2.5 \text{ m s}^{-1}$	B1	3
	(b)	$I = 3000 \times 5$ (or $2000(10 - 2.5)$)	M1	
		$= 15\,000$ Ns	A1	2

[5]

14.	(a)	"$v^2 = u^2 + 2as$": $V^2 = 2 . 9.8 . 1.6$	M1	
		$\Rightarrow$ V = 5.6 m s^{-1}	A1	2
	(b)	$78 . 5.6 = 84 . v$	M1 A1	
		$\Rightarrow v = 5.2 \text{ m s}^{-1}$	A1	3
	(c)	$84 . 5.2 = F . 0.06 - 84g . 0.06$	M1 A1 A1	
		$\Rightarrow F = 8103.2$ N	A1	4
		"$F = ma$": $8103.2 - 84g = 84a \Rightarrow a = 86.67$	M1 A1	
	(d)	"$v^2 = u^2 + 2as$": $5.2^2 = 2 . 86.67 . s$	M1	
		$\Rightarrow s \approx 0.156$ m, or 0.16 m to 2 s.f.	A1	2

[11]

1. This question produced very many correct responses. In part (a) most candidates were able to apply the conservation of momentum principle with few problems, with many candidates achieving all four marks. As usual a significant number, maybe fewer than in previous years, made sign errors, with the occasional candidate missing the odd '*m*'s or '*u*'s. Very few put '*g*'s into the equation while others had difficulty in manipulating the fractions Arithmetic errors in working out the value of *k* were not uncommon and negative values obtained for *k* seldom alerted the candidates to a possible error in their work. In the second part, the majority of candidates chose to use the change in momentum of *P* with many correct answers being obtained. However there were the inevitable errors with signs, more than in part (a), with too many candidates thinking that a negative answer was acceptable, misunderstanding the meaning of 'magnitude'.

2. This proved to be a good starter and was well-answered by the majority of candidates. In part (a), most knew that impulse = change in momentum and almost all errors were with the signs. Candidates would be well-advised to put impulses, with arrows, on their diagrams as well as velocities. There are still some candidates giving a negative answer for a magnitude which always loses a mark. Most used conservation of momentum in part (b) which was preferable since it did not rely on their answer from the previous part. Those who used impulse = change in momentum again, applied to the other particle, could lose two marks if their answer to part (a) was wrong.

3. The relevant principles here were well known: virtually all candidates could apply the law of conservation of linear momentum in part (a), and could find an impulse in part (b) by attempting to find the change in momentum of one particle. Problems usually arose in relation to the signs of the velocities in question and some weaker candidates evidently failed to realise that, in their standard formulae such as '$I = mv - mu$', the velocities concerned are velocities not speeds and hence could have negative values. A significant minority failed to give the units of the impulse correctly in part (b).

4. Candidates fared much better on this question that on Q1. Almost all could write down appropriate equations involving conservation of linear momentum in (a) and (b), and an appropriate expression for an impulse in (c). If errors occurred, they tended to be in the signs in parts (b) and (c), candidates failing to take note of the different directions of motion. However, many fully correct answers were seen here.

5. The relevant principles here were well known: virtually all candidates could apply the law of conservation of linear momentum in part (a), and could find an impulse in part (b) by attempting to find the change in momentum of one particle. Problems usually arose in relation to the signs of the velocities in question and some weaker candidates evidently failed to realise that, in their standard formulae such as '$I = mv - mu$', the velocities concerned are velocities not speeds and hence could have negative values.

6. Virtually all candidates realised that they had to apply the principle of conservation of momentum and made a reasonable attempt to do so. Mistakes tended to arise in relation to the signs of the terms, with some taking no account of the directions of motion. Many too failed to make clear the direction in which they were taking their unknown velocity as positive in their equations. A clearly drawn diagram would have helped both candidates and examiners. In finding the impulse, again most knew what to do in principle but errors arose in the signs of the terms. The units of the answer for the impulse were often incorrect.

7. Most could make good attempts at the first three parts of the question, though a misreading of the information (confusing '*AC*' and '*BC*' was not uncommon). In part (d) the most common mistake was to confuse signs again (similar to qu.1) in writing down the impulse-momentum equation, but most could then go on to use their result in an appropriate way to get a value for the time.

8. Part (a) was almost universally done correctly. In part (b), most found the deceleration, but almost all assumed that the only force acting was the resistance, failing to take account of the weight of the hammer and peg.

9. Most could form a correct conservation of momentum equation and could make an attempt to interpret the data about the speeds after the collision by putting the two speeds in terms of a single unknown. Several however found their unknown to be $0.6u$ without apparently realising that they had found the speed of Q rather than P. It was pleasing to see most candidates keeping the letter u in their working all the time. In part (b) several correct answers were seen; most correctly obtained the deceleration, but a number failed to use the correct sign for their acceleration term in their equation to find u (simply riding roughshod over the fact the u^2 was coming out to be negative).

10. This proved to be a fairly friendly opening question with many candidates gaining full marks. The general principles of momentum and impulse were well known. A number lost a mark by leaving their answer for the magnitude of the impulse in part (b) as a negative number, and some thought that the combined mass of the two trucks in part (a) was $600m$ rather than $600 + m$. A few also failed to realise that the velocities before the collision would be of different signs.

11. Most realised that they should use 'impulse = change in momentum', but very few provided a clear justification for the signs they used for the various components in their equations. It was sadly very rare to see any diagram at all with the direction of the unknown velocities drawn in and the positive direction clearly identified. So too, the statement of the direction of the velocity in part (b) often bore no relation to the working given. In part (c), a number failed to see that if the direction of motion of S was unaltered, the direction of motion of T could scarcely be unaltered if T was not somehow to pass through S and appear on the other side!

12. The routine application of the principle of conservation of momentum was generally well done. It was slightly disappointing to see a significant number of candidates failing to give the units of an impulse correctly in part (a). Some candidates also failed to realise that in parts (b) and (c), they had to use the velocity of *A* immediately before the collision, rather than the zero velocity of *A* at the start of the question. Some candidates also failed to understand that 'speed' and 'magnitude' had to be positive quantities.

13. This proved to be a very comfortable opening question for almost all candidates: all realised that they had to write down a momentum equation, and most did so correctly. Some errors though occurred in part (b), with some failing to give the answer as a magnitude, leaving it as a negative quantity.

14. No Report available for this question.