A particle $P$ of mass 2.5 kg rests in equilibrium on a rough plane under the action of a force of magnitude $X$ newtons acting up a line of greatest slope of the plane, as shown in Figure 3. The plane is inclined at 20° to the horizontal. The coefficient of friction between $P$ and the plane is 0.4. The particle is in limiting equilibrium and is on the point of moving up the plane. Calculate

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

(b) the value of $X$.  

The force of magnitude $X$ newtons is now removed.

(c) Show that $P$ remains in equilibrium on the plane.
Question 4 continued

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(Total 10 marks)
A smooth bead $B$ is threaded on a light inextensible string. The ends of the string are attached to two fixed points $A$ and $C$ on the same horizontal level. The bead is held in equilibrium by a horizontal force of magnitude 6 N acting parallel to $AC$. The bead $B$ is vertically below $C$ and $\angle BAC = \alpha$, as shown in Figure 1. Given that $\tan \alpha = \frac{3}{4}$, find

(a) the tension in the string, 

(b) the weight of the bead.

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\[ 3 \cdot 4 \tan \alpha = 6 \]

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Two forces $\mathbf{P}$ and $\mathbf{Q}$ act on a particle. The force $\mathbf{P}$ has magnitude 7 N and acts due north. The resultant of $\mathbf{P}$ and $\mathbf{Q}$ is a force of magnitude 10 N acting in a direction with bearing 120°. Find

(i) the magnitude of $\mathbf{Q}$,

(ii) the direction of $\mathbf{Q}$, giving your answer as a bearing.
A parcel of weight 10 N lies on a rough plane inclined at an angle of 30° to the horizontal. A horizontal force of magnitude $P$ newtons acts on the parcel, as shown in Figure 2. The parcel is in equilibrium and on the point of slipping up the plane. The normal reaction of the plane on the parcel is 18 N. The coefficient of friction between the parcel and the plane is $\mu$. Find

(a) the value of $P$, 

(b) the value of $\mu$. 

The horizontal force is removed.

(c) Determine whether or not the parcel moves.
A particle of weight 24 N is held in equilibrium by two light inextensible strings. One string is horizontal. The other string is inclined at an angle of 30° to the horizontal, as shown in Figure 1. The tension in the horizontal string is \( Q \) newtons and the tension in the other string is \( P \) newtons. Find

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

(b) the value of \( Q \).
A particle $P$ is attached to one end of a light inextensible string. The other end of the string is attached to a fixed point $O$. A horizontal force of magnitude 12 N is applied to $P$. The particle $P$ is in equilibrium with the string taut and $OP$ making an angle of 20° with the downward vertical, as shown in Figure 1.

Find

(a) the tension in the string,  

(b) the weight of $P$.  

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Figure 1

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5. Figure 3

A small ring of mass 0.25 kg is threaded on a fixed rough horizontal rod. The ring is pulled upwards by a light string which makes an angle 40° with the horizontal, as shown in Figure 3. The string and the rod are in the same vertical plane. The tension in the string is 1.2 N and the coefficient of friction between the ring and the rod is \( \mu \). Given that the ring is in limiting equilibrium, find

(a) the normal reaction between the ring and the rod,

(b) the value of \( \mu \).
Question 5 continued

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(Total 10 marks)
Two forces $P$ and $Q$ act on a particle at a point $O$. The force $P$ has magnitude 15 N and the force $Q$ has magnitude $X$ newtons. The angle between $P$ and $Q$ is 150°, as shown in Figure 1. The resultant of $P$ and $Q$ is $R$.

Given that the angle between $R$ and $Q$ is 50°, find

(a) the magnitude of $R$, \hspace{1cm} (4)

(b) the value of $X$. \hspace{1cm} (5)
A package of mass 4 kg lies on a rough plane inclined at 30° to the horizontal. The package is held in equilibrium by a force of magnitude 45 N acting at an angle of 50° to the plane, as shown in Figure 3. The force is acting in a vertical plane through a line of greatest slope of the plane. The package is in equilibrium on the point of moving up the plane. The package is modelled as a particle. Find

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

(b) the coefficient of friction between the plane and the package.
Question 7 continued
A small package of mass 1.1 kg is held in equilibrium on a rough plane by a horizontal force. The plane is inclined at an angle $\alpha$ to the horizontal, where $\tan \alpha = \frac{3}{4}$. The force acts in a vertical plane containing a line of greatest slope of the plane and has magnitude $P$ newtons, as shown in Figure 2.

The coefficient of friction between the package and the plane is 0.5 and the package is modelled as a particle. The package is in equilibrium and on the point of slipping down the plane.

(a) Draw, on Figure 2, all the forces acting on the package, showing their directions clearly.

(b) (i) Find the magnitude of the normal reaction between the package and the plane.

