## Activity description

In this activity the friction model $F \leq \mu R$ is used to solve two sets of problems. The first set consists of simple problems involving bodies in limiting equilibrium. Problems in the second set are more complex, and students solve these by combining the friction model with Newton's Second Law and the constant acceleration equations.

### Suitability

Level 3 (Advanced)

### Time

1–2 hours

### Resources

Student information sheet, worksheet
*Optional*: slideshow

### Equipment

Calculators
Students might choose to use a spreadsheet for the extension activity.

### Key mathematical language

Model, force, resistive force, friction, normal reaction, coefficient of friction, limiting equilibrium, sliding, slipping, acceleration, deceleration

## Notes on the activity

The accompanying slide show includes the ideas and examples discussed in the information sheet.

Questions 1–5 are relatively simple problems involving bodies that are on the point of sliding. They can be attempted after discussion of the friction model and the first two examples. Depending on the experience or confidence of the students, these questions could be tackled by estimation only, or students could use estimation to decide whether the given answers are likely to be correct.

After reviewing Newton's Second Law and the constant acceleration equations, the third example combines these with the friction model to find the distance covered by a skidding car in coming to rest. Questions 6–11 are of similar complexity.

## During the activity

Questions 1–5 could be attempted by students individually or discussed in pairs or small groups, depending on students' needs.

Questions 6–11 could be attempted by students working individually or in pairs.

## Points for discussion

Ask students how they know whether or not they can use $F = \mu R$.

Also encourage students to estimate values first, such as the smallest force needed to make a body slide.

Discuss the conditions that enable the friction model, Newton's Second Law ($F = ma$), and the constant acceleration equations to be applied.

It might also be worth discussing the force diagram for the coffee cup in Question 7 and, in particular, making sure that students understand which force is causing the cup to accelerate.

## Extensions

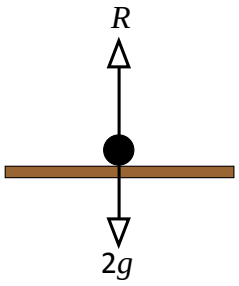
Students consider how using different values for $\mu$ would affect their solutions. Students could choose to do this by estimation, by calculation, or by finding an expression for the quantity required in terms of $\mu$. Alternatively some might use a spreadsheet.


## Acknowledgement

Some of these problems originally appeared Nuffield Advanced Mathematics *Mechanics 1*. Longman 1994. ISBN 0-582-09979-X.

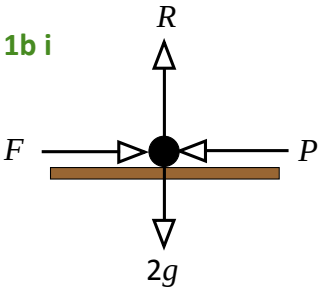
## Answers

**1a i**




**ii** 19.6 N

**1b i**

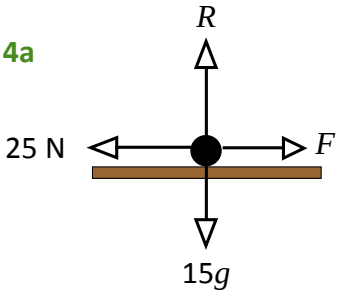



**ii** 9.8 N

**2** No (maximum friction = 47.04 N)

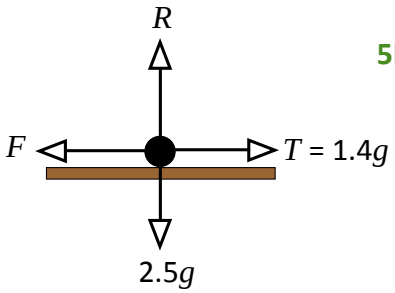
**3** 2.57 N (3 sf)

**4a**




**4b** $\mu = 0.170$ (3 sf)

**5a**

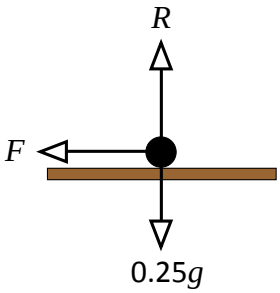



**5b** $\mu = 0.56$

**6a** 7.35 $ms^{-2}$

**6b** 2.04 seconds (3 sf)

**7a**




**7b** 0.3 N

**7c** 0.122 (3 sf)

**8a** 1.4 $ms^{-2}$

**8b i** 0.28 m $s^{-2}$

**ii** 0.114 (3 sf)

**9a** 88.2 N

**9b i** 88.2 N

**ii** 94.2 N

**10** 0.143 (3 sf)

**11** 32.7 metres