

QQQ – Mechanics Year 2 – Chapter 5 – Resolving Forces & Friction (Version 2)

Total Marks: 24

(24 = Platinum, 22 = Gold, 19 = Silver, 16 = Bronze)

1.

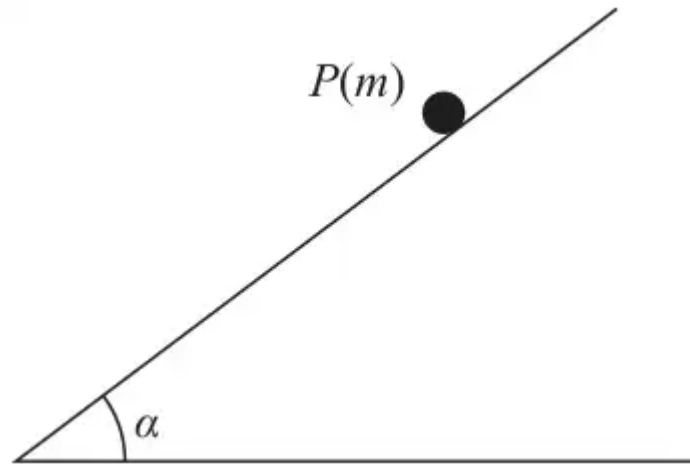


Figure 3

A particle P of mass m is held at rest at a point on a rough inclined plane, as shown in Figure 3.

It is given that

- the plane is inclined to the horizontal at an angle α , where $\tan \alpha = \frac{5}{12}$
- the coefficient of friction between P and the plane is μ , where $\mu < \frac{5}{12}$

The particle P is released from rest and slides down the plane.

Air resistance is modelled as being negligible.

Using the model,

(a) find, in terms of m and g , the magnitude of the normal reaction of the plane on P , (2)

(b) show that, as P slides down the plane, the acceleration of P down the plane is

$$\frac{1}{13}g(5 - 12\mu)$$

(4)

(c) State what would happen to P if it is released from rest but $\mu \geq \frac{5}{12}$ (1)

(Total 7 marks)

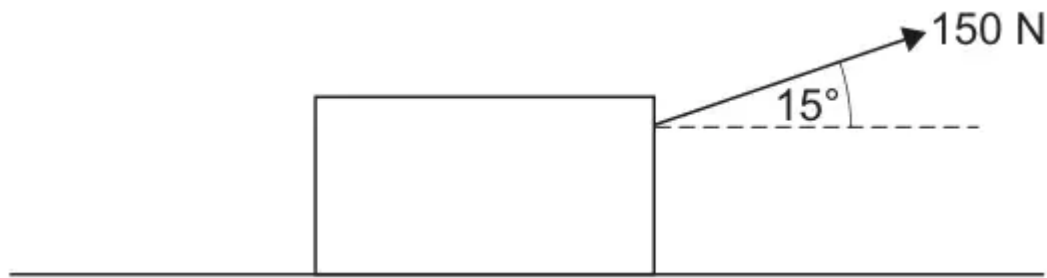
2. In this question use $g = 9.8 \text{ m s}^{-2}$

A boy attempts to move a wooden crate of mass 20 kg along horizontal ground. The coefficient of friction between the crate and the ground is 0.85

- (a) The boy applies a horizontal force of 150 N. Show that the crate remains stationary.

[3 marks]

- (b) Instead, the boy uses a handle to pull the crate forward. He exerts a force of 150 N, at an angle of 15° above the horizontal, as shown in the diagram.



