

4.3 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]
