UNIVERSITY MECHANICAL ENGINEERING • EXERCISE SHEET

3.2 Particle kinetics

Name: _____ Class: _____ Date: _____ **Total: 14 marks**

KEY WORDS free-body diagram • normal force • friction

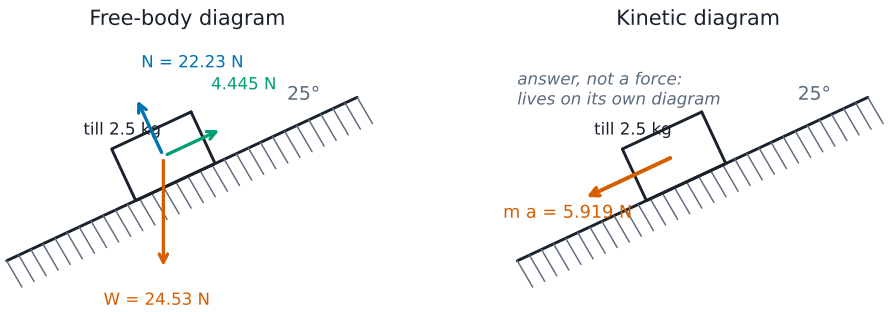
Objective

Draw the free-body and kinetic diagrams, then integrate the equation of motion for ramps, friction and circular demand.

1 Key knowledge and worked examples

■ The two diagrams

Free-body: every external force. Kinetic: the single vector ma. N from the perpendicular equation ($mg\cos\beta$ on a ramp); friction $\mu_s N$ at most, $\mu_k N$ once sliding.



Forces on one diagram, the answer on the other

■ Worked example. The certification ramp

$\beta = 25°$, $\mu_k = 0.20$: $a = 9.81(0.4226 - 0.1813) = 2.368$ m/s^2, $v = 2.665$ m/s after 1.50 m ✓; the cart test slips beyond $\mu_s g = 3.434$ m/s^2 ✓.

2 Practice

A 4.0 kg crate slides down a 20° ramp with $\mu_k = 0.25$.

2.1 The normal force and the friction force (two decimals), with the perpendicular equation stated. [4]

2.2 The acceleration down the slope (three decimals) and the speed after 2.00 m from rest (three decimals). [4]

2.3 The crate rides a flat pallet braking on the test floor with $\mu_s = 0.30$. The braking acceleration at which it starts to slide, and the verdict if the pallet brakes at 2.5 m/s^2. [3]

2.4 A spinner holds the same crate at $r = 0.450$ m, $\omega = 3.00$ rad/s, $\dot{\omega} = 2.00$ rad/s^2 (total acceleration 4.149 m/s^2, from sheet 3.1). The friction force needed and the minimum μ (three decimals). [3]

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Solutions

2.1

- Perpendicular: $N = mg\cos 20^\circ = 36.87$ N.
- Friction $= \mu_k N = 0.25 \times 36.87 = 9.22$ N up-slope.

2.2

- $a = g(\sin 20^\circ - 0.25\cos 20^\circ) = 1.051$ m/s^2.
- $v = \sqrt{2 \times 1.051 \times 2.00} = 2.050$ m/s.

2.3

- Slides when $a > \mu_s g = 2.943$ m/s^2.
- $2.5 < 2.943$: it holds, margin 15%.

2.4

- $F = ma = 4.0 \times 4.149 = 16.60$ N.
- $\mu_{min} = 16.60/(4.0 \times 9.81) = 0.423$.

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