RAFFLES INSTITUTION
PRELIMINARY EXAMINATION 2025
Higher 2

CANDIDATE NAME		CLASS INDEX NUMBER	

CLASS 2 5 S 0 _ _

PHYSICS 9749/02

Paper 2 Structured Questions

17 September 2025

2 hours

You must answer on the question paper.

No additional materials are needed.

INSTRUCTIONS
- Answer **all** questions.
- Use a black or dark blue pen. You may use an 2B pencil for any diagrams or graphs.
- Write your name, index number and class in the spaces at the top of the page.
- Write your answer to each question in the space provided.
- Do **not** use an erasable pen. Do **not** use correction fluid or tape.
- You may use an approved calculator.

INFORMATION
- The total mark for this paper is 80.
- The number of marks for each question or part question is shown in brackets [ ].

For Examiner's Use	
1	/ 6
2	/ 6
3	/ 9
4	/ 10
5	/ 8
6	/ 9
7	/ 12
8	/ 20
Deduction	
Total	/ 80

Data

speed of light in free space	c	=	3.00×10^{8} m s^{-1}
permeability of free space	μ_0	=	$4\pi \times 10^{-7}$ H m^{-1}
permittivity of free space	ε_0	=	8.85×10^{-12} F m^{-1}
		=	$(1/(36\pi)) \times 10^{-9}$ F m^{-1}
elementary charge	e	=	1.60×10^{-19} C
the Planck constant	h	=	6.63×10^{-34} J s
unified atomic mass constant	u	=	1.66×10^{-27} kg
rest mass of electron	m_e	=	9.11×10^{-31} kg
rest mass of proton	m_p	=	1.67×10^{-27} kg
molar gas constant	R	=	8.31 J K^{-1} mol^{-1}
the Avogadro constant	N_A	=	6.02×10^{23} mol^{-1}
the Boltzmann constant	k	=	1.38×10^{-23} J K^{-1}
gravitational constant	G	=	6.67×10^{-11} N m^{2} kg^{-2}
acceleration of free fall	g	=	9.81 m s^{-2}

Formulae

uniformly accelerated motion	s	=	$ut + \frac{1}{2}at^2$
	v^2	=	$u^2 + 2as$
work done on/by a gas	W	=	$p\Delta V$
hydrostatic pressure	p	=	ρgh
gravitational potential	ϕ	=	$-Gm/r$
temperature	T/K	=	$T/°\text{C} + 273.15$
pressure of an ideal gas	p	=	$\frac{1}{3}\frac{Nm}{V}\langle c^2 \rangle$
mean translational kinetic energy of an ideal gas molecule	E	=	$\frac{3}{2}kT$
displacement of particle in s.h.m.	x	=	$x_0 \sin \omega t$
velocity of particle in s.h.m.	v	=	$v_0 \cos \omega t = \pm \omega \sqrt{x_0^2 - x^2}$
electric current	I	=	$Anvq$
resistors in series	R	=	$R_1 + R_2 + \ldots$
resistors in parallel	$1/R$	=	$1/R_1 + 1/R_2 + \ldots$
electric potential	V	=	$\frac{Q}{4\pi\varepsilon_0 r}$
alternating current/voltage	x	=	$x_0 \sin \omega t$
magnetic flux density due to a long straight wire	B	=	$\frac{\mu_0 I}{2\pi d}$
magnetic flux density due to a flat circular coil	B	=	$\frac{\mu_0 NI}{2r}$
magnetic flux density due to a long solenoid	B	=	$\mu_0 nI$
radioactive decay	x	=	$x_0 \exp(-\lambda t)$
decay constant	λ	=	$\ln 2 / t_{1/2}$

Answer **all** the questions in the spaces provided.

1 Fig. 1.1 shows a cuboid made of glass.

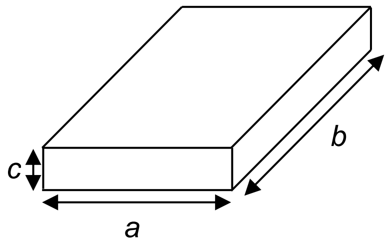

Fig. 1.1

A student measures the mass m of the cuboid and the side lengths a, b and c. The measurements are shown in Table 1.1.

