Braking forces and deceleration

4.5.6.3.4 · Forces · revision notes

When a vehicle brakes, work done by friction between the brakes and the wheels reduces its kinetic energy and heats the brakes. You need to explain this energy transfer, link braking force to speed and deceleration, explain the dangers of large decelerations and (Higher) estimate the forces involved in braking.

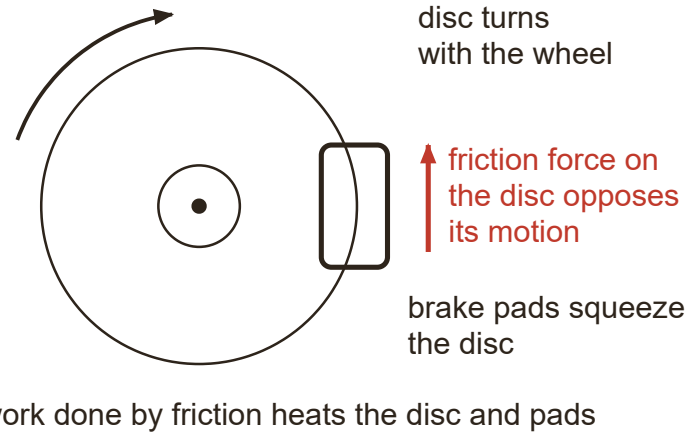
Key facts

- Braking: work done by friction reduces kinetic energy, and the brakes get hotter
- $E_k = ½ m v^2$
- Greater braking force → greater deceleration ($F = m a$)
- Grade 8+ only Typical car braking force: a few thousand newtons
- Work done by brakes = braking force × braking distance = kinetic energy lost
- Greater speed → greater braking force needed to stop in the same distance
- Large decelerations: brakes overheat, skidding, loss of control

Notes

Energy transfer when braking

- When a force is applied to the brakes, work is done by the friction force between the brakes and the wheels.



Braking: friction between the pads and the disc does work, transferring kinetic energy to thermal energy.

- This work done reduces the kinetic energy of the vehicle.
- The energy is transferred to the thermal energy store of the brakes, so the temperature of the brakes increases.
- Work done by the brakes = braking force × braking distance = kinetic energy lost.

Braking force, speed and deceleration

- The greater the speed of a vehicle, the greater the braking force needed to stop it in a certain distance, because it has more kinetic energy.
- The greater the braking force, the greater the deceleration of the vehicle (F = m a).
- For the same braking force, a vehicle with a greater mass has a smaller deceleration.

Dangers of large decelerations

- Large decelerations need large braking forces, which may make the brakes **overheat** and work less well.
- The wheels may lock and the tyres skid, so the driver may **lose control** of the vehicle.
- Large decelerations also mean large forces on the people inside, which can cause injuries.

Estimating braking forces Grade 8+ only

- Use typical values: car mass ~1000 kg, speeds ~10 m/s to 30 m/s, braking distances of tens of metres.
- Energy method: braking force = ½ m v^2 ÷ braking distance.
- Motion method: find the deceleration with $v^2 - u^2 = 2\,a\,s$ or $a = \Delta v \div t$, then use F = m a.
- Example: a 1000 kg car stopping from 20 m/s in 40 m: F = ½ × 1000 × 20^2 ÷ 40 = 5000 N (~5 kN).

How to answer each type of question

Describe the energy transfer during braking 2 marks **Grade 4**

1. Say that work is done by friction between the brakes and the wheels.
2. Name the stores: from kinetic to thermal (the brakes get hotter).

Example. Describe the energy transfer when a moving car brakes to a stop.

Model answer.

Work is done by the friction force between the brakes and the wheels (1).

Energy is transferred from the kinetic energy store of the car to the thermal energy store of the brakes, so the brakes get hotter (1).

Explain the dangers of large decelerations

3 marks | Grade 5

1. Say that a large deceleration needs a large braking force.
2. Give the danger to the brakes: overheating.
3. Give the danger to control: skidding.

Example. Explain the dangers of a car braking with a very large deceleration.

Model answer.

A very large braking force is needed, so the brakes may overheat (1)
and become less effective (1).
The tyres may skid on the road, so the driver may lose control of the car (1).

Calculate a braking force using kinetic energy

4 marks | Grade 7

1. Calculate the kinetic energy with $E_k = ½ m v^2$.
2. Set work done by the brakes = kinetic energy.
3. Use W = F s and rearrange for F.

Example. A van of mass 2000 kg is travelling at 12 m/s. It brakes and stops in a braking distance of 24 m.
Calculate the average braking force.

Model answer.

$E_k = 0.5 \times 2000 \times 12^2$ (1)
$E_k = 144\,000$ J (1)
$144\,000 = F \times 24$ (1)
$F = 6000$ N (1)

Estimate a braking force

3 marks | Grade 8

1. Use the values given, or state sensible estimates.
2. Find the deceleration (or the kinetic energy).
3. Use F = m a (or $F = E_k \div$ distance) and round sensibly.

Example. A fully loaded bus has a mass of about 15 000 kg.
Estimate the braking force needed to stop it from 10 m/s in a distance of 25 m.

Model answer.

$0 - 10^2 = 2 \times a \times 25$, so the deceleration is 2 m/s^2 (1)
$F = 15\,000 \times 2$ (1)
$F \approx 30\,000$ N (~30 kN) (1)

Don’t lose marks

- Saying the kinetic energy is 'lost' or 'used up'. It is transferred to the thermal store of the brakes (and the surroundings).
- Forgetting to square the speed in $E_k = ½ m v^2$.
- Just writing 'it is dangerous' for large decelerations. Name the dangers: brakes overheating, skidding, loss of control.
- Mixing up the braking distance (m) with the braking force (N).

More tips

Memory tricks

- Braking chain: friction → work done → kinetic energy decreases → brakes heat up.
- Braking force × braking distance = $½ m v^2$ links force, distance, mass and speed in one line.
- Double the speed means four times the kinetic energy, so four times the braking force to stop in the same distance.

Exam technique

- Use the terms 'work done', 'kinetic energy store' and 'thermal energy store'.
- $E_k = ½ m v^2$ and $W = F s$ are both on the equation sheet. They are often combined in 4-mark questions: pick both, set them equal and rearrange for F.
- In estimates, state the values you assume and give the answer to 1 or 2 significant figures.

What each grade needs

What you need to be able to do, from the first marks up to the top grade.

Grade 4 — **Describe the energy transfer when a vehicle brakes**
Energy is transferred from the kinetic store of the vehicle to the thermal store of the brakes.

Grade 5 — **Calculate the work done by a braking force**
$W = F s$, where s is the braking distance.

Grade 5 — **Link braking force to deceleration**
The greater the braking force, the greater the deceleration ($F = m a$).

Grade 5 — **Link speed to the braking force needed**
A faster vehicle needs a greater braking force to stop in the same distance.

Grade 5 — **Explain the dangers of large decelerations**
The brakes may overheat, and the vehicle may skid so the driver loses control.

Grade 7 — **Calculate a braking force from kinetic energy**
Braking force × braking distance = $½ m v^2$.

Grade 8 — **Estimate braking forces for typical road vehicles**
Use typical masses and speeds with $F = m a$ or work done = kinetic energy.

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