

2 Friction, springs, and circular motion – Part 2

Name: _____ Class: _____ Date: _____

Vocabulary

Write each word three times.

English	Write it 3 times (English)		
normal force	_____	_____	_____
Friction	_____	_____	_____
Static friction	_____	_____	_____
Kinetic friction	_____	_____	_____
coefficient of friction	_____	_____	_____
Hooke's law	_____	_____	_____
spring constant	_____	_____	_____
centripetal acceleration	_____	_____	_____
centripetal force	_____	_____	_____

Recall

In Part A you drew free-body diagrams and used $\sum F = ma$. Now meet three everyday forces that appear again and again:

- **Friction** slows sliding – you feel it when you drag a heavy box.
- A **spring** pulls back when you stretch it.
- Anything moving in a **circle** needs a force pulling it inward.

Each idea below has a worked example before the Practice.

New ideas

■ 1 The normal force

When an object rests on a surface, the surface pushes back at right angles to it. This is the **normal force** N . On a flat floor it balances the weight, so $N = mg$.

Worked example. A 5.0 kg box on a level floor has $N = mg = 5.0 \times 9.8 = 49$ N.

■ 2 Friction

Friction acts along a surface and opposes sliding. It comes in two kinds:

- **Static friction** (before sliding) adjusts itself up to a maximum $f_s \leq \mu_s N$ to stop motion starting.
- **Kinetic friction** (while sliding) is $f_k = \mu_k N$.

Here μ is the **coefficient of friction** (a number for how rough the contact is).

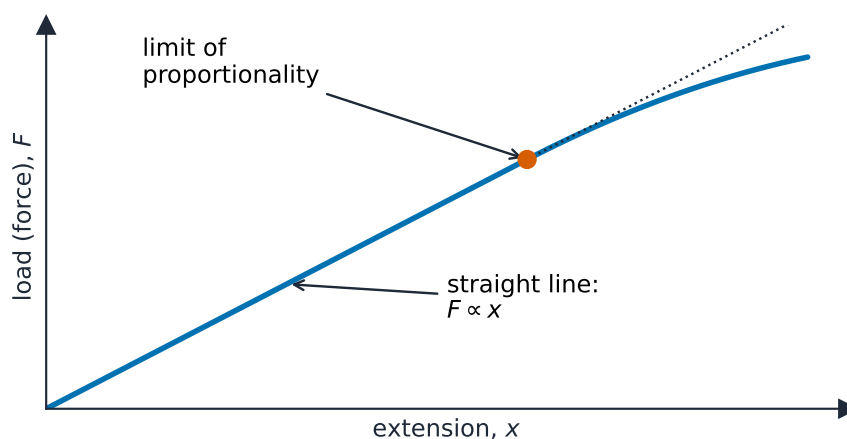
Worked example. A crate with $N = 49$ N and $\mu_s = 0.40$ needs a push above $f_{s,\max} = \mu_s N = 0.40 \times 49 = 19.6$ N to start moving. A 15 N push is too small, so it stays still.

■ 3 Springs and Hooke's law

A spring pulls (or pushes) back toward its natural length. **Hooke's law** says the force is proportional to the stretch x :

$$F_s = kx,$$

where k is the **spring constant** (its stiffness).



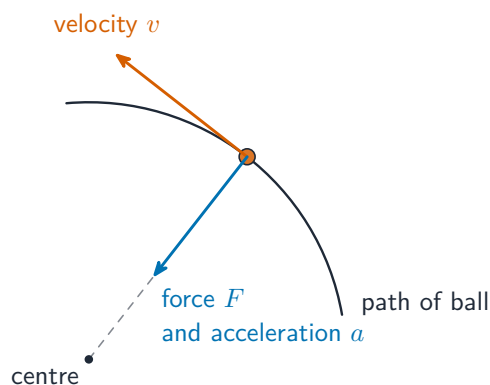
$$F = kx \text{ (straight section)} \\ k = \text{gradient}$$

Worked example. A spring with $k = 200$ N/m holds a 0.50 kg mass at rest. The spring force balances the weight, $kx = mg$, so $x = \frac{mg}{k} = \frac{0.50 \times 9.8}{200} = 0.025$ m = 2.5 cm.

■ 4 Circular motion

An object moving in a circle at steady speed is still **accelerating**, because its direction keeps changing. This **centripetal acceleration** points to the centre:

$$a_c = \frac{v^2}{r}.$$



It is caused by a real inward **centripetal force** tension, gravity, or friction.

$$F_c = \frac{mv^2}{r} - \text{supplied by}$$

Watch out: there is no outward “centrifugal” force pulling you out of the circle. The only force is the real one pulling you **inward**; you feel pushed out only because your body wants to keep going straight.

Practice

Try these in order. The methods are all above.

2.1 A 4.0 kg block sits on a flat floor. Find the normal force on it ($g = 9.8 \text{ m/s}^2$). [2]

2.2 Using that block, the coefficient of static friction is $\mu_s = 0.30$. Find the largest static friction force before it slides. [2]

2.3 A spring stretches 0.040 m when a 12 N force pulls it. Find the spring constant k . [2]

2.4 Explain why an object going around a circle at constant speed is still accelerating. [2]

2.5 A 0.30 kg ball is whirled in a circle of radius 0.80 m at 4.0 m/s. Find the centripetal force needed. [3]

2.6 A student says a car turning a corner is pushed **outward** by a force. Correct this statement. [2]