M1 - Dynamics

Date:

Time:
Total marks available:
Total marks achieved: _____
Questions

Q1.

A railway truck \( P \), of mass \( m \) kg, is moving along a straight horizontal track with speed 15 ms\(^{-1}\). Truck \( P \) collides with a truck \( Q \) of mass 3000 kg, which is at rest on the same track. Immediately after the collision the speed of \( P \) is 3 ms\(^{-1}\) and the speed of \( Q \) is 9 ms\(^{-1}\). The direction of motion of \( P \) is reversed by the collision.

Modelling the trucks as particles, find

(a) the magnitude of the impulse exerted by \( P \) on \( Q \),

(b) the value of \( m \).

(Total 5 marks)

Q2.

A car of mass 1000 kg is towing a caravan of mass 750 kg along a straight horizontal road. The caravan is connected to the car by a tow-bar which is parallel to the direction of motion of the car and the caravan. The tow-bar is modelled as a light rod. The engine of the car provides a constant driving force of 3200 N. The resistances to the motion of the car and the caravan are modelled as constant forces of magnitude 800 newtons and \( R \) newtons respectively.

Given that the acceleration of the car and the caravan is 0.88 m s\(^{-2}\),

(a) show that \( R = 860 \),

(b) find the tension in the tow-bar.

(Total 6 marks)

Q3.

Two particles \( A \) and \( B \), of mass 5\( m \) kg and 2\( m \) kg respectively, are moving in opposite directions along the same straight horizontal line. The particles collide directly. Immediately before the collision, the speeds of \( A \) and \( B \) are 3 m s\(^{-1}\) and 4 m s\(^{-1}\) respectively. The direction of motion of \( A \) is unchanged by the collision. Immediately after the collision, the speed of \( A \) is 0.8 m s\(^{-1}\).

(a) Find the speed of \( B \) immediately after the collision.

(b) Find the value of \( m \).
Q4.

Particle \( P \) has mass 3 kg and particle \( Q \) has mass 2 kg. The particles are moving in opposite directions on a smooth horizontal plane when they collide directly. Immediately before the collision, \( P \) has speed 3 m s\(^{-1}\) and \( Q \) has speed 2 m s\(^{-1}\). Immediately after the collision, both particles move in the same direction and the difference in their speeds is 1 m s\(^{-1}\).

(a) Find the speed of each particle after the collision. 

(b) Find the magnitude of the impulse exerted on \( P \) by \( Q \).

(Total 8 marks)

Q5.

Two particles \( A \) and \( B \) are moving on a smooth horizontal plane. The mass of \( A \) is \( km \), where \( 2 < k < 3 \), and the mass of \( B \) is \( m \). The particles are moving along the same straight line, but in opposite directions, and they collide directly. Immediately before they collide the speed of \( A \) is \( 2u \) and the speed of \( B \) is \( 4u \). As a result of the collision the speed of \( A \) is halved and its direction of motion is reversed.

(a) Find, in terms of \( k \) and \( u \), the speed of \( B \) immediately after the collision.

(b) State whether the direction of motion of \( B \) changes as a result of the collision, explaining your answer.

Given that \( k = \frac{7}{3} \),

(c) find, in terms of \( m \) and \( u \), the magnitude of the impulse that \( A \) exerts on \( B \) in the collision.

(Total 9 marks)

Q6.

Two particles \( B \) and \( C \) have mass \( m \) kg and 3 kg respectively. They are moving towards each other in opposite directions on a smooth horizontal table. The two particles collide directly. Immediately before the collision, the speed of \( B \) is 4 m s\(^{-1}\) and the speed of \( C \) is 2 m s\(^{-1}\). In the collision the direction of motion of \( C \) is reversed and the direction of motion of \( B \) is unchanged. Immediately after the collision, the speed of \( B \) is 1 m s\(^{-1}\) and the speed of \( C \) is 3 m s\(^{-1}\).

Find

(a) the value of \( m \),

(b) the magnitude of the impulse received by \( C \).

(Total 5 marks)
Q7.

Two particles $A$ and $B$, of mass 7 kg and 3 kg respectively, are attached to the ends of a light inextensible string. Initially $B$ is held at rest on a rough fixed plane inclined at angle $\theta$ to the horizontal, where $\tan \theta = \frac{5}{12}$. The part of the string from $B$ to $P$ is parallel to a line of greatest slope of the plane. The string passes over a small smooth pulley, $P$, fixed at the top of the plane. The particle $A$ hangs freely below $P$, as shown in above. The coefficient of friction between $B$ and the plane is $\frac{2}{3}$. The particles are released from rest with the string taut and $B$ moves up the plane.

(a) Find the magnitude of the acceleration of $B$ immediately after release. (10)

(b) Find the speed of $B$ when it has moved 1 m up the plane. (2)

When $B$ has moved 1 m up the plane the string breaks. Given that in the subsequent motion $B$ does not reach $P$,

(c) find the time between the instants when the string breaks and when $B$ comes to instantaneous rest. (4)

(Total 16 marks)

Q8.

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 $4u$ m s$^{-1}$ and $Q$ has speed $ku$ m s$^{-1}$, 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)
Q9.

A particle of mass 0.4 kg is held at rest on a fixed rough plane by a horizontal force of magnitude $P$ newtons. The force acts in the vertical plane containing the line of greatest slope of the inclined plane which passes through the particle. The plane is inclined to the horizontal at an angle $\alpha$, where $\tan \alpha = \frac{3}{4}$, as shown in Figure 2.

The coefficient of friction between the particle and the plane is $\frac{1}{3}$.

Given that the particle is on the point of sliding up the plane, find

(a) the magnitude of the normal reaction between the particle and the plane, \( \text{(5 marks)} \)

(b) the value of $P$. \( \text{(5 marks)} \)

(Total 10 marks)

Q10.

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, \( \text{(2 marks)} \)

(b) the value of $m$. \( \text{(4 marks)} \)

(Total 6 marks)
Q11.

Two particles $A$ and $B$ are moving on a smooth horizontal plane. The mass of $A$ is $2m$ and the mass of $B$ is $m$. The particles are moving along the same straight line but in opposite directions and they collide directly. Immediately before they collide the speed of $A$ is $2u$ and the speed of $B$ is $3u$. The magnitude of the impulse received by each particle in the collision is \( \frac{7mu}{2} \).

Find

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

(b) the speed of $B$ immediately after the collision.

(Total 6 marks)

Q12.

A small brick of mass 0.5 kg is placed on a rough plane which is inclined to the horizontal at an angle $\theta$, where $\tan \theta = \frac{4}{3}$, and released from rest. The coefficient of friction between the brick and the plane is $\frac{1}{3}$.

Find the acceleration of the brick.

(Total 9 marks)

Q13.

A car of mass 800 kg pulls a trailer of mass 200 kg along a straight horizontal road using a light towbar which is parallel to the road. The horizontal resistances to motion of the car and the trailer have magnitudes 400 N and 200 N respectively. The engine of the car produces a constant horizontal driving force on the car of magnitude 1200 N. Find

(a) the acceleration of the car and trailer, 

(b) the magnitude of the tension in the towbar.

The car is moving along the road when the driver sees a hazard ahead. He reduces the force produced by the engine to zero and applies the brakes. The brakes produce a force on the car of magnitude $F$ newtons and the car and trailer decelerate. Given that the resistances to motion are unchanged and the magnitude of the thrust in the towbar is 100 N,

(c) find the value of $F$.

(Total 13 marks)

Q14.

Two particles $P$ and $Q$ have masses $4m$ and $m$ respectively. The particles are moving towards each other
on a smooth horizontal plane and collide directly. The speeds of $P$ and $Q$ immediately before the collision are $2u$ and $5u$ respectively. Immediately after the collision, the speed of $P$ is $\frac{1}{2} u$ and its direction of motion is reversed.

(a) Find the speed and direction of motion of $Q$ after the collision.

(b) Find the magnitude of the impulse exerted on $P$ by $Q$ in the collision.