Table 1.1

quantity	measurement
m	(0.234 ± 0.002) kg
a	(5.13 ± 0.01) cm
b	(11.38 ± 0.01) cm
c	(1.72 ± 0.01) cm

(a) Determine the density ρ of the glass.

ρ = ... kg m^{-3} [1]

(b) Determine the value of ρ together with its actual uncertainty.
Give your answer to an appropriate number of significant figures.

ρ = ...±.............................. kg m^{-3} [3]

(c) The true value of the density of the glass is different from the answer in **(a)** because of a systematic error in the measurements.

Suggest **one** possible cause of this systematic error.

....

....

....

.... [2]

[Total: 6]

2 A cantilever is set up on a rough table using a rigid uniform metre rule of mass 0.11 kg, a 1.5 kg block and a 5.0 g mass as shown in Fig. 2.1.

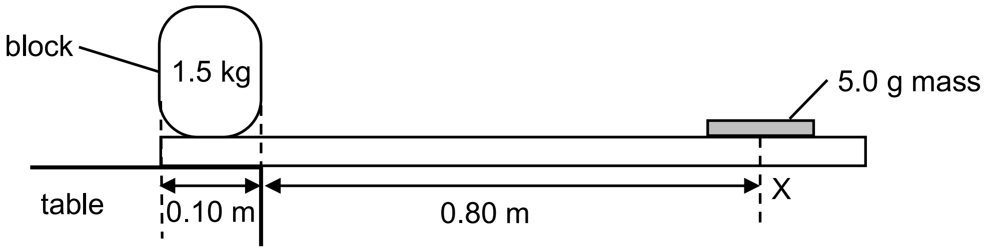

Fig. 2.1

(a) Determine the maximum number of 5.0 g masses that can be stacked above point X such that the cantilever does not topple.

maximum number = ... [3]

(b) The structure in Fig. 2.1 is modified by adding an inextensible string that passes over a frictionless pulley with its ends tied to the 1.5 kg block and to the centre of the metre rule as shown in Fig. 2.2. The string remains taut.

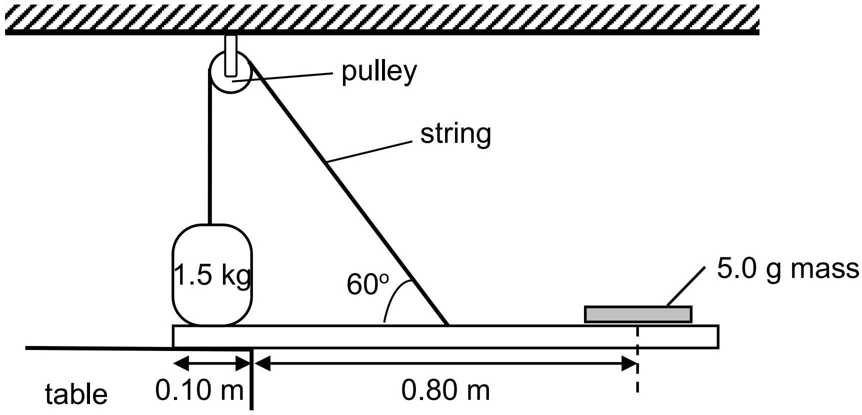

Fig. 2.2

State and explain how this modification will affect your answer in **(a)**.

....

....

....

....

....

.... [3]

[Total: 6]

3 In a machine, a peg that is fixed to a wheel rotates in a vertical circle of radius r. Both the peg and the wheel rotate with a constant angular velocity ω and period T about the centre of wheel O. The peg is in contact with a horizontal slot in a yoke. As the peg undergoes uniform circular motion, the yoke of mass m moves vertically up and down within a well.

Fig. 3.1 shows the positions of the peg and yoke at different times t.

