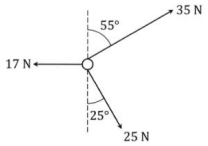
Q1

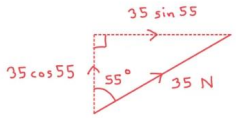
1

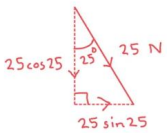
The following force diagram shows three forces acting on a particle:



Find the magnitude and direction of the resultant forces acting on the particle in the horizontal and vertical directions.

[5]





In the horizontal direction ($\rightarrow$ is +):

$35\sin 55 + 25\sin 25 - 17 = 22.235778...$

22.2 N (3 s.f.) to the right

In the vertical direction ($\uparrow$ is +):

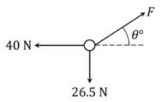
$35\cos 55 - 25\cos 25 = -2.582519...$

2.58 N (3 s.f.) down

Q2

2

The following force diagram shows three forces acting on a particle:



Given that the particle is in equilibrium, find:

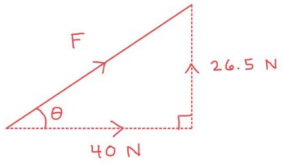
(i) the magnitude of force F

(ii) the angle, θ, that F makes with the horizontal.

Give both your answers correct to 3 significant figures.

[4]

To balance the other two forces we must have:



(i) $\sqrt{40^2 + 26.5^2} = 47.981767...$

48.0 N (3 s.f.)

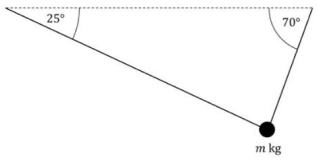
(ii) $\theta = \tan^{-1}\left(\frac{26.5}{40}\right) = 33.524473...$

33.5° (3 s.f.)

Q3

3

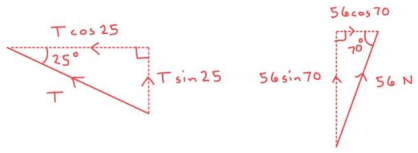
A particle of mass m kg hangs in equilibrium, suspended by two light inextensible strings. The strings are inclined at 25° and 70° to the horizontal, as shown in the diagram below:



Given that the tension in the string angled at 70° to the horizontal is 56 N, find the value of m.

[6]

Consider the tensions in the two strings:



In the horizontal direction, equilibrium means

$$T\cos 25 = 56\cos 70 \Rightarrow T = \frac{56\cos 70}{\cos 25}$$

In the vertical direction, equilibrium means

$$mg = T\sin 25 + 56\sin 70$$

$$m = \frac{T\sin 25 + 56\sin 70}{g}$$

$$m = \frac{\left(\frac{56\cos 70}{\cos 25}\right)\sin 25 + 56\sin 70}{10} = 6.155403\ldots$$

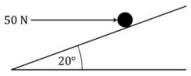
use $g = 10\ ms^{-2}$

$$m = 6.16 \text{ (3 s.f.)}$$

Q4a

4a

A particle of mass 12 kg is being pushed up a smooth slope (no friction) by a force of 50 N that acts horizontally. The slope is inclined at 20° to the horizontal, as shown in the diagram below:



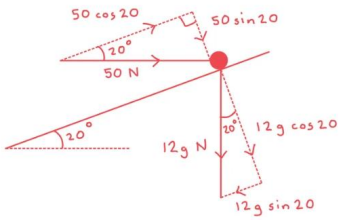
(a) Calculate the acceleration of the particle up the slope.

[3]

(b) Calculate the normal reaction force of the slope on the particle.

[3]

a) Decompose forces parallel and perpendicular to slope:



Parallel to the slope ($\nearrow$ is +):

$$50\cos 20 - 12g\sin 20 = 12a \qquad F = ma$$

use $g = 10\ ms^{-2}$

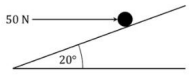
$$a = \frac{50\cos 20 - 12(10)\sin 20}{12} = 0.495184\ldots$$

$$a = 0.495\ ms^{-2} \text{ (3 s.f.)}$$

Q4b

4b

A particle of mass 12 kg is being pushed up a smooth slope by a force of 50 N that acts horizontally. The slope is inclined at 20° to the horizontal, as shown in the diagram below:

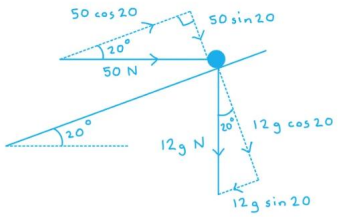


(a) Calculate the acceleration of the particle up the slope.