(Total 7 marks)
Q15.

Particle \( P \) has mass 3 kg and particle \( Q \) has mass \( m \) kg. The particles are moving in opposite directions along a smooth horizontal plane when they collide directly. Immediately before the collision, the speed of \( P \) is 4 m s\(^{-1}\) and the speed of \( Q \) is 3 m s\(^{-1}\). In the collision the direction of motion of \( P \) is unchanged and the direction of motion of \( Q \) is reversed. Immediately after the collision, the speed of \( P \) is 1 m s\(^{-1}\) and the speed of \( Q \) is 1.5 m s\(^{-1}\).

(a) Find the magnitude of the impulse exerted on \( P \) in the collision.

(b) Find the value of \( m \).

(Total 6 marks)

Q16.

A woman travels in a lift. The mass of the woman is 50 kg and the mass of the lift is 950 kg. The lift is being raised vertically by a vertical cable which is attached to the top of the lift. The lift is moving upwards and has constant deceleration of 2 m s\(^{-2}\). By modelling the cable as being light and inextensible, find

(a) the tension in the cable,

(b) the magnitude of the force exerted on the woman by the floor of the lift.

(Total 6 marks)

Q17.

Two particles \( A \) and \( B \), of mass 2 kg and 3 kg respectively, are moving towards each other in opposite directions along the same straight line on a smooth horizontal surface. The particles collide directly. Immediately before the collision the speed of \( A \) is 5 m s\(^{-1}\) and the speed of \( B \) is 6 m s\(^{-1}\). The magnitude of the impulse exerted on \( B \) by \( A \) is 14 N s. Find

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

(b) the speed of \( B \) immediately after the collision.

(Total 6 marks)
A truck of mass 1750 kg is towing a car of mass 750 kg along a straight horizontal road. The two vehicles are joined by a light towbar which is inclined at an angle $\theta$ to the road, as shown in Figure 4. The vehicles are travelling at 20 m s$^{-1}$ as they enter a zone where the speed limit is 14 m s$^{-1}$. The truck's brakes are applied to give a constant braking force on the truck. The distance travelled between the instant when the brakes are applied and the instant when the speed of each vehicle is 14 m s$^{-1}$ is 100 m.

(a) Find the deceleration of the truck and the car.

(b) The constant braking force on the truck has magnitude $R$ newtons. The truck and the car also experience constant resistances to motion of 500 N and 300 N respectively. Given that $\cos \theta = 0.9$, find

(b) the force in the towbar,

(c) the value of $R$.

(Total 11 marks)
Three particles $A$, $B$ and $C$ have masses $3m$, $2m$ and $2m$ respectively. Particle $C$ is attached to particle $B$. Particles $A$ and $B$ are connected by a light inextensible string which passes over a smooth light fixed pulley. The system is held at rest with the string taut and the hanging parts of the string vertical, as shown in Figure 5. The system is released from rest and $A$ moves upwards.

(a) (i) Show that the acceleration of $A$ is $\frac{g}{7}$
(ii) Find the tension in the string as $A$ ascends.

At the instant when $A$ is 0.7 m above its original position, $C$ separates from $B$ and falls away. In the subsequent motion, $A$ does not reach the pulley.

(b) Find the speed of $A$ at the instant when it is 0.7 m above its original position.

(c) Find the acceleration of $A$ at the instant after $C$ separates from $B$.

(d) Find the greatest height reached by $A$ above its original position.

(Total 16 marks)
Q20.

Two particles $A$ and $B$ have masses $2m$ and $3m$ respectively. The particles are connected by a light inextensible string which passes over a smooth light fixed pulley. The system is held at rest with the string taut. The hanging parts of the string are vertical and $A$ and $B$ are above a horizontal plane, as shown in Figure 2. The system is released from rest.

(a) Show that the tension in the string immediately after the particles are released is $\frac{12}{5}mg$. 

After descending 1.5 m, $B$ strikes the plane and is immediately brought to rest. In the subsequent motion, $A$ does not reach the pulley.

(b) Find the distance travelled by $A$ between the instant when $B$ strikes the plane and the instant when the string next becomes taut.

Given that $m = 0.5$ kg,

(c) find the magnitude of the impulse on $B$ due to the impact with the plane.

(Total 14 marks)

Q21.

Particle $P$ of mass $m$ and particle $Q$ of mass $km$ are moving in opposite directions on a smooth horizontal plane when they collide directly. Immediately before the collision the speed of $P$ is $5u$ and the speed of $Q$ is $u$. Immediately after the collision the speed of each particle is halved and the direction of motion of each particle is reversed.

Find

(a) the value of $k$, 

(b) the magnitude of the impulse exerted on $P$ by $Q$ in the collision.
Q22.

A lift of mass 200 kg is being lowered into a mineshaft by a vertical cable attached to the top of the lift. A crate of mass 55 kg is on the floor inside the lift, as shown in Figure 2. The lift descends vertically with constant acceleration. There is a constant upwards resistance of magnitude 150 N on the lift. The crate experiences a constant normal reaction of magnitude 473 N from the floor of the lift.

(a) Find the acceleration of the lift.

(b) Find the magnitude of the force exerted on the lift by the cable.

(Total for question = 7 marks)

Q23.
Two particles $P$ and $Q$ have mass 4 kg and 0.5 kg respectively. The particles are attached to the ends of a light inextensible string. Particle $P$ is held at rest on a fixed rough plane, which is inclined to the horizontal at an angle $\alpha$ where $\tan \alpha = \frac{4}{3}$. The coefficient of friction between $P$ and the plane is 0.5. The string lies along the plane and passes over a small smooth light pulley which is fixed at the top of the plane. Particle $Q$ hangs freely at rest vertically below the pulley. The string lies in the vertical plane which contains the pulley and a line of greatest slope of the inclined plane, as shown in Figure 4. Particle $P$ is released from rest with the string taut and slides down the plane.

Given that $Q$ has not hit the pulley, find

(a) the tension in the string during the motion,

(b) the magnitude of the resultant force exerted by the string on the pulley.

(Total for question = 15 marks)
Q24.

A fixed rough plane is inclined at $30^\circ$ to the horizontal. A small smooth pulley $P$ is fixed at the top of the plane. Two particles $A$ and $B$, of mass 2 kg and 4 kg respectively, are attached to the ends of a light inextensible string which passes over the pulley $P$. The part of the string from $A$ to $P$ is parallel to a line of greatest slope of the plane and $B$ hangs freely below $P$, as shown in Figure 2. The coefficient of friction between $A$ and the plane is $\mu$. Initially $A$ is held at rest on the plane. The particles are released from rest with the string taut and $A$ moves up the plane.

Find the tension in the string immediately after the particles are released.

(Total 9 marks)

Q25.

A particle $P$ of mass 4 kg is moving up a fixed rough plane at a constant speed of 16 m s$^{-1}$ under the action of a force of magnitude 36 N. The plane is inclined at $30^\circ$ to the horizontal. The force acts in the vertical plane containing the line of greatest slope of the plane through $P$, and acts at $30^\circ$ to the inclined plane, as shown in Figure 2. The coefficient of friction between $P$ and the plane is $\mu$. Find

(a) the magnitude of the normal reaction between $P$ and the plane,
(b) the value of $\mu$

The force of magnitude 36 N is removed.

(c) Find the distance that $P$ travels between the instant when the force is removed and the instant when it comes to rest.

(Total 14 marks)
Q26.

Two particles $A$ and $B$ have masses $2m$ and $3m$ respectively. The particles are attached to the ends of a light inextensible string. Particle $A$ is held at rest on a smooth horizontal table. The string passes over a small smooth pulley which is fixed at the edge of the table. Particle $B$ hangs at rest vertically below the pulley with the string taut, as shown in Figure 2. Particle $A$ is released from rest. Assuming that $A$ has not reached the pulley, find

(a) the acceleration of $B$,  

(b) the tension in the string,  

(c) the magnitude and direction of the force exerted on the pulley by the string.  