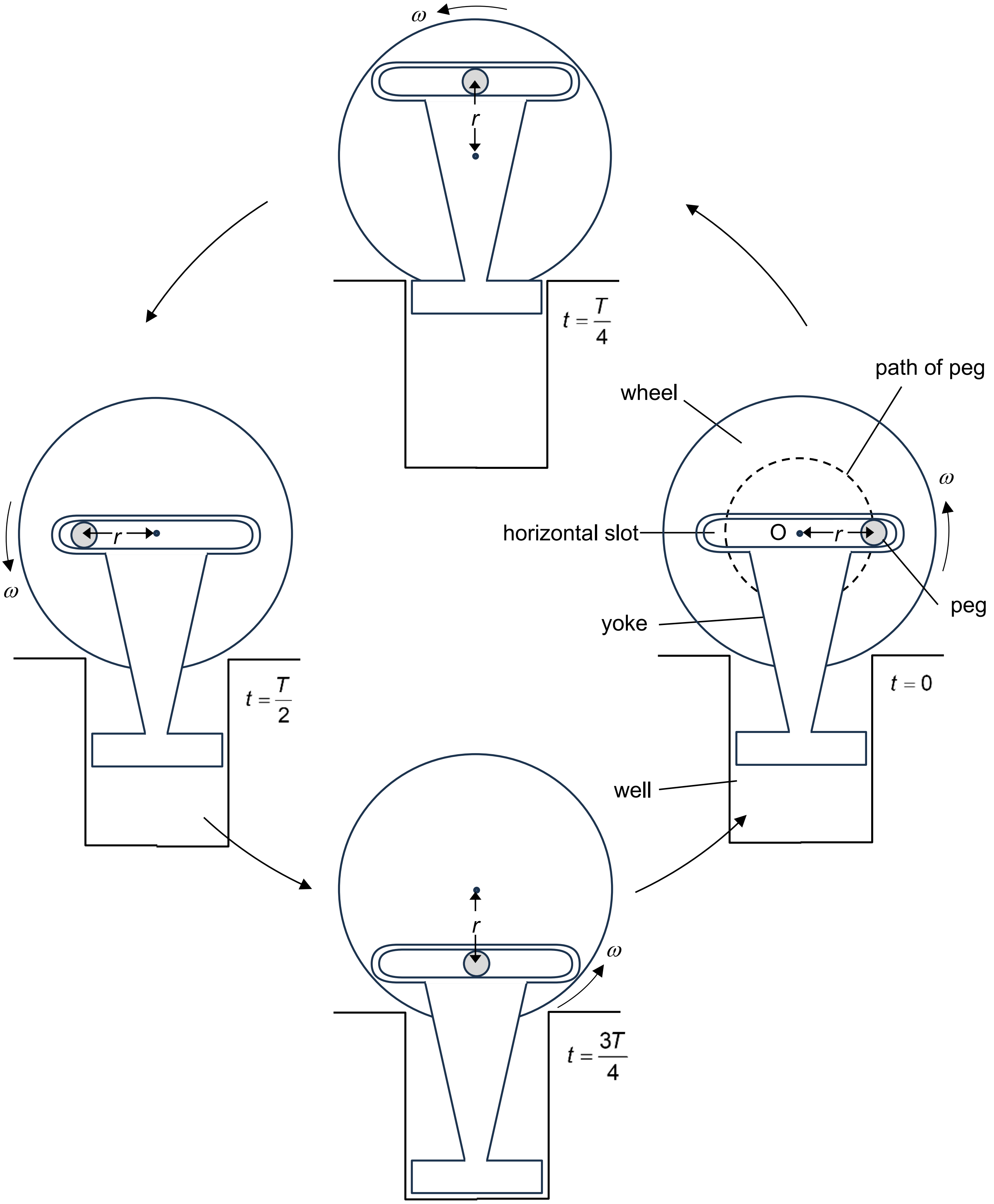

Fig. 3.1

(a) State and explain the motion of the yoke.

....

....

....

.... [2]

(b) Given that r = 0.080 m, T = 0.40 s and m = 0.30 kg, determine:

(i) **1.** the maximum speed v_0 of the yoke

v_0 = ... m s^{-1} [2]

2. the maximum acceleration a_0 of the yoke.

a_0 = ... m s^{-2} [2]

(ii) On Fig. 3.2, sketch a line to show the variation of net force F on the yoke with time t. Take the equilibrium position of the yoke as the zero of displacement and the upwards direction as positive.