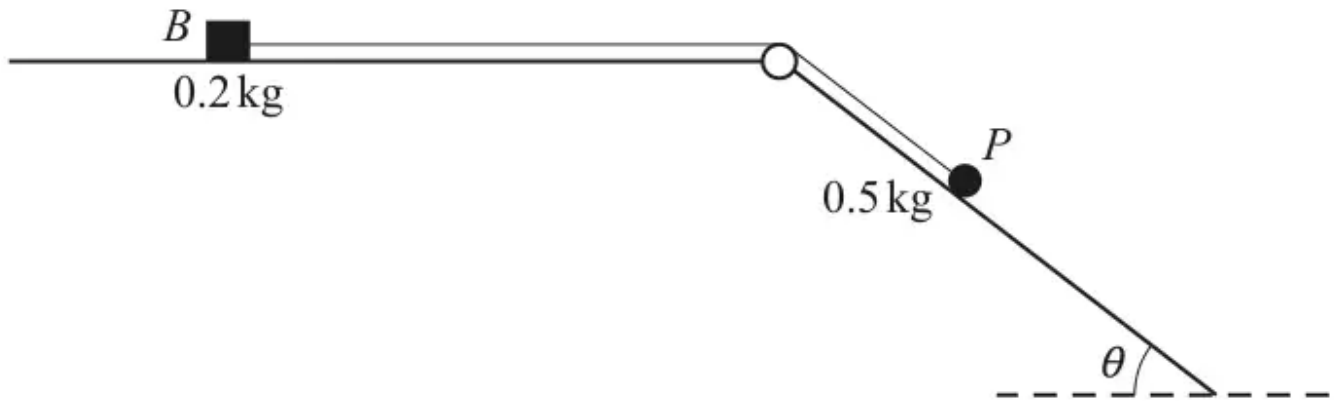
Determine whether the crate remains stationary.

Fully justify your answer.

[5 marks]

(Total 8 marks)

3.



The diagram shows a small block B , of mass 0.2 kg , and a particle P , of mass 0.5 kg , which are attached to the ends of a light inextensible string. The string is taut and passes over a small smooth pulley fixed at the intersection of a horizontal surface and an inclined plane.

The block can move on the horizontal surface, which is rough. The particle can move on the inclined plane, which is smooth and which makes an angle of θ with the horizontal where $\tan \theta = \frac{3}{4}$.

The system is released from rest. In the first 0.4 seconds of the motion P moves 0.3 m down the plane and B does not reach the pulley.

- (a) Find the tension in the string during the first 0.4 seconds of the motion. [4]
- (b) Calculate the coefficient of friction between B and the horizontal surface. [5]

(Total 9 marks)

Solutions

1.

Mark scheme (a)

Scheme	Marks	AO
$(R =) mg \cos \alpha$	M1	3.4
$= \frac{12}{13}mg$	A1	1.1b
	(2)	

Notes

M1: Correct no. of terms, condone sin/cos confusion and sign errors, dimensionally correct.

Allow use of a different symbol for the angle.

A1: Accept $0.92mg$ or better. Must be positive.

Mark scheme (b)

Scheme	Marks	AO
Equation of motion down the plane	M1	2.1
$mg \sin \alpha - F = ma$ or $mg \sin \alpha - F = -ma$	A1	1.1b
$(F =) \mu \times \text{their } R$	M1	3.4
$\frac{1}{13}g(5 - 12\mu) *$	A1*	2.2a
	(4)	

Notes

M1: Correct no. of terms, condone sin/cos confusion and sign errors

(M0 if they use g for a)

N.B. Must be using mg or m not W for the weight.

A1: Any correct equation e.g. $mg \sin \alpha = ma + F$

N.B. F does not need to be substituted.

M1: $\mu \times \text{their } R$ seen (possibly on a diagram), any trig does not need to be replaced.

M0 if they use $\mu = \frac{5}{12}$

M0 for just μR with R not replaced.

A1*: Given answer correctly obtained, with at least one further line of working with both trig ratios substituted as fractions.

Allow $\frac{g}{13}(5 - 12\mu)$ or $\frac{g(5 - 12\mu)}{13}$

Mark scheme (c)

Scheme	Marks	AO
P wouldn't move	B1	2.4
	(1)	
	(7 marks)	

Notes

B1: e.g. P (or the particle or the object) would stay at rest, P would not slide down, would not roll down the plane, static equilibrium, equilibrium at rest

Allow 'it' for P or just 'stays at rest oe'

B0 for wouldn't accelerate, would be in equilibrium (only), would stop

N.B. Ignore reasons but not contradictions.