(Total 10 marks)

Q27.

One end of a light inextensible string is attached to a block $P$ of mass 5 kg. The block $P$ is held at rest on a smooth fixed plane which is inclined to the horizontal at an angle $\alpha$, where $\sin \alpha = \frac{3}{5}$. The string lies along a line of greatest slope of the plane and passes over a smooth light pulley which is fixed at the top
of the plane. The other end of the string is attached to a light scale pan which carries two blocks $Q$ and $R$, with block $Q$ on top of block $R$, as shown in Figure 3. The mass of block $Q$ is 5 kg and the mass of block $R$ is 10 kg. The scale pan hangs at rest and the system is released from rest. By modelling the blocks as particles, ignoring air resistance and assuming the motion is uninterrupted, find

(a) (i) the acceleration of the scale pan,
(ii) the tension in the string,

(b) the magnitude of the force exerted on block $Q$ by block $R$,

(c) the magnitude of the force exerted on the pulley by the string.

(Total 16 marks)
Q28.

A particle P of mass 2.7 kg lies on a rough plane inclined at 40° to the horizontal. The particle is held in equilibrium by a force of magnitude 15 N acting at an angle of 50° to the plane, as shown in Figure 4. The force acts in a vertical plane containing a line of greatest slope of the plane. The particle is in equilibrium and is on the point of sliding down the plane.

Find

(a) the magnitude of the normal reaction of the plane on P,

(b) the coefficient of friction between P and the plane.

The force of magnitude 15 N is removed.

(c) Determine whether P moves, justifying your answer.

(Total 13 marks)

Q29.

Two forces $(4i - 2j)$ N and $(2i + qj)$ N act on a particle P of mass 1.5 kg. The resultant of these two forces is parallel to the vector $(2i + j)$.

(a) Find the value of q.

At time $t = 0$, P is moving with velocity $(-2i + 4j)$ m s$^{-1}$.

(b) Find the speed of P at time $t = 2$ seconds.

(Total 10 marks)
Q30.

A particle $P$ of mass 2 kg is moving under the action of a constant force $F$ newtons. The velocity of $P$ is $(2i - 5j)$ m s$^{-1}$ at time $t = 0$, and $(7i + 10j)$ m s$^{-1}$ at time $t = 5$ s.

Find

(a) the speed of $P$ at $t = 0$,

(b) the vector $F$ in the form $ai + bj$,

(c) the value of $t$ when $P$ is moving parallel to $i$.

(Total 11 marks)
## Mark Scheme

### Q1.

<table>
<thead>
<tr>
<th>Question Number</th>
<th>Scheme</th>
<th>Marks</th>
</tr>
</thead>
<tbody>
<tr>
<td>(a)</td>
<td><img src="image-url" alt="Diagram" /></td>
<td>M1 A1</td>
</tr>
<tr>
<td></td>
<td>[ I = 3000 \times 9 = 27,000 \text{ (N s)} ]</td>
<td>(2)</td>
</tr>
<tr>
<td>(b)</td>
<td>Conservation of linear momentum</td>
<td>M1 A1</td>
</tr>
<tr>
<td></td>
<td>[ 15m = -3m + 3000 \times 9 ]</td>
<td>A1</td>
</tr>
<tr>
<td></td>
<td>Leading to</td>
<td>(3)</td>
</tr>
<tr>
<td></td>
<td>[ m = 1500 ]</td>
<td>5</td>
</tr>
</tbody>
</table>

*Alternative to (b)*

<table>
<thead>
<tr>
<th>Scheme</th>
<th>Marks</th>
</tr>
</thead>
<tbody>
<tr>
<td>For P</td>
<td>M1 A1</td>
</tr>
<tr>
<td>Leading to</td>
<td>A1</td>
</tr>
<tr>
<td>[ 27,000 = m(15-(-3)) ]</td>
<td>(3)</td>
</tr>
<tr>
<td>[ m = 1500 ]</td>
<td></td>
</tr>
</tbody>
</table>

### Q2.
<table>
<thead>
<tr>
<th>Question Number</th>
<th>Scheme</th>
</tr>
</thead>
<tbody>
<tr>
<td>(a)</td>
<td>![Diagram]</td>
</tr>
<tr>
<td></td>
<td>For the whole system</td>
</tr>
<tr>
<td></td>
<td>( R(\rightarrow) ) ( 3200 - 800 - R = 1750 \times 0.88 )</td>
</tr>
<tr>
<td></td>
<td>Leading to ( R = 860 )</td>
</tr>
<tr>
<td>(b)</td>
<td>For the caravan</td>
</tr>
<tr>
<td></td>
<td>( R(\rightarrow) ) ( T - 860 = 750 \times 0.88 )</td>
</tr>
<tr>
<td></td>
<td>Leading to ( T = 1520 ) (N)</td>
</tr>
<tr>
<td>Alternative for (b)</td>
<td>For the car</td>
</tr>
<tr>
<td></td>
<td>( R(\rightarrow) ) ( 3200 - 800 - T = 1000 \times 0.88 )</td>
</tr>
<tr>
<td></td>
<td>Leading to ( T = 1520 ) (N)</td>
</tr>
</tbody>
</table>
(a) M1 for attempt at CLM equation, with correct no. of terms, correct masses and dimensionally consistent. Allow consistent extra g's, consistent missing m's and sign errors. However, M0 if masses are not paired with the correct speeds. First A1 for a correct equation. Second A1 for $v = 1.5$. ($-1.5 \text{ A0}$) N.B. Allow M1 for an attempt to equate the impulses on the particles but must have $5m (0.8 - 3)$ or $5m (3 - 0.8)$ on one side of the equation and $2m (\pm v \pm 4)$ on the other.

(b) M1 for attempt at impulse = difference in momenta, for either particle, (must be considering one particle) (M0 if g's are included or if mass omitted or if just m used) Allow Initial Momentum – Final Momentum. A1 cao (i.e. no ft on their v) for a correct equation in m only. A1 for $m = 0.3$
<table>
<thead>
<tr>
<th>Question Number</th>
<th>Scheme</th>
<th>Marks</th>
</tr>
</thead>
</table>
| (a)             | ![Diagram](image1) | \[ CLM: 3x3 - 2x2 = 3v + 2(v+1) \]
|                 |        | \[ v = 0.6 \text{ m s}^{-1}; v' = 1.6 \text{ m s}^{-1} \] | M1 A1
|                 |        | (A1 ft) (5) |
| (b)             | \[ 3(v - 3) \text{ OR } 2(v + 1 - -2) \]
|                 | = 7.2 \text{ Ns} \quad = 7.2 \text{ Ns} | M1 A1 ft
|                 | A1     | (3) (8) |

Q5.
Q6.

<table>
<thead>
<tr>
<th>Question Number</th>
<th>Scheme</th>
<th>Marks</th>
</tr>
</thead>
</table>
| (a)             | Conservation of momentum: 4m - 6 = m + 9  
|                 | m = 5  | M1 A1 A1 (3) |
| (b)             | Impulse = change in momentum  
|                 | = 3 × 3 - (3 × -2) = 15  | M1 A1 (2) [5] |

