

# Forces, friction and motion on slopes

Physics grades 11-12 (A Level · IB · Class 11-12) · Lab answers

The sample data give  $\mu_s = 0.51$  for wood on wood and 0.89 for wood on sandpaper. Your values will depend on the materials, but the rougher surface should always give a steeper slipping angle and the mass should not matter.

**Level:** Physics grades 11-12 (A Level · IB · Class 11-12) · **Curriculum:** IB A.2

## Question 1 Mean heights

Wood:  $(0.27 + 0.28 + 0.26 + 0.29 + 0.27) \div 5 = 1.37 \div 5 = \mathbf{0.274\text{ m}}$ ; half the range =  $(0.29 - 0.26) \div 2 = \mathbf{0.015\text{ m}}$ . Sandpaper:  $2.00 \div 5 = \mathbf{0.400\text{ m}}$ .

## Question 2 Angles

Wood:  $\sin \theta = 0.274 \div 0.60 = 0.4567$ , so  $\theta = \mathbf{27.2^\circ}$ . Sandpaper:  $\sin \theta = 0.400 \div 0.60 = 0.6667$ , so  $\theta = \mathbf{41.8^\circ}$ .

## Question 3 Proving the method

At the limit,  $mg \sin \theta = \mu_s N$  and  $N = mg \cos \theta$ . Dividing gives  $\mu_s = \tan \theta$ , and the mass cancels.

## Question 4 Coefficients

Wood:  $\tan 27.2^\circ = \mathbf{0.51}$ . Sandpaper:  $\tan 41.8^\circ = \mathbf{0.89}$ .

## Question 5 Uncertainty

For  $h = 0.26\text{ m}$ :  $\tan \theta = 0.481$ . For  $h = 0.29\text{ m}$ :  $\tan \theta = 0.552$ . Half the range =  $\pm \mathbf{0.04}$ , so  $\mu_s = 0.51 \pm 0.04$ .

## Question 6 Sliding down

$a = g(\sin 30^\circ - \mu_k \cos 30^\circ) = 9.81 \times (0.500 - 0.40 \times 0.866) = 9.81 \times 0.1536 = \mathbf{1.5\text{ m/s}^2}$ .

## Question 7 Effect of mass

Both the friction limit and the weight component along the slope are proportional to the normal force, so the mass cancels and **the angle stays the same**.

### Question 8 Improvement

Use a smaller increase in angle (a screw jack or a slow hand lift), measure the angle with a digital angle gauge, and **average more trials**.