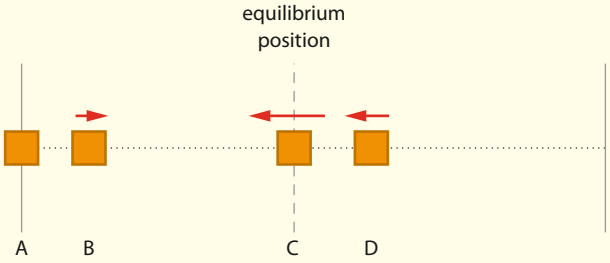
Additional Topic 9 questions

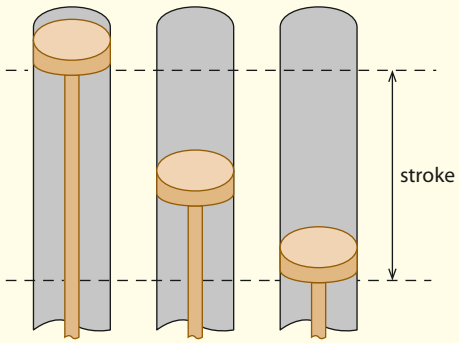
Test yourself

9.1 Simple harmonic motion

1 A body performs SHM along a horizontal straight line between the extremes shown by the solid grey lines in the diagram.
The arrows represent the direction of motion of the body. The body is shown in four positions: A, B, C and D. Copy the diagram and, in each position, draw arrows to represent the direction and relative magnitude of:
a the acceleration of the body
b the net force on the body.

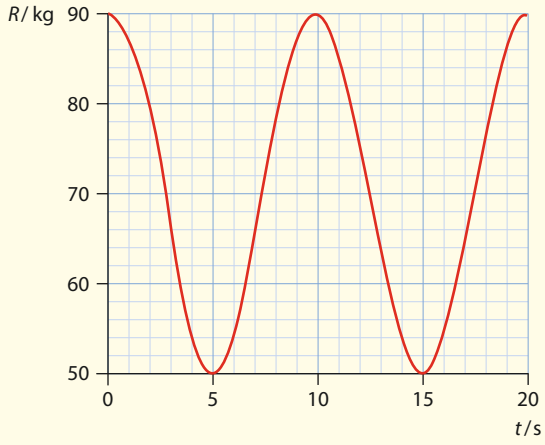


2 The piston (of mass 0.25 kg) of a car engine has a **stroke** (i.e. distance between extreme positions) of 9.0 cm and operates at 4500 rev min^{-1}, as shown in the diagram.



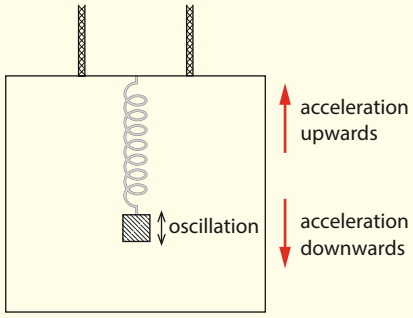
a Calculate the acceleration of the piston at maximum displacement.
b Calculate the velocity as the piston moves past its equilibrium point.
c What is the net force exerted on the piston at maximum displacement?

3 A passenger on a cruise ship in rough seas stands on a set of 'weighing scales'. The reading R of the scales (in kilograms) as a function of time is shown in the diagram.



Use the graph to determine:
a the mass of the passenger
b the amplitude of the waves in the sea.

4 A body is suspended vertically at the end of a spring that is attached to the ceiling of an elevator, as shown in the diagram. The elevator moves with constant acceleration. Discuss **qualitatively** the effect, if any, of the acceleration on the period of oscillations of the mass when the acceleration is:
a upwards
b downwards.



5 A body of mass 1.80 kg executes SHM such that its displacement from equilibrium is given by $x = 0.360\cos(6.80t)$, where x is in metres and t is in seconds. Determine:
a the amplitude, frequency and period of the oscillations
b the total energy of the body
c the kinetic energy and the elastic potential energy of the body when the displacement is 0.125 m.

9.2 Single-slit diffraction

6 In a single-slit diffraction experiment the slit width is 0.025 mm and the wavelength of light is 625 nm.
- **a** Calculate the angle of the first diffraction minimum.
- **b** State an approximate value for the ratio of the intensity of the central maximum to the intensity of the first maximum to the side.

7 White light illuminates a slit. The first diffraction minimum for a wavelength of 625 nm is observed at 14°.
- **a** Calculate the slit width.
- **b** Determine the wavelength of light for which the first secondary maximum occurs at an angle of 14°. (The first secondary maximum appears at an angle (in radians) of approximately $\frac{3\lambda}{2b}$.)
- **c** Explain why the central maximum will be white but the spot at 14° will be coloured.

9.3 Interference

8 Discuss the effect on the bright spots in a Young's two-slit experiment of:
- **a** decreasing the separation of the slits
- **b** increasing the wavelength of light
- **c** increasing the distance to the screen
- **d** increasing the distance of the source from the slits
- **e** using white light as the source.

9 A diffraction grating with 350 lines per mm produces first-order maxima at angles 8.34° and 8.56° for two separate wavelengths of light.
- **a** Determine these wavelengths.
- **b** Calculate the angle that separates the second-order maxima of these wavelengths.

10 In a two-slit interference experiment with slits of negligible width, five maxima are observed on each side of the central maximum. When the slits are replaced by two slits of finite width separated by the same distance as before, the third maximum on either side of the central maximum is missing (i.e. the intensity of light there is zero). Calculate the width of the slits in terms of their separation, d.

11 When a thin soap film of uniform thickness is illuminated with white light, it appears purple in colour. Explain this observation carefully.

12 A car moves along a road that is parallel to the twin antennas of a radio station broadcasting at a frequency of 95.0 MHz (see diagram). The antennas are 30.0 m apart and the distance of A from the mid-point of the antennas is 2.0 km. When in position A, the reception is good, but it drops to almost zero at position B. Calculate the distance AB.

13 Two radio transmitters are 80.0 m apart on a north–south line. They emit coherently at a wavelength of 1.50 m. A satellite in a north–south orbit travelling at 7.50 km s^{-1} receives a signal that alternates in intensity with a frequency of 0.560 Hz. Assuming that the signal received by the satellite is the superposition of the waves from the individual transmitters, find:
- **a** the distance between two consecutive points where the satellite receives a strong signal
- **b** the height of the satellite from the Earth's surface.

14 A soap film will appear dark if it is very thin and will reflect all colours when thick. Carefully justify these statements using interference from thin films.