Q7.
<table>
<thead>
<tr>
<th>Question Number</th>
<th>Scheme</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>(a)</strong></td>
<td></td>
</tr>
<tr>
<td><img src="image" alt="Diagram" /></td>
<td></td>
</tr>
</tbody>
</table>
| \[ \tan \theta = \frac{5}{12} \]  
| \[ \sin \theta = \frac{5}{13} \]  
| \[ \cos \theta = \frac{12}{13} \]  
| For A: 7g − T = 7a  
| For B: parallel to plane \( T - F - 3g \sin \theta = 3a \)  
| perpendicular to plane \( R = 3g \cos \theta \)  
| \( F = \mu R = 3g \cos \theta = 2g \cos \theta \)  
| Eliminating \( T \), \( 7g - F - 3g \sin \theta = 10a \)  
| Equation in \( g \) and \( a \):  
| \[ 7g - 2g \times \frac{12}{13} - 3g \times \frac{5}{13} \]  
| \[ 7g - \frac{39}{13}g = 4g = 10a \]  
| \( a = \frac{2g}{5} \) or 3.9 or 3.92 |
| **(b)** After 1 m,  
| \( v^2 = u^2 + 2as \)  
| \( v^2 = 0 + 2 \times \frac{2g}{5} \times 1 \)  
| \( v = 2.8 \) |
| **(c)**  
| \[ - (F + 3g \sin \theta) = 3a \]  
| \[ \frac{2}{3} \times 3g \times \frac{12}{13} + 3g \times \frac{5}{13} = 3g = -3a, \ a = -g \]  
| \( v = u + at, 0 = 2.8 - 9.8t, \)  
| \( t = \frac{2}{7} \) oe, 0.29. 0.286 |

<table>
<thead>
<tr>
<th>Marks</th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>M1</strong></td>
<td><strong>A1</strong></td>
</tr>
<tr>
<td><strong>DM1</strong></td>
<td><strong>A1</strong></td>
</tr>
<tr>
<td><strong>(10)</strong></td>
<td></td>
</tr>
<tr>
<td><strong>M1</strong></td>
<td><strong>A1</strong></td>
</tr>
<tr>
<td><strong>(2)</strong></td>
<td></td>
</tr>
<tr>
<td><strong>M1</strong></td>
<td><strong>A1</strong></td>
</tr>
<tr>
<td><strong>DM1</strong></td>
<td><strong>A1</strong></td>
</tr>
<tr>
<td><strong>(4)</strong></td>
<td><strong>[16]</strong></td>
</tr>
</tbody>
</table>
### Q8.

<table>
<thead>
<tr>
<th>Question Number</th>
<th>Scheme</th>
<th>Marks</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>(a)</strong></td>
<td><img src="image" alt="Diagram" /></td>
<td>M1 A1 &lt;br&gt; M1 A1 cso (4)</td>
</tr>
<tr>
<td></td>
<td>$4mu - 3mku = -2mu + 3mk \frac{u}{2}$ &lt;br&gt; $k = \frac{4}{3}$</td>
<td></td>
</tr>
<tr>
<td><strong>(b)</strong></td>
<td>For $P$, $I = m (2u - 4u)$ &lt;br&gt; $= 6mu$ &lt;br&gt; <strong>OR</strong> For $Q$, $I = 3m (\frac{ku}{2} - ku)$</td>
<td>M1 A1 &lt;br&gt; A1 (3) &lt;br&gt; (M1A1) [7]</td>
</tr>
</tbody>
</table>

### Q9.

<table>
<thead>
<tr>
<th>Question Number</th>
<th>Scheme</th>
<th>Marks</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>(a)</strong></td>
<td>$F = \frac{1}{2} R$ &lt;br&gt; $(\uparrow) R \cos \alpha - F \sin \alpha = 0.4g$ &lt;br&gt; $R = \frac{3}{5} g = 6.53 \text{ or } 6.5$</td>
<td>B1 &lt;br&gt; M1 A1 &lt;br&gt; M1 A1 (5)</td>
</tr>
<tr>
<td><strong>(b)</strong></td>
<td>$(\rightarrow) P - F \cos \alpha - R \sin \alpha = 0$ &lt;br&gt; $P = \frac{28}{15} g = 5.66 \text{ or } 5.7$</td>
<td>M1 A2 &lt;br&gt; M1 A1 (5) [10]</td>
</tr>
</tbody>
</table>

### Q10.
<table>
<thead>
<tr>
<th>Question Number</th>
<th>Scheme</th>
<th>Marks</th>
</tr>
</thead>
<tbody>
<tr>
<td>(a)</td>
<td>$I = 2 \times 12 - 2 \times 3 = 18 \text{ N s}$</td>
<td>M1 A1 (2)</td>
</tr>
<tr>
<td>(b)</td>
<td>LM</td>
<td>M1 A1</td>
</tr>
<tr>
<td></td>
<td>$2 \times 12 - 8m = 2 \times 3 + 4m$</td>
<td>DM1 A1 (4)</td>
</tr>
<tr>
<td></td>
<td>Solving to $m = 1.5$</td>
<td></td>
</tr>
<tr>
<td><strong>Alternative to (b)</strong></td>
<td></td>
<td>[6]</td>
</tr>
<tr>
<td></td>
<td>$I = m \left(4 - (-8)\right) = 18$</td>
<td>M1 A1</td>
</tr>
<tr>
<td></td>
<td>Solving to $m = 1.5$</td>
<td>DM1 A1 (4)</td>
</tr>
</tbody>
</table>
**Q11.**

<table>
<thead>
<tr>
<th>Question Number</th>
<th>Scheme</th>
<th>Marks</th>
</tr>
</thead>
<tbody>
<tr>
<td>(a)</td>
<td>For A: [ \frac{7mu}{2} = 2m(v_A - 2u) ] [ v_A = \frac{u}{4} ]</td>
<td>M1 A1</td>
</tr>
<tr>
<td></td>
<td>For B: [ \frac{7mu}{2} = m(v_B - 3u) ] [ v_B = \frac{u}{2} ]</td>
<td>A1 (3)</td>
</tr>
<tr>
<td></td>
<td>OR CLM: [ 4mu - 3mu = 2m \left( \frac{u}{4} \right) + mv_B ] [ v_B = \frac{u}{2} ]</td>
<td>M1 A1</td>
</tr>
</tbody>
</table>

**Q12.**

<table>
<thead>
<tr>
<th>Question Number</th>
<th>Scheme</th>
<th>Marks</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>[ 0.5g \sin \theta - F = 0.5a ] [ F = \frac{1}{2} R ] seen [ R = 0.5g \cos \theta ]</td>
<td>M1 A1 A1</td>
</tr>
<tr>
<td></td>
<td>Use of ( \sin \theta = \frac{3}{5} ) or ( \cos \theta = \frac{4}{5} ) or decimal equiv or decimal angle e.g. 53.1° or 53° [ a = \frac{3g}{5} ] or 5.88 m s(^{-2}) or 5.9 m s(^{-2})</td>
<td>B1 M1 A1</td>
</tr>
</tbody>
</table>
### Q13.

<table>
<thead>
<tr>
<th>Question Number</th>
<th>Scheme</th>
<th>Marks</th>
</tr>
</thead>
</table>
| **(a)** | For whole system: \(1200 - 400 - 200 = 1000a\)  
\[a = 0.6 \text{ m/s}^2\] | M1 A1 |
| **(b)** | For trailer: \(T - 200 = 200 \times 0.6\)  
\[T = 320 \text{ N}\] | A1 (3) |
| **OR:** | For car: \(1200 - 400 - T = 800 \times 0.6\)  
\[T = 320 \text{ N}\] | M1 A1 ft |
| **(c)** | For trailer: \(200 + 100 = 200f \text{ or/} -200f\)  
\[f = 1.5 \text{ m/s}^2 \text{ (-1.5)}\]  
For car: \(400 + F - 100 = 800f \text{ or/} -800f\)  
\[F = 900\]  
(N.B. For both: \(400 + 200 + F = 1000f\)) | M1 A1 A1 |

[](https://www.example.com) [13]

### Q14.

<table>
<thead>
<tr>
<th>Question Number</th>
<th>Scheme</th>
<th>Marks</th>
</tr>
</thead>
</table>
| **(a)** | \(4m \cdot 2u - m \cdot 5u = -4m \cdot \frac{1}{2}u + mv\)  
\(3mu = -2mu + mv\)  
\(v = 5u, \text{ opposite direction}\) | M1 A1 |
| **(b)** | \[I = 4m(\frac{5}{2}u - 2u) \text{ OR } I = m(5u - 5u)\]  
\[= 10mu\] | M1 A1 |

A1, A1 eso (4)  
A1 (3)  
7
### Q15.

