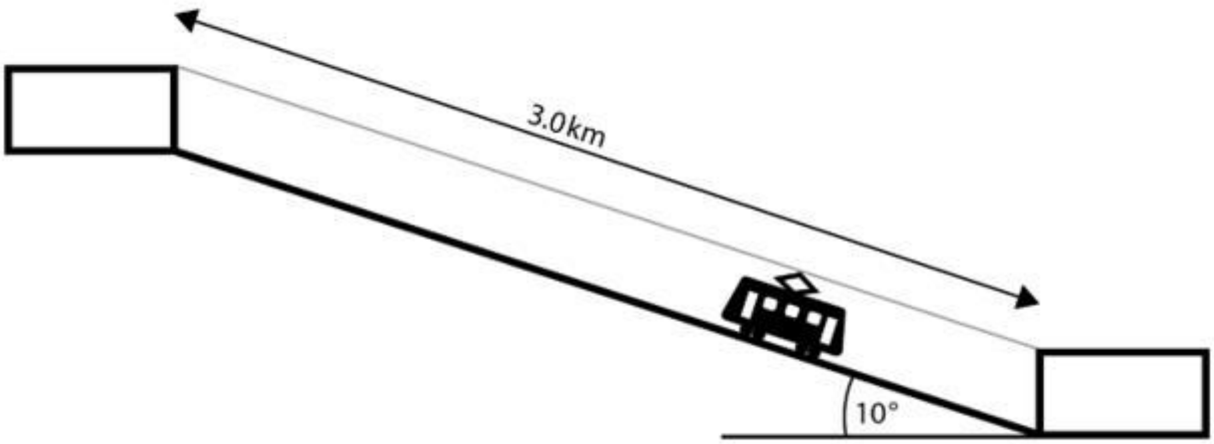
1. EXE.2.SL.TZ0.2

An Alpine village uses an electric tram system to transport visitors from a lower station up to an upper station at the village. The length of the tramline is 3.0 km and the gradient of the tramline is a constant 10°.



The tram has a weight of 5.0×10^4 N and can carry a maximum of 75 passengers of average weight 710 N.

The energy is supplied to each tram through a single overhead cable with a resistance per unit length of $0.024\ \Omega\ \text{km}^{-1}$. The tram rails are used for the return path of the current. The return path and the connections from the cable to the electric motor in the tram have negligible resistance.

The power supply maintains a constant emf of 500 V between the rails and the cable at the upper station.

Assume that the current through the motor is constant at 600 A and that the motor efficiency is always 0.90 for the entire range of voltages available to the tram.

(a)

A tram is just leaving the lower railway station.

Determine, as the train leaves the lower station,

[[N/A]]

(a.i)

the pd across the motor of the tram,

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(a.ii)

the mechanical power output of the motor.

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(b)

Discuss the variation in the power output of the motor with distance from the lower station.

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(c)

The total friction in the system acting on the tram is equivalent to an opposing force of 750 N.

For one particular journey, the tram is full of passengers.

Estimate the maximum speed *v* of the tram as it leaves the lower station.

[4]

(d)

The tram travels at v throughout the journey. Two trams are available so that one is returning to the lower station on another line while the other is travelling to the village. The journeys take the same time.

It takes 1.5 minutes to unload and 1.5 minutes to load each tram. Ignore the time taken to accelerate the tram at the beginning and end of the journey.

Estimate the maximum number of passengers that can be carried up to the village in one hour.

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(e)

There are eight wheels on each tram with a brake system for each wheel. A pair of brake pads clamp firmly onto an annulus made of steel.

The train comes to rest from speed v. Ignore the energy transferred to the brake pads and the change in the gravitational potential energy of the tram during the braking.

Calculate the temperature change in each steel annulus as the tram comes to rest.

Data for this question

The inner radius of the annulus is 0.40 m and the outer radius is 0.50 m.

The thickness of the annulus is 25 mm.

The density of the steel is 7860 kg m^{-3}

The specific heat capacity of the steel is 420 J kg^{-1} K^{-1}

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(f)

The speed of the tram is measured by detecting a beam of microwaves of wavelength 2.8 cm reflected from the rear of the tram as it moves away from the station. Predict the change in wavelength of the microwaves at the stationary microwave detector in the station.