(ii) Find the value of $P$.
Question 5 continued

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Turn over
A small box of mass 15 kg rests on a rough horizontal plane. The coefficient of friction between the box and the plane is 0.2. A force of magnitude $P$ newtons is applied to the box at 50° to the horizontal, as shown in Figure 1. The box is on the point of sliding along the plane.

Find the value of $P$, giving your answer to 2 significant figures.

$\text{Figure 1}$
A particle of mass \( m \) kg is attached at \( C \) to two light inextensible strings \( AC \) and \( BC \). The other ends of the strings are attached to fixed points \( A \) and \( B \) on a horizontal ceiling. The particle hangs in equilibrium with \( AC \) and \( BC \) inclined to the horizontal at 30° and 60° respectively, as shown in Figure 1.

Given that the tension in \( AC \) is 20 N, find

(a) the tension in \( BC \),

(b) the value of \( m \).
A small box is pushed along a floor. The floor is modelled as a rough horizontal plane and the box is modelled as a particle. The coefficient of friction between the box and the floor is $\frac{1}{2}$. The box is pushed by a force of magnitude 100 N which acts at an angle of $30^\circ$ with the floor, as shown in Figure 1.

Given that the box moves with constant speed, find the mass of the box.
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, 

(b) the value of $P$. 

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Question 7 continued

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Leave blank
A particle of weight 120 N is placed on a fixed rough plane which is inclined at an angle $\alpha$ to the horizontal, where $\tan \alpha = \frac{3}{4}$.

The coefficient of friction between the particle and the plane is $\frac{1}{2}$.

The particle is held at rest in equilibrium by a horizontal force of magnitude 30 N, which acts in the vertical plane containing the line of greatest slope of the plane through the particle, as shown in Figure 2.

(a) Show that the normal reaction between the particle and the plane has magnitude 114 N.

(b) Find the greatest possible value of $P$.

(c) Find the magnitude and direction of the frictional force acting on the particle when $P = 30$. 

Figure 2

![Figure 2](image1)

The horizontal force is removed and replaced by a force of magnitude $P$ newtons acting up the slope along the line of greatest slope of the plane through the particle, as shown in Figure 3. The particle remains in equilibrium.

Figure 3

![Figure 3](image2)
A particle of weight $W$ newtons is held in equilibrium on a rough inclined plane by a horizontal force of magnitude 4 N. The force acts in a vertical plane containing a line of greatest slope of the inclined plane. The plane is inclined to the horizontal at an angle $\alpha$, where $\tan \alpha = \frac{3}{4}$, as shown in Figure 1.

The coefficient of friction between the particle and the plane is $\frac{1}{2}$.

Given that the particle is on the point of sliding down the plane,

(i) show that the magnitude of the normal reaction between the particle and the plane is 20 N,

(ii) find the value of $W$.  

(9)
Question 3 continued
A box of mass 5 kg lies on a rough plane inclined at 30° to the horizontal. The box is held in equilibrium by a horizontal force of magnitude 20 N, as shown in Figure 2. The force acts in a vertical plane containing a line of greatest slope of the inclined plane. The box is in equilibrium and on the point of moving down the plane. The box is modelled as a particle.

Find

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

(b) the coefficient of friction between the box and the plane.
Question 3 continued

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3. A particle $P$ of mass 2 kg is attached to one end of a light string, the other end of which is attached to a fixed point $O$. The particle is held in equilibrium, with $OP$ at 30º to the downward vertical, by a force of magnitude $F$ newtons. The force acts in the same vertical plane as the string and acts at an angle of 30º to the horizontal, as shown in Figure 3.

![Figure 3](image)

Find

(i) the value of $F$,

(ii) the tension in the string. 

(8)
Question 3 continued
A particle of weight 8 N is attached at \( C \) to the ends of two light inextensible strings \( AC \) and \( BC \). The other ends, \( A \) and \( B \), are attached to a fixed horizontal ceiling. The particle hangs at rest in equilibrium, with the strings in a vertical plane. The string \( AC \) is inclined at 35° to the horizontal and the string \( BC \) is inclined at 25° to the horizontal, as shown in Figure 1. Find

(i) the tension in the string \( AC \),

(ii) the tension in the string \( BC \).
A box of mass 2 kg is held in equilibrium on a fixed rough inclined plane by a rope. The rope lies in a vertical plane containing a line of greatest slope of the inclined plane. The rope is inclined to the plane at an angle $\alpha$, where $\tan \alpha = \frac{3}{4}$, and the plane is at an angle of $30^\circ$ to the horizontal, as shown in Figure 1. The coefficient of friction between the box and the inclined plane is $\mu = \frac{1}{3}$ and the box is on the point of slipping up the plane. By modelling the box as a particle and the rope as a light inextensible string, find the tension in the rope.

\[ (8) \]