<table>
<thead>
<tr>
<th>Question Number</th>
<th>Scheme</th>
<th>Marks</th>
</tr>
</thead>
<tbody>
<tr>
<td>(a)</td>
<td>For ( P ), (-I = 3(1 - 4))</td>
<td>M1 A1</td>
</tr>
<tr>
<td></td>
<td>( I = 9 \text{ Ns} )</td>
<td>A1 (3)</td>
</tr>
<tr>
<td>(b)</td>
<td>For ( Q ), ( 9 = m(1.5 - -3) )</td>
<td>M1 A1</td>
</tr>
<tr>
<td></td>
<td>( m = 2 )</td>
<td>A1</td>
</tr>
<tr>
<td>OR</td>
<td>( 12 - 3m = 3 + 1.5m )</td>
<td>M1 A1</td>
</tr>
<tr>
<td></td>
<td>( m = 2 )</td>
<td>A1 (3)</td>
</tr>
</tbody>
</table>

### Notes for Question

**Q (a)**

M1 for attempt at Impulse = difference in momenta for particle \( P \), (must be considering one particle i.e. have same mass in both terms) (M0 if \( g \) is included or if mass omitted).

First A1 for \( \pm 3(1 - 4) \)

Second A1 for 9 (Must be positive). Allow change of sign at end to obtain magnitude.

**N.B.** For M1 they may use CLM to find a value for \( m \) first and then use it when considering the change in momentum of \( Q \) to find the impulse.

**Q (b)**

**EITHER**

M1 for attempt at:
their Impulse from (a) = difference in momenta for particle \( Q \), (must be considering one particle) (M0 if \( g \) is included or if mass omitted).

First A1 for \( 9 = m(1.5 - -3) \) oe.

Second A1 for \( m = 2 \).

**OR**

M1 for attempt at CLM equation, with correct no. of terms, dimensionally correct. Allow consistent extra \( g \)'s and sign errors.

First A1 for a correct equation i.e. \( 12 - 3m = 3 + 1.5m \) oe.

Second A1 for \( m = 2 \).
Q16.

<table>
<thead>
<tr>
<th>Question Number</th>
<th>Scheme</th>
<th>Marks</th>
</tr>
</thead>
<tbody>
<tr>
<td>(a)</td>
<td>For system, $T - 950g - 50g = 1000 \times -2$ $T = 7800 \text{ N}$</td>
<td>M1 A1 A1</td>
</tr>
<tr>
<td>(b)</td>
<td>For woman, $R - 50g = 50 \times -2$ $R = 390 \text{ N}$</td>
<td>M1 A1 A1</td>
</tr>
</tbody>
</table>

Notes for Question

Q (a) (In both parts, use the mass to decide which part of the system is being considered and M marks can only be scored if an equation contains only forces acting on that part of the system)
M1 is for a complete method for finding $T$ i.e. for an equation in $T$ only, dimensionally correct, with the correct number of terms.
First A1 for a correct equation.
Second A1 for 7800 (N).

Q (b) M1 is for a complete method for finding $R$ i.e. for an equation in $R$ only, dimensionally correct, with the correct number of terms.
First A1 for a correct equation.
Second A1 for 390 (N).
N.B. Equation for lift only is: $T - 950g - R = 950 \times (-2)$
<table>
<thead>
<tr>
<th>Question Number</th>
<th>Scheme</th>
<th>Marks</th>
</tr>
</thead>
<tbody>
<tr>
<td>(a)</td>
<td><img src="image.png" alt="Diagram" /></td>
<td>M1A1 A1 (3)</td>
</tr>
</tbody>
</table>

\[ 2v + 10 = 14 \]
\[ v = 2 \text{ m s}^{-1} \]

\[ 3w + 18 = 14 \]
\[ w = \frac{4}{3} \text{ m s}^{-1} \]

(b) \[ 2v + 10 = 14 \]  
\[ v = 2 \text{ m s}^{-1} \]  
\[ 3w + 18 = 14 \]  
\[ w = \frac{4}{3} \text{ m s}^{-1} \]  

**Notes for Question**

Q (a)  
M1 for attempt at Impulse = difference in momenta for particle \( A \), (must be considering one particle) (M0 if \( g \) is included or if mass omitted).
First A1 for \(-14 = 2(\pm v - 5)\)
Second A1 for 2 (Must be positive). Allow change of sign at end to obtain speed.

Either  
M1 for attempt at Impulse = difference in momenta for particle \( B \), (must be considering one particle) (M0 if \( g \) is included or if mass omitted).
First A1 \( 14 = 3(\pm w - 6) \)
Second A1 for \( 4/3, 1.3 \) or better (Must be positive). Allow change of sign at end to obtain speed.

OR  
M1 for attempt at CLM equation, with correct no. of terms, dimensionally correct. Allow consistent extra \( g \)'s and sign errors.
First A1 (Not f.t.) for a correct equation e.g.
\[ 2 \times 5 - 3 \times 6 = -2 \times 2 + 3w \]
Second A1 for speed is \( 4/3, 1.3 \) or better

N.B. They may find the speed of \( B \) first and then use CLM to find the speed of \( A \).
It must be clear which speed is which, in order to gain the A marks for the answers.
<table>
<thead>
<tr>
<th>Question Number</th>
<th>Scheme</th>
<th>Marks</th>
</tr>
</thead>
</table>
| (a)             | Use of $v^2 = u^2 + 2as$  
$14^2 = 20^2 - 2\alpha \times 100$  
Deceleration is 1.02 (m s$^{-2}$) | M1  
A1  
A1 |
| (b)             | Horizontal forces on the car:  
$\pm T \cos \theta - 300 = 750 \times -1.02 = -765$  
$T = \frac{1550}{3}$  
The force in the tow-bar is 1550/3, 520 (N) or better (allow –ve answer) | M1A2 ft.  
A1 |
| (c)             | Horizontal forces on the truck:  
$\pm T \cos \theta - 500 - R = 1750 \times -1.02$  
Braking force $R = 1750$ (N) | M1A2 ft.  
A1 |
|                 | **ALT**: Whole system:  
$800 + R = 2500 \times 1.02$  
$R = 1750$ | M1A2 ft.  
[11] |

**Notes for Question**

Q (a)  
M1 for a complete method to produce an equation in $a$ only.  
First A1 for a correct equation.  
Second A1 for 1.02 (m s$^{-2}$) oe. must be POSITIVE.

Q (b)  
M1 for considering *the car ONLY* horizontally to produce an equation in $T$ only, with usual rules, i.e. correct no. of terms AND $T$ resolved:  
$\pm T \cos \theta - 300 = 750 \times -1.02$  
A2 ft on their $a$ for a correct equation (*300 and $a$ must have same sign*); -1 each error (treat $\cos 0.9$ as an A error)  
A1 for 1550/3 oe, 520 or better (N) N.B. Allow a negative answer.

Q (c)  
M1 for considering *the truck ONLY* horizontally to produce an equation, with usual rules, i.e. correct no. of terms AND $T$ resolved:  
$\pm T \cos \theta - 500 - R = 1750 \times -1.02$  
A2 ft on their $T$ and $a$ for a correct equation (*500, $a$ and $R$ must have same sign*). -1 each error (treat $\cos 0.9$ as an A error)  
A1 for 1750 (N).

OR  
M1 for considering *the whole system* to produce an equation in $R$ only, with usual rules, i.e. correct no. of terms.  
A2 ft on their $a$ for a correct equation (*$a$ and $R$ must have same sign*). -1 each error  
A1 for 1750 (N).