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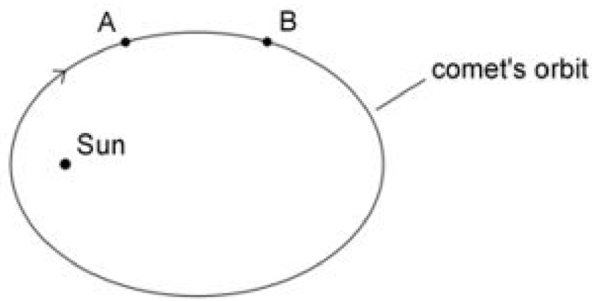
2. EXE.2.SL.TZ0.11

(a)

A comet orbits the Sun in an elliptical orbit. A and B are two positions of the comet.



Explain, with reference to Kepler's second law of planetary motion, the change in the kinetic energy of the comet as it moves from A to B.

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(b)

An asteroid (minor planet) orbits the Sun in a circular orbit of radius 4.5×10^8 km. The radius of Earth's orbit is 1.5×10^8 km. Calculate, in years, the orbital period of the asteroid.

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3. EXE.2.SL.TZ0.12

One of Kepler's laws suggests that for moons that have circular orbits around a planet:

$$\frac{T^2}{4\pi r^3} = k$$

where T is the orbital period of the moon, r is the radius of its circular orbit about the planet, and k is a constant.

(a)

Show that $k = \frac{1}{GM}$.

[2]

(b)

The table gives data relating to the two moons of Mars.

Moon	T / hour	r / Mm
Phobos	7.66	9.38
Deimos	30.4	-

Determine r for Deimos.

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(c)

Determine the mass of Mars.

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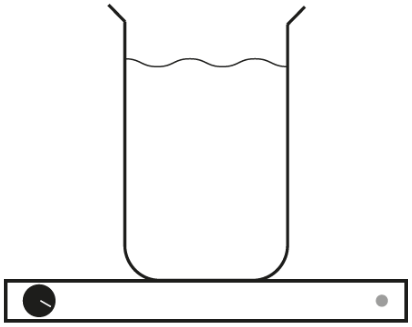
4. 24M.2.SL.TZ1.102

An experiment is conducted to measure the specific heat capacity of water. A mass of water is placed in a glass beaker and energy is transferred from an electric heater.



The data collected are:

Mass of water = (0.250 ± 0.002) kg

Change in temperature of the water = (14.0 ± 0.5) °C

Energy transferred from the electric heater = (16 000 ± 300) J

(a.i)

Calculate the specific heat capacity of water.

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(a.ii)

Determine the absolute uncertainty in the specific heat capacity of water.

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(a.iii)

Write down the specific heat capacity of water and its absolute uncertainty to the appropriate number of significant figures.

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(b)

Outline **one** source of systematic error in the experiment and its effect on the calculated value of the specific heat capacity of water.

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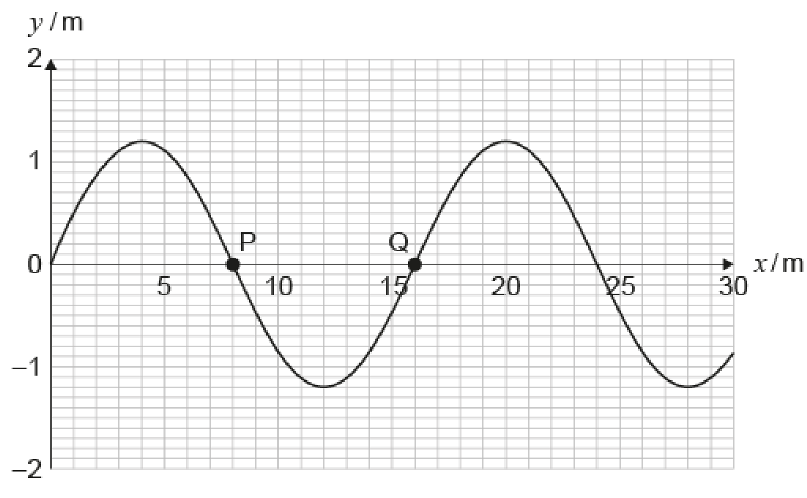
5. 23M.2.SL.TZ1.3

(a)

A transverse water wave travels to the right. The diagram shows the shape of the surface of the water at time t = 0. P and Q show two corks floating on the surface.