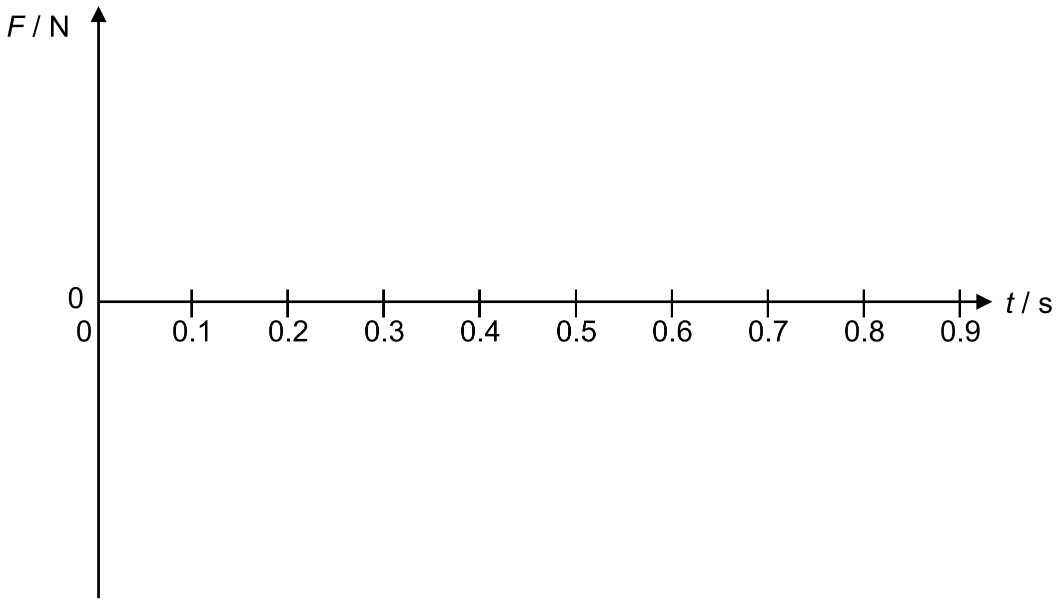

Fig. 3.2

[3]

[Total: 9]

4 Polarised light of wavelength 590 nm is incident normally on a double slit, as shown in Fig. 4.1.

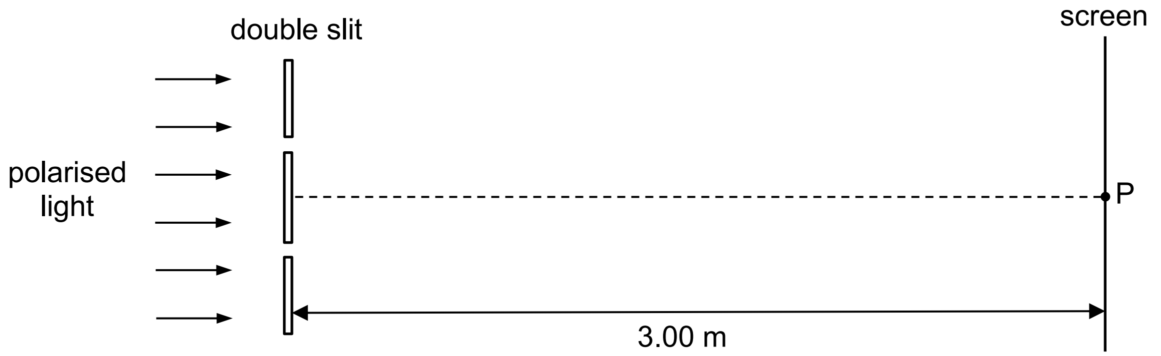

Fig. 4.1 (not to scale)

The separation of the two slits of equal width is very small compared to the distance of 3.00 m between the slits and the screen. The double slit and the screen are parallel.

An interference pattern consisting of bright and dark fringes is observed on the screen. Point P is equidistant from both slits.

(a) **(i)** Explain how the bright and dark fringes are formed.

....

....

....

....

....

.... [3]

(ii) Explain why some bright fringes are observed to be missing from the interference pattern.

....

.... [1]

(b) One of the two slits is covered.

(i) The distance between the first dark fringes on either side of point P on the screen is 35.4 mm. Determine the width of each slit.

width = ... mm [3]

(ii) Parallel light from a second source of the same wavelength of 590 nm is also incident on the uncovered slit. The angle between the two beams of light is 0.0040 rad, as shown in Fig. 4.2.