2.

Mark scheme (a)

Scheme	Marks	AO
Uses model for maximum friction = μmg	B1	AO3.3
Makes an appropriate comparison	M1	AO1.1a
Explains clearly why crate remains stationary	E1	AO2.4

Typical solution

$$F_{\max} = \mu mg$$

$$= 0.85 \times 20 \times 9.8$$

$$= 166.6 \text{ N}$$

$$150 < 166.6$$

$\therefore$ crate does not move

Mark scheme (b)

Scheme	Marks	AO
Forms an equation by resolving vertically Condone one of sign error or cos error	M1	AO3.1b
Obtains correct reaction force	A1	AO1.1b
Uses maximum friction = μR With 'their' reaction force Must identify maximum or limiting friction	B1F	AO1.1b
Compares $150 \cos 15^\circ$ with 'their' maximum friction	M1	AO1.1a
Explains, using their values, why the crate begins to move.	E1F	AO2.4
	(8 marks)	

Typical solution

$$20g = R + 150 \sin 15^\circ$$

$$R = 157.177 \text{ N}$$

$$F_{\max} = \mu \times 157.177$$

$$= 133.6 \text{ N}$$

$$150 \cos 15^\circ = 145 \text{ N}$$

$$145 > 133.6$$

$\therefore$ crate begins to move

3.

Mark scheme (a)

Scheme	Marks	AO
$0.3 = \frac{1}{2}a \times 0.4^2 (\Rightarrow a = 3.75)$	B1	3.1b
$0.5g \sin \theta - T = 0.5a$	M1	3.3
$0.5g \times \frac{3}{5} - T = 0.5 \times 3.75$	A1ft	1.1
$T = 1.065 \text{ N}$	A1	1.1
	[4]	

Notes

B1: Cao seen or implied by correct T

M1: Use of N II parallel to the plane (correct number of terms) – weight must be resolved (but allow sin/cos confusion in component of the weight – may still be in terms of θ and a (or their incorrect values of θ and a))

Allow sign errors but M0 if using $0.5g$ for the mass on the rhs or if only resolving the mass (e.g. $0.5 \sin \theta$) on the lhs

A1ft: 'correct' equation in terms of T with their a

Allow $0.5g \times \sin 36.9 - T = 0.5 \times '3.75'$ or $0.5g \times \sin 0.644 - T = 0.5 \times '3.75'$ (in radians)

A0 if $a = 0$ or $\pm g$ (or a component of g)

A1: Allow 1.07 www

Mark scheme (b)

Scheme	Marks	AO
$R = 0.2g$	B1	1.1
$T - F = 0.2a$ or $T - \mu R = 0.2a$	M1*	3.3
$1.065 - F = 0.2(3.75)$	A1	1.1
$0.315 = \mu \times 0.2 \times 9.8$	M1dep*	3.4
$\mu = 0.161$	A1	1.1
	[5]	

Notes

B1: Where R is the normal contact force of surface acting on B – may be implied in N II applied horizontally

M1*: Use of N II horizontally for B or $0.5g \sin \theta - F = 0.7a$ for the whole system (M0 if any other mass used for whole system)

Correct number of terms (M0 if mass is $0.2g$) – allow sign errors

A1: Or for a correct statement without explicitly seeing F e.g. $1.065 - 0.2g\mu = 0.2(3.75)$ (which would imply the next M mark as well)

$F = 0.315$ or $\mu R = 0.315$ or $F = 0.32$

M1dep*: Use of $F = \mu R$ where $R = 0.2g$ - may be implied in N II applied horizontally

A1: Allow awrt 0.161 or 0.163 from using $T = 1.07$ www

$$\mu = \frac{9}{56}$$