[[N/A]]

(a.i)

State what is meant by a transverse wave.

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(a.ii)

The frequency of the wave is 0.50 Hz. Calculate the speed of the wave.

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(a.iii)

Plot on the diagram the position of P at time t = 0.50 s.

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(a.iv)

Sketch the phase difference between the oscillations of the two corks is π radians.

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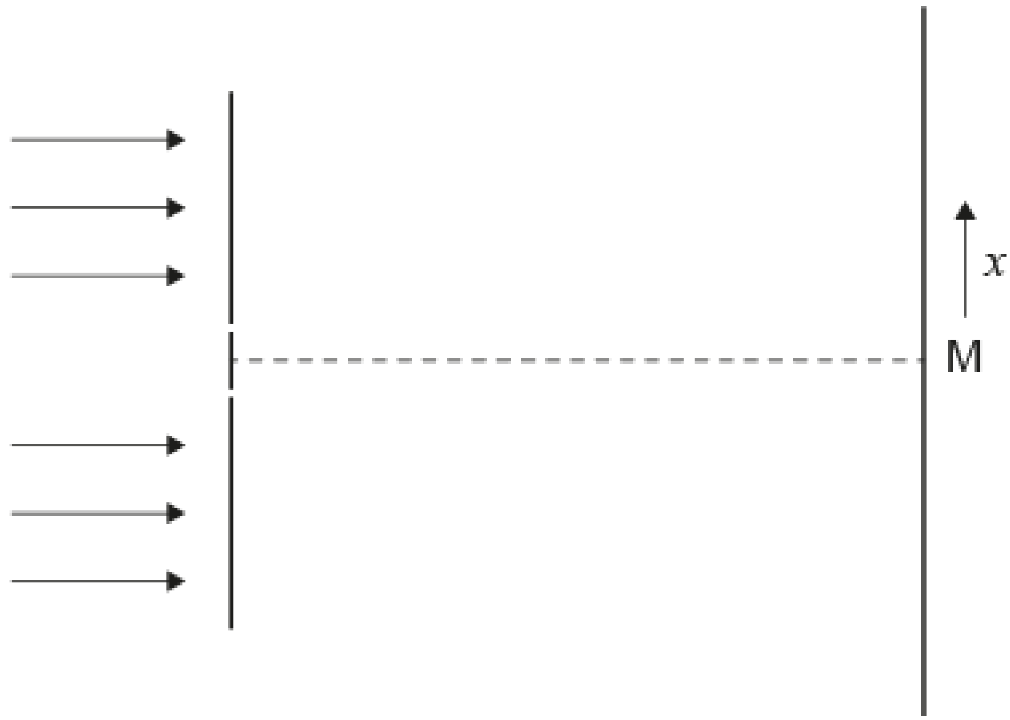
(b)

Monochromatic light is incident on two very narrow slits. The light that passes through the slits is observed on a screen. M is directly opposite the midpoint of the slits. x represents the displacement from M in the direction shown.



A student argues that what will be observed on the screen will be a total of two bright spots opposite the slits. Explain why the student's argument is incorrect.