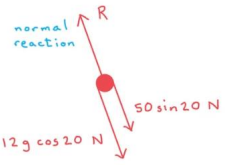
[3]

(b) Calculate the normal reaction force of the slope on the particle.

[3]



b) Consider forces perpendicular to slope:



There is no acceleration into or away from the slope, so those forces must be balanced:

$$R = 12g\cos 20 + 50\sin 20$$
$$= 12(10)\cos 20 + 50\sin 20 \quad \text{use } g = 10\ ms^{-2}$$
$$= 129.864121...$$

$$R = 130\ N\ (3\ s.f.)$$

Q5a

5a

A particle of mass 15 kg is sliding down a rough slope that is angled 25° to the horizontal. The coefficient of friction between the particle and the slope is 0.3.

(a) Calculate the frictional force between the particle and the slope.

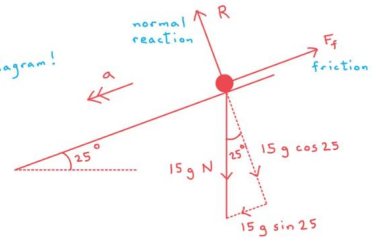
[3]

(b) Hence calculate the acceleration of the particle down the slope.

[3]

a)

Draw a diagram!



Perpendicular forces are balanced, so

$$R = 15g\cos 25$$

And particle is moving, so

$$F_f = F_{max} = \mu R = (0.3)(15g\cos 25)$$
$$= 4.5g\cos 25 = 4.5(10)\cos 25 \quad \text{use } g = 10\ ms^{-2}$$
$$= 45\cos 25 = 40.783850...$$

$$F_f = 40.8\ N\ (3\ s.f.)$$

Q5b

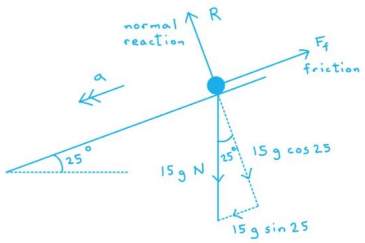
5b

A particle of mass 15 kg is sliding down a rough slope that is angled 25° to the horizontal. The coefficient of friction between the particle and the slope is 0.3.

(a) Calculate the frictional force between the particle and the slope.

$F_f = 4.5g\cos 25 = 40.8$ N (3 s.f.) [3]

(b) Hence calculate the acceleration of the particle down the slope. [3]



b) Consider forces parallel to slope (← is +):

$15g\sin 25 - F_f = 15a$ $\quad F = ma$

$$a = \frac{15g\sin 25 - F_f}{15}$$

$$= \frac{15g\sin 25 - 4.5g\cos 25}{15}$$

$$= \frac{15(10)\sin 25 - 4.5(10)\cos 25}{15} \quad \text{use } g = 10\ ms^{-2}$$

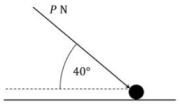
$$= 1.507259...$$

$a = 1.51\ ms^{-2}$ (3 s.f.)

Q6

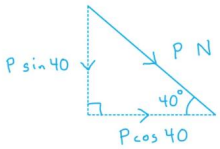
6

A particle of mass 0.9 kg is at rest on a rough horizontal plane. A force of magnitude P N is acting on the particle at an angle of 40° to the horizontal.

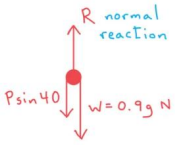


Given that the coefficient of friction between the plane and the particle is 0.3, and that the particle is on the point of moving to the right under the influence of the force, find the value of P.

[6]



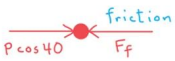
Consider forces in the vertical direction (↑ is +):



Vertical forces are balanced, so

$$R = P\sin 40 + 0.9g$$

Now consider forces in the horizontal direction (→ is +):



Horizontal forces are balanced, so

$$P\cos 40 = F_f$$

The particle is on the point of moving, so

$$F_f = F_{max} = \mu R = 0.3(P\sin 40 + 0.9g)$$

$$F_f = 0.3P\sin 40 + 0.27g$$

Combining the above equations gives:

$$P\cos 40 = 0.3P\sin 40 + 0.27g$$

Combining the above equations gives:

$$P\cos 40 = 0.3P\sin 40 + 0.27g$$

$$P\cos 40 - 0.3P\sin 40 = 0.27g$$

$$P(\cos 40 - 0.3\sin 40) = 0.27g$$

$$P = \frac{0.27g}{\cos 40 - 0.3\sin 40}$$

$$= \frac{0.27(10)}{\cos 40 - 0.3\sin 40}$$ ← use $g = 10\ ms^{-2}$

$$= 4.710330\ldots$$

$$P = 4.71 \text{ (3 s.f.)}$$