N.B. If 300 and 500 are given separately, penalise any sign errors only ONCE.
<table>
<thead>
<tr>
<th>Question Number</th>
<th>Scheme</th>
<th>Marks</th>
</tr>
</thead>
</table>
| **(a)** | $4mg - T = 4ma$  
| | $T - 3mg = 3ma$  
| | Condone the use of $4mg - 3mg = 4ma + 3ma$ in place of one of these equations. | M1A1 |
| Reach **given answer** $a = \frac{g}{7}$ correctly ***** | A1 |
| Form an equation in $T$:  
| | $T = 3mg + 3\left(\frac{T}{4}\right)$, $T = 3mg + 3m\frac{g}{7}$, or $T = 4mg - 4m\frac{g}{7}$ | M1 |
| | $T = \frac{24}{7}mg$ or equivalent, 33.6$m$, 34$m$ | A1 |
| (7) | |
| **(b)** | $v^2 = u^2 + 2as = 2 \times \frac{g}{7} \times 0.7 = 1.96$, $v = 1.4$ ms$^{-1}$ | M1A1 |
| (2) | |
| **(c)** | $3mg - T = 3ma$  
| | $T - 2mg = 2ma$  
| | $a = \frac{g}{5}$ | M1A1 |
| (4) | A1 |
| **(d)** | $0 = 1.96 - 2 \times \frac{g}{5} \times s$ | M1 |
| | $s = \frac{5 \times 1.96}{2g} = 0.5$ (m) | A1 |
| Total height = 0.7 + 0.5 = 1.2 (m) | A1 ft |
| **Alt d** | Using energy: $3mgs - 2mgs = \frac{1}{2} 3m \times 1.4^2 + \frac{1}{2} 2m \times 1.4^2$ | M1 |
| | $s = \frac{2.5 \times 1.96^2}{g} = 0.5$ (m) | A1 |
| Total height = 0.7 + 0.5 = 1.2 (m) | A1 ft |
| (3) | |

[16]
Notes for Question

Question (a)(i) and (ii)
First M1 for resolving vertically (up or down) for B+C, with correct no. of terms.
First A1 for a correct equation.
Second M1 for resolving vertically (up or down) for A, with correct no. of terms.
Second A1 for a correct equation.
Third A1 for g/7, obtained correctly. Given answer (1.4 A0)

Third M1 for an equation in T only
Fourth A1 for 24mg/7 oe or 33.6m or 34m

N.B. If they omit m throughout (which gives a = g/7), can score max M1A0M1A0A0M1A0 for part (a) BUT CAN SCORE ALL OF THE MARKS in parts (b), (c) and (d).

Question (b)
M1 for an equation in v only (usually $v^2 = u^2 + 2as$)
A1 for 1.4 (ms\(^{-1}\)) allow $\sqrt{(g/5)}$ oe.

Question (c)
First M1 for resolving vertically (up or down) for A or B, with correct no. of terms. (N.B. M0 if they use the tension from part (a))
First A1 for a correct equation for A.
Second A1 for a correct equation for B.
N.B. ‘Whole system’ equation: $3mg - 2mg = 5ma$ earns first 3 marks but any error loses all 3
Third A1 for g/5 oe or 1.96 or 2.0 (ms\(^{-2}\)) (allow a negative answer)

Question (d)
M1 for an equation in s only using their v from (b) and a from (c).
either $0 = 1.4^2 - 2(g/5)s$ or $1.4^2 = 0 + 2(g/5)s$
First A1 for $s = 0.5$ (m) correctly obtained
Second A1 ft for their $0.5 + 0.7 = 1.2$ (m)

Alternative using conservation of energy
M1 for an equation in s only, with correct number of terms, using their v from (b):-
$(3mgs - 2mgs) = \frac{1}{2} 3m (1.4)^2 + \frac{1}{2} 2m (1.4)^2$
First A1 for $s = 0.5$ (m) correctly obtained
Second A1 ft for their $0.5 + 0.7 = 1.2$ (m)
<table>
<thead>
<tr>
<th>Question Number</th>
<th>Scheme</th>
<th>Marks</th>
</tr>
</thead>
</table>
| **a** | \(3mg - T = 3ma\)  
\(T - 2mg = 2ma\)  
\(T = 2mg + 2\left(mg - \frac{T}{3}\right)\)  
\(T = \frac{12}{5}mg\)  *Given Answer* | M1A1  
M1A1  
DM1  
A1 |
| **b** | \(a = \frac{g}{5}\)  
At time of impact \(v^2 = u^2 + 2as = 2 \times \frac{g}{5} \times 1.5 = 0.6g\)  
Vertical motion under gravity \(0 = 0.6g - 2gs\)  
Total distance \(2 \times 0.3 = 0.6\) (m) | B1  
M1A1  
M1  
DM1A1 |
| **c** | Impulse = \(3m(v - u) = -3mu\)  
Magnitude = \(3m\sqrt{0.6g} = \text{3.6 (Ns)}\) (3.64) | M1  
A1 |

Total (6)  

Total (6)  

Total (2)  

[14]
**Q21.**

**Question (a)**
First M1 for resolving vertically (up or down) for B, with correct no. of terms etc (allow if they omit m but have the 3)
First A1 for a correct equation.
Second M1 for resolving vertically (up or down) for A, with correct no. of terms etc (allow if they omit m but have the 2)
Second A1 for a correct equation.
Third M1, dependent on the first two M marks, for eliminating a
Third A1 for \( T = \frac{12mg}{5} \) given answer

N.B. Either equation above can be replaced by the whole system equation
M1A1 for \( 3mg - 2mg = 5ma \); any error loses both marks.

N.B. If m has been omitted in (a), which has led to a dimensionally incorrect value of a, can score max B0M1A0M1M1A0 in (b) and M1A0 in (c).

**Question (b)**
B1 for \( a = g/5 \) found (possibly in part (a)) and used here.
First M1 for using *suvat with their a from part (a)*, to find the speed v (or \( v^2 \)) of B at impact
First A1 for \( \sqrt{(0.6g)} \) oe, 2.4 or better (may be implied) found correctly.
Second M1 for using *suvat with a = \pm g , to obtain an equation in s only, using their v (or \( v^2 \)) with final velocity = 0*
Third M1, dependent on second M1, for doubling their s value
Second A1 for 0.6 (m)

**Question (c)**
M1 for \( \pm 3m \times \) (their v) or \( \pm 1.5 \times \) (their v) or
\( \pm m \times \) (their v) or \( \pm 0.5 \times \) (their v)
M0 if 3m missing or extra g
A1 for 3.6 or 3.64 (Ns)
<table>
<thead>
<tr>
<th>Question Number</th>
<th>Scheme</th>
<th>Marks</th>
</tr>
</thead>
<tbody>
<tr>
<td>(a)</td>
<td>[ m.5u - kmu = - \frac{m.5u}{2} + \frac{km.u}{2} ] [ k = 5 ]</td>
<td>M1 A1</td>
</tr>
<tr>
<td>(b)</td>
<td>For ( P : I = m\left(\frac{5u}{2} - 5u\right) ) OR For ( Q : I = km\left(\frac{u}{2} - u\right) ) [ \frac{15mu}{2} ] [ \frac{15mu}{2} ]</td>
<td>M1 A1</td>
</tr>
</tbody>
</table>

**Notes**

(a) M1 for attempt at CLM equation, with correct no. of terms, dimensionally correct. Allow consistent extra g’s and cancelled m’s and u’s and sign errors.

First A1 for a correct equation with or without m’s and u’s

Second A1 for \( k = 5 \)

N.B. They may find the impulse on each particle and then equate the impulses to produce an equation. Apply the scheme to this equation.

(b) M1 for attempt at impulse = difference in momenta, for either particle. (must be considering one particle) (M0 if g’s are included or if m or u omitted) Allow \( \pm m(\frac{5}{2}u - 5u) \) or \( \pm km(\frac{1}{2}u - u) \).