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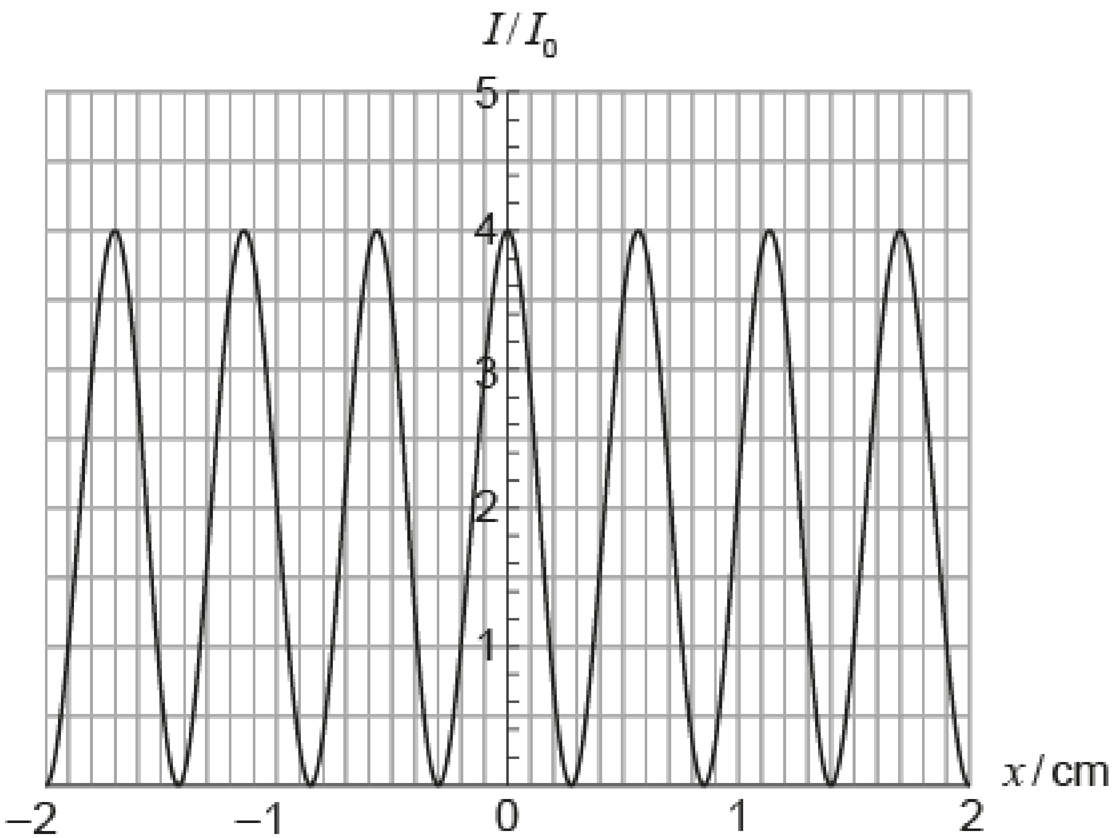
(c)

The graph shows the actual variation with displacement x from M of the intensity of the light on the screen. I_0 is the intensity of light at the screen from one slit only.



The slits are separated by a distance of 0.18 mm and the distance to the screen is 2.2 m.

Determine, in m, the wavelength of light.

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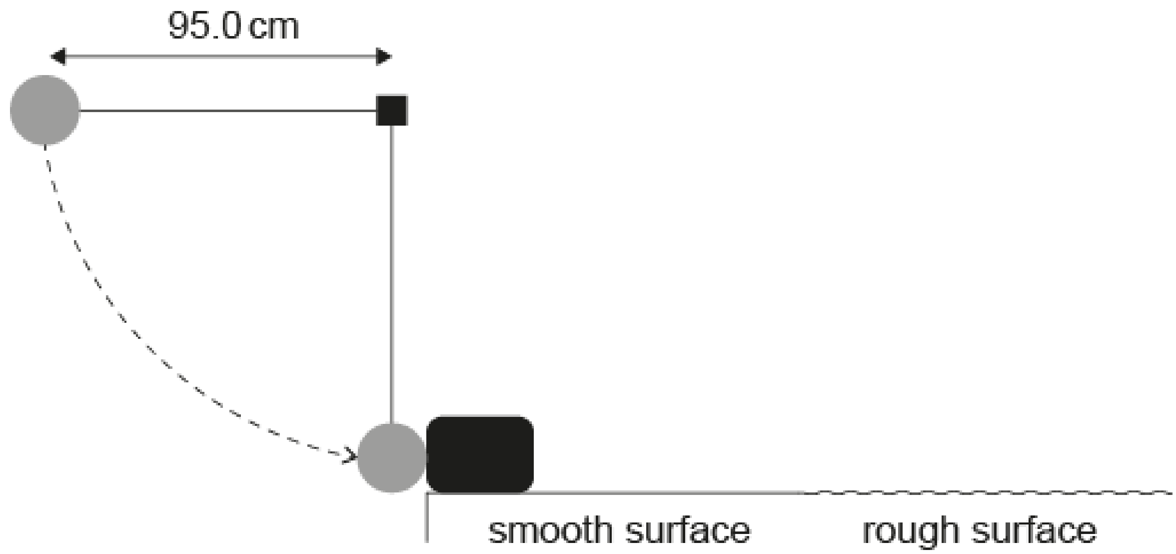
6. 23M.2.HL.TZ1.1

