

5.3 Newton's laws and friction

Name: _____ Class: _____ Date: _____

Total: 25 marks

KEY WORDS normal reaction • coefficient of friction

Newton's laws and friction

Objective

Apply $F = ma$ to single bodies along and perpendicular to the motion, include resistance and friction $F = \mu R$ on horizontal and inclined planes, and handle forces at angles (objectives 4.1, 4.4).

1 Key knowledge and worked examples

Rules of the road. Draw the diagram; resolve perpendicular (usually $R = mg \cos \theta$ or $R = mg - T \sin \alpha$) and along the motion; every term signed. Friction opposes motion with $F = \mu R$ when sliding. $\tan \theta = \frac{3}{4}$ means $\sin \theta = \frac{3}{5}$, $\cos \theta = \frac{4}{5}$ – use the fractions, not decimals.

Worked example – two ropes at angles (WME01 June 2025 Q4). Forces 800 N at 25° above the line of motion and 500 N at α below it keep a 15000 kg barge moving straight: perpendicular equilibrium $800 \sin 25^\circ = 500 \sin \alpha$ gives $\alpha = 43^\circ$; along the motion, with resistance 750 N, $800 \cos 25^\circ + 500 \cos \alpha - 750 = 15000a$ gives $a = 0.023 \text{ m s}^{-2}$.

2 Practice

2.1 A 4 kg block slides on a smooth horizontal surface under a 20 N horizontal force. Find its acceleration and the normal reaction. [3]

2.2 The surface is now rough with $\mu = 0.25$. Find the acceleration under the same 20 N force. [4]

2.3 A person of mass 80 kg stands in a lift accelerating upwards at 1.5 m s^{-2} . Find the normal reaction from the lift floor. [4]

2.4 An 8 kg crate on rough horizontal ground ($\mu = 0.4$) is pulled by a rope at 30° above the horizontal with tension 50 N. Find its acceleration. [4]

3 Exam-style questions

3.1 (*Edexcel IAL WME01 June 2025 Q4.*) Two ropes are attached to a point on the front of a barge of mass 15 tonnes. The barge is pulled along a straight canal by a horizontal force of 800 N acting at 25° to the direction of motion and a horizontal force of 500 N acting at α° to the direction of motion, on the other side of it. The barge accelerates along the canal, and the total resistance to motion is 750 N. (a) Find α . (b) Find the acceleration of the barge. [7]

3.2 (*Edexcel IAL WME01 June 2025 Q6c.*) A package of mass 2 kg is held at rest on a rough plane inclined at θ to the horizontal, where $\tan \theta = \frac{3}{4}$, by a force of X N directed up the plane along a line of greatest slope. The coefficient of friction between the package and the plane is $\frac{1}{4}$. Find the smallest possible value of X . [3]

Solutions

2.1 $a = \frac{20}{4} = 5 \text{ m s}^{-2}$; $R = 4g = 39.2 \text{ N}$.

2.2 $R = 39.2 \text{ N}$, friction $= 0.25(39.2) = 9.8 \text{ N}$; $a = \frac{20 - 9.8}{4} = 2.55 \text{ m s}^{-2}$ (2.6).

2.3 $R - 80g = 80(1.5)$, so $R = 80(9.8 + 1.5) = 904 \text{ N}$.

2.4 Perpendicular: $R = 8g - 50 \sin 30^\circ = 78.4 - 25 = 53.4 \text{ N}$. Friction $= 0.4(53.4) = 21.36 \text{ N}$. Along: $50 \cos 30^\circ - 21.36 = 8a$, so $a = \frac{43.30 - 21.36}{8} = 2.74 \text{ m s}^{-2}$ (2.7).

3.1 (a) No acceleration perpendicular to the canal: $800 \sin 25^\circ = 500 \sin \alpha$, so $\sin \alpha = \frac{800(0.4226)}{500} = 0.676$ and $\alpha = 43^\circ$ (nearest degree). (b) Along the canal: $800 \cos 25^\circ + 500 \cos 42.55^\circ - 750 = 15000a$: $725.0 + 368.1 - 750 = 343.1 = 15000a$, so $a = 0.023 \text{ m s}^{-2}$.

3.2 Least X when friction acts UP the slope at its limit (helping hold the package). Perpendicular: $R = 2g \cos \theta = 2(9.8)(\frac{4}{5}) = 15.68 \text{ N}$; friction $= \frac{1}{4}(15.68) = 3.92 \text{ N}$. Along: $X = 2g \sin \theta - 3.92 = 2(9.8)(\frac{3}{5}) - 3.92 = 11.76 - 3.92 = 7.84 \text{ N}$ ($= \frac{4}{5}g$).

Local review guidance: resolution both perpendicular and along, all terms present and signed; friction μR only once R is found; answers to 2–3 s.f. with units, or as exact multiples of g when the question says "show". This is authored classroom guidance.