First A1 for \( \pm m(\frac{5}{2}u - 5u) \) or \( \pm km(\frac{1}{2}u - u) \)

A1 for 7.5mu oe cao (-7.5mu is A0) Allow change of sign at end to obtain magnitude

Q22.
<table>
<thead>
<tr>
<th>Question Number</th>
<th>Scheme</th>
<th>Marks</th>
</tr>
</thead>
</table>
| (a)             | For crate, $55g - 473 = 55a$  
                   | $a = 1.2 \text{ m s}^{-2}$ | M1 A1 A1 (3) |
| (b)             | For system, $55g + 200g + 7T - 150 = 255a$  
                   | Magnitude = 2040 N or 2000 N | M1 A2 A1 |
|                 | OR     |       |
|                 | For lift, $200g + 473 - 150 = 200a$  
                   | Magnitude = 2040 N or 2000 N | M1 A2 A1 (4) |

**Notes**

(a) M1 for an equation in $a$ only, with usual rules.  
First A1 for a correct equation  
Second A1 for $1.2 \text{ m s}^{-2}$.  Allow $1.2 \text{ m s}^{-2}$ if appropriate

(b) M1 for an equation, in $T$ and $a$, for the system or the lift only, with usual rules. ($a$ does not need to be a numerical value)  
A2 (-1 each error) for a correct equation ($\text{Allow} \pm T$). We do **not** need to see a numerical value for $a$.  
Third A1 for 2040 (N) or 2000 (N)  
**N.B.** In both parts of this question use the mass which is being used to guide you as to which part of the system is being considered.
<table>
<thead>
<tr>
<th>Question Number</th>
<th>Scheme</th>
<th>Marks</th>
</tr>
</thead>
<tbody>
<tr>
<td>(a)</td>
<td>( R = 4g \cos \alpha ) [ T - 0.5g = 0.5a ] [ 4g \sin \alpha - T - F = 4a ] (OR: [ 4g \sin \alpha - F - 0.5g = 4.5a ]) ( F = \frac{1}{2} R; ) [ \sin \alpha = \frac{4}{5} \text{ or } \cos \alpha = \frac{3}{5} ] Eliminating ( \alpha ) or finding ( a ) Solving for ( T ) (must have had an ( a )) ( T = \frac{2g}{3} \text{ N or 6.5N or 6.53N} )</td>
<td>M1 A1 M1 A1 M1 A1 B1; B1 M1 M1 A1</td>
</tr>
</tbody>
</table>

(b) \[ \text{Magnitude} = 2T \cos \left( \frac{90 - \alpha}{2} \right) \] \begin{align*} &= 2 \times \frac{2g}{3} \times \varphi \sqrt{\frac{3}{\sqrt{10}}} \approx 0.94868.. \end{align*} \[ = 12N \text{ or 12.4N} \left( \frac{4g}{\sqrt{10}} \right) \] | M1 A1 A1 ft on \( T \) A1 |

### Notes

(a) First M1 for resolving perp to plane, with usual criteria
First A1 for a correct equation
Second M1 for resolving vertically, with usual criteria
Second A1 for a correct equation, in terms of \( a \) and \( T \)
Third M1 for resolving parallel to the slope, with usual criteria.
Third A1 for a correct equation, in terms of \( a \), \( F \) and \( T \)
N.B. Their \( a \) could be UP the slope in which case all 4 marks for the 2 equations are available with \(-a\) replacing \( a \), provided they are consistent. If they are inconsistent, then assume the vertical resolution is the correct one and mark accordingly.

Either of the above two equations can be replaced by the ‘whole system’ equation
N.B. If they use \( a = 0 \), in any of the above 3 equations, and they use the equation to find \( T \), they lose both marks for that equation, and they lose the two M marks for eliminating and solving.
First B1 for \( F = \frac{1}{2} R \) seen or implied;
Second B1 for \( \sin \alpha = 0.8 \) or \( \cos \alpha = 0.6 \) seen or implied. Allow close approximations if \( \alpha = 53.1^\circ \) used.
Fourth M1 independent for eliminating \( a \) or finding \( a \).
Fifth M1 for solving for \( T \) but must have had an \( a \).
Fourth A1 for \( 2g/3 \), 6.5 or 6.53.
First M1 for a complete method for finding the magnitude of the resultant (N.B. M0 if same tensions used)

\[ 2T \cos \left( \frac{90^\circ - \alpha}{2} \right) \]  . Allow sin/cos confusion and allow \( 2T \cos \left( \frac{\alpha}{2} \right) \)

OR \( \sqrt{(T + T \sin \alpha)^2 + (T \cos \alpha)^2} \). Allow sin/cos confusion and allow omission of \( \sqrt{\text{sign}} \) but only if \( R^2 = \ldots \) is included

OR \( \sqrt{T^2 + T^2 - 2T^2 \cos(90^\circ + \alpha)} \). Allow \( (90^\circ - \alpha) \) but must be cos and allow omission of \( \sqrt{\text{sign}} \) but only if \( R^2 = \ldots \) is included

OR \( \frac{T \sin(90 + \alpha)}{\sin \left( \frac{90^\circ - \alpha}{2} \right)} \). (Sine Rule) Allow sign errors in angles but must be sin

First A1 for correct expression in terms of \( T \) and \( \alpha \)
Second A1, fit on their \( T \), for a ‘correct’ single numerical answer
Third A1 cao for 12 (N) or 12.4 (N)
### Q24.

<table>
<thead>
<tr>
<th>Question Number</th>
<th>Scheme</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td><img src="image" alt="Diagram" /></td>
</tr>
</tbody>
</table>

**Equation of motion of B:** \( 4g - T = 4a \)
**Equation of motion of A:** \( T - F - 2g \sin 30 = 2a \)
**OR:** \( 4g - F - 2g \sin 30 = 6a \)

Resolve perpendicular to the plane at A: \( R = 2g \cos 30 \)

Use of \( F = \mu R \): \( F = \frac{1}{\sqrt{3}} \times 2g \cos 30(= g) \)

\[
T - g - g = T - 2g = 2a
\]

\[
2T - 4g = 4g - T, \ 3T = 8g, \ T = \frac{8g}{3} (= 26) \quad 26.1(N)
\]

**Notes for Question**

First M1 for resolving vertically (up or down) for B, with correct no. of terms.
First A1 for a correct equation.
Second M1 for resolving parallel to the plane (up or down) for A, with correct no. of terms.
A2 for a correct equation (-1 each error)

**OR:** M2 A3 for the whole system equation - any method error loses all the marks.
B1 for perpendicular resolution
Third M1 for sub for \( R \) in \( F = \mu R \)
Fourth DM1, dependent on first and second M marks, for eliminating \( a \).
Fourth A1 for \( 8g/3, 26.1 \) or \( 26 \) (N). (392/15 oe is A0)

### Q25.


<table>
<thead>
<tr>
<th>Question Number</th>
<th>Scheme</th>
<th>Marks</th>
</tr>
</thead>
</table>
| (a)             | ![Diagram](image)  
\[R + 36 \sin 30^\circ = 4g \cos 30^\circ\]  
\[R = 15.9 \text{ m} \]  
   | M1 A1  
   | M1 A1 |
| (b)             | Use of  \[F_r = \mu R\]  
\[36 \cos 30^\circ = F + 4g \sin 30^\circ\]  
\[\mu = \frac{36 \cos 30^\circ - 4g \sin 30^\circ}{R} \approx 0.726\]  
\[\mu \approx 0.73\]  | B1  
   | M1 A1  
   | M1 A1 |
| (c)             | After force is removed  
\[\bar{R} = 4g \cos 30^\circ\]  
\[-\mu 4g \cos 30^\circ - 4g \sin 30^\circ = 4a\]  
\[a = (\text{-})11.06 \text{ m/s}^2\]  
\[v^2 = u^2 + 2as \Rightarrow 0^2 = 16^2 - 2 \times 11.06 \times s\]  
\[s = \frac{16^2}{2 \times 11.06} \approx 11.6 \text{ m}\]  | B1  
   | M1 A1  
   | M1  
   | A1  |