A ball of mass 0.800 kg is attached to a string. The distance to the centre of the mass of the ball from the point of support is 95.0 cm. The ball is released from rest when the string is horizontal. When the string becomes vertical the ball collides with a block of mass 2.40 kg that is at rest on a horizontal surface.



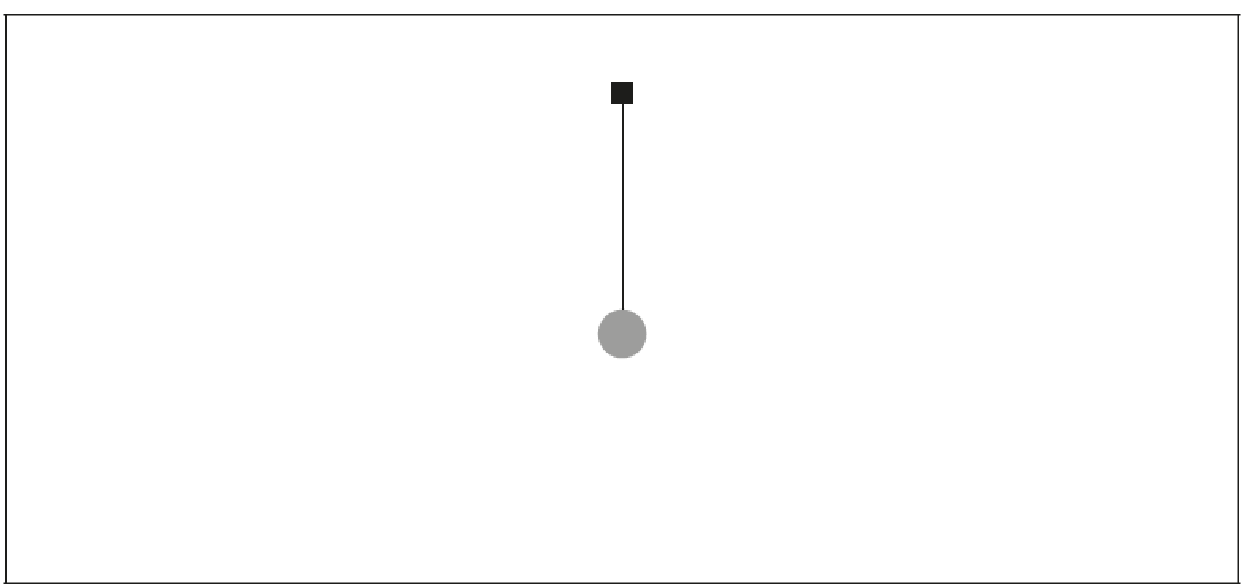
(a)

Just before the collision of the ball with the block,

[[N/A]]

(a.i)

draw a free-body diagram for the ball.



[2]

(a.ii)

show that the speed of the ball is about 4.3 m s^{-1}.

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(a.iii)

determine the tension in the string.

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(b)

After the collision, the ball rebounds and the block moves with speed 2.16 m s^{-1}.

[[N/A]]

(b.i)

Show that the collision is elastic.

[4]

(b.ii)

Calculate the maximum height risen by the centre of the ball.

[2]

(c)

The coefficient of dynamic friction between the block and the rough surface is 0.400.

Estimate the distance travelled by the block on the rough surface until it stops.

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