**Total Marks:** 14
### Q26.

<table>
<thead>
<tr>
<th></th>
<th>Scheme</th>
<th>Marks</th>
</tr>
</thead>
<tbody>
<tr>
<td>(a)</td>
<td>For $A$, $T = 2ma$</td>
<td>B1</td>
</tr>
<tr>
<td></td>
<td>For $B$, $3mg - T = 3ma$</td>
<td>M1 A1</td>
</tr>
<tr>
<td></td>
<td>$3mg = 5ma$</td>
<td>DM1</td>
</tr>
<tr>
<td></td>
<td>$\frac{3g}{5} = a$ \hspace{1cm} (5.9 or 5.88 m s$^{-2}$)</td>
<td>A1</td>
</tr>
<tr>
<td>(b)</td>
<td>$T = \frac{6mg}{5}$; 12m : 11.8m</td>
<td>B1</td>
</tr>
<tr>
<td>(c)</td>
<td>$F = \sqrt{T^2 + T'^2}$</td>
<td>M1 A1 ft</td>
</tr>
<tr>
<td></td>
<td>$F = \frac{6mg\sqrt{2}}{5}$; 1.7mg (or better); 16.6m; 17m</td>
<td>A1</td>
</tr>
<tr>
<td></td>
<td>Direction clearly marked on a diagram, with an arrow, and 45° (oe) marked</td>
<td>B1</td>
</tr>
</tbody>
</table>

| Notes for Question |
|---|---|
| Q (a) | B1 for $T = 2ma$
First M1 for resolving vertically (up or down) for $B$, with correct no. of terms. (allow omission of $m$, provided 3 is there)
First A1 for a correct equation.
Second M1, dependent on first M1, for eliminating $T$, to give an equation in $a$ only.
Second A1 for 0.6g, 5.88 or 5.9.
N.B. ‘Whole system’ equation: $3mg = 5ma$ earns first 4 marks but any error loses all 4. |
| Q (b) | B1 for $\frac{6mg}{5}$, 11.8m, 12m |

| Q (c) | M1 $\sqrt{(T^2 + T'^2)}$ or $\frac{T}{\sin 45°}$ or $\frac{T}{\cos 45°}$ or $2T \cos 45°$ or $2T \sin 45°$ (allow if $m$ omitted)
(M0 for $T \sin 45°$)
First A1 ft on their $T$.
Second A1 cao for $\frac{6mg\sqrt{2}}{5}$ oe, 1.7mg (or better), 16.6m, 17m |
|   | B1 for the direction clearly shown on a diagram with an arrow and 45° marked. |

### Q27.
<table>
<thead>
<tr>
<th>Question Number</th>
<th>Scheme</th>
<th>Marks</th>
</tr>
</thead>
</table>
| (a)             | \[ T - 5gsin\alpha = 5a \\
|                 | \[ 15g - T = 15a \\
|                 | solving for \(a\) \\
|                 | \(a = 0.6g\) \\
|                 | solving for \(T\) \\
|                 | \(T = 6g\) | M1 A1 A1 A1 (8) |
| (b)             | For \(Q\): \[ 5g - \frac{N}{2} = 5a \]
|                 | \(N = 2g\) | M1 A1 A1 f.t. (3) |
| (c)             | \[ F = 2T \cos\left(\frac{90^\circ - \alpha}{2}\right) \]
|                 | \[ = 12g \cos 26.56^\circ \]
<p>|                 | [ = 105 \text{ N} ] | M1 A2 A1 f.t. A1 (5) [16] |</p>
<table>
<thead>
<tr>
<th>Question Number</th>
<th>Scheme</th>
<th>Marks</th>
</tr>
</thead>
<tbody>
<tr>
<td>a</td>
<td><img src="image" alt="Diagram" /></td>
<td>M1A2</td>
</tr>
<tr>
<td></td>
<td>Perpendicular to the slope: ( R = 2.7g \cos 40 + 15\cos 40 ) ( = 31.8 ) (N) or ( 32 ) (N)</td>
<td>A1</td>
</tr>
<tr>
<td>b</td>
<td>Parallel to the slope: ( F = 2.7g \sin 40 - 15\cos 50 ) ( (F = 7.366..) )</td>
<td>M1A2</td>
</tr>
<tr>
<td></td>
<td>Use of ( F = \mu R ) ( \mu = \frac{2.7g \sin 40 - 15\cos 50}{R} = 0.23 ) or ( 0.232 )</td>
<td>M1</td>
</tr>
<tr>
<td></td>
<td>( (5) )</td>
<td>A1</td>
</tr>
<tr>
<td>c</td>
<td>Component of wt parallel to slope = ( 2.7g \sin 40 ) ( (=17.0) )</td>
<td>B1</td>
</tr>
<tr>
<td></td>
<td>( F_{\text{max}} = 0.232 \times 2.7 \times g \times \cos 40^\circ = 4.7... ) (N)</td>
<td>M1A1</td>
</tr>
<tr>
<td></td>
<td>( 17.0 &gt; 4.70 ) so the particle moves</td>
<td>A1</td>
</tr>
<tr>
<td></td>
<td>( (4) )</td>
<td></td>
</tr>
</tbody>
</table>
Notes for Question

N.B. Only penalise over- or under-accuracy after using \( g = 9.8 \),
(or use of \( g = 9.81 \)), once in whole question.

**Question (a)**
First M1 for resolving perpendicular to the slope, with correct no. of terms, and both the 2.7g and 15 terms resolved.
First A2 for a correct equation; -1 each error.
Third A1 for 32 (N) or 31.8 (N)

**Question (b)**
First M1 for resolving parallel to the slope, with correct no. of terms, and both the 2.7g and 15 terms resolved.
First A2 for a correct equation; -1 each error.
Second M1 for use of \( F = \mu R \)
Third A1 for 0.23 or 0.232

**Question (c)**
B1 for component of weight down the plane 2.7gsin40° (17 or better)
M1 for using their NEW \( R \) and \( \mu \) to find max friction (M0 if they use \( R \) from (a))
First A1 for 4.7( or better) (should be 4.701242531)
Second A1 for comparison and correct conclusion.

N.B. If first A mark is 0, the second A mark must also be 0.
### Q29.

<table>
<thead>
<tr>
<th>Question Number</th>
<th>Scheme</th>
</tr>
</thead>
<tbody>
<tr>
<td>(a)</td>
<td></td>
</tr>
<tr>
<td>(b)</td>
<td></td>
</tr>
</tbody>
</table>

#### Notes for Question

**Question (a)**
- First M1 for \((4i - 2j) + (2i + qj)\)
- First A1 for \((6i + (q - 2)j)\) (seen or implied)
- Second M1, dependent on first M1, for using ‘parallel to \((2i + j)\)’ to obtain an equation in \(q\) only.
- Second A1 for \(q = 5\)

**Question (b)**
- First M1 for their resultant force = 1.5a
- First A1 for \(a = 4i + 2j\)
- Second M1 for \((-2i + 4j) + 2\times\text{their a}\) \((\text{M0 if force is used instead of a})\)
- Second A1 ft for their velocity at \(t = 2\)
- Third M1 for finding the magnitude of their velocity at \(t = 2\)
- Third A1 for 10 (ms\(^{-1}\))

N.B. In (b), if they use scalars throughout, M0A0M0A0M0A0

### Q30.
<table>
<thead>
<tr>
<th>Question Number</th>
<th>Scheme</th>
<th>Marks</th>
</tr>
</thead>
</table>
| **(a)** speed = $\sqrt{2^2 + (-5)^2}$  
= $\sqrt{29} = 5.4$ or better | M1 A1 | (2) |
| **(b)** $\frac{((7i+10j)-(2i - 5j))}{5}$  
= $\frac{5i + 15j}{5} = i + 3j$  
$F = ma = 2(i + 3j) = 2i + 6j$ | M1 A1 A1 DM1 A1ft | (5) |
| **(c)** $v = u + at = (2i - 5j) + (i + 3j)t$  
$(-5 + 3t)j$  
Parallel to $i \Rightarrow -5 + 3t = 0$  
$t = 5/3$ | M1 A1 M1 A1 | (4) [11] |