Fig. 4.2 (not to scale)

Each beam forms a separate diffraction pattern on the screen.

With reference to the Rayleigh criterion, explain whether the two diffraction patterns formed on the screen are seen as being separate.

....

....

....

....

....

.... [3]

[Total: 10]

5 An ideal gas at a temperature of 22 °C is trapped in a metal cylinder of volume 0.20 m^3 at a pressure of 1.6×10^6 Pa.

(a) State what is meant by an ideal gas.

....

....

....

.... [2]

(b) Calculate the amount of gas contained in the cylinder.

amount = ... mol [2]

(c) The gas has a molar mass of 4.2×10^{-2} kg mol^{-1}.

Calculate the root-mean-square speed of the gas molecules in the cylinder.

root-mean-square speed = ... m s^{-1} [2]

(d) The cylinder is taken to high altitude where the temperature is –50 °C and the pressure is 3.6×10^4 Pa. A valve on the cylinder is opened to allow gas to escape.

Calculate the mass of gas remaining in the cylinder when it reaches equilibrium with its surroundings.

mass of gas remaining = ... kg [2]

[Total: 8]

6 A potentiometer wire PR, mounted on a metre rule (not shown), is used to measure the electromotive force (e.m.f.) E of a solar cell with internal resistance as shown in Fig. 6.1.

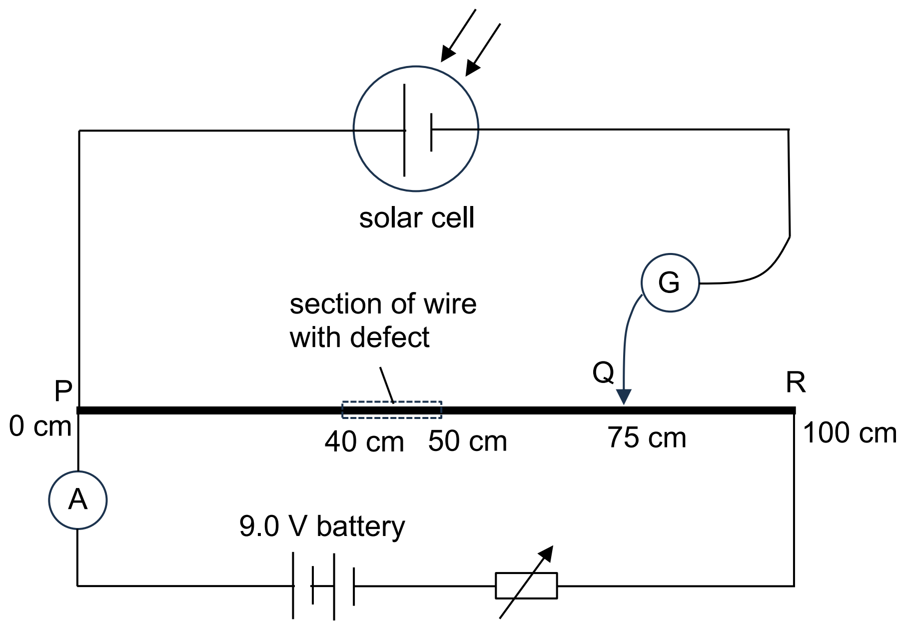

Fig. 6.1

Points P and R of the wire are at the 0 cm and 100 cm marks on the metre rule respectively. The 9.0 V battery has negligible internal resistance.

The potentiometer wire has a resistivity of $5.0 \times 10^{-7}\ \Omega$ m. It is found that there is defect in a small section of the wire, from 40 cm to 50 cm marks, where the cross-sectional area is 20% smaller than the rest of the wire which has a cross-sectional area of 5.7×10^{-8} m^2.

(a) State what is meant by e.m.f. of a battery.

....

.... [1]

(b) Calculate the resistance of the potentiometer wire PR.

resistance = ... Ω [2]

(c) When the variable resistor is set to a resistance of 25 Ω, the galvanometer shows no deflection when the jockey Q is in contact with the wire at the 75 cm mark.

(i) Calculate the current I shown on the ammeter.

I = ... A [2]

(ii) Calculate E.

E = ... V [2]

(d) **(i)** Explain why the internal resistance of the solar cell does not have to be considered in the calculation in **(c)(ii)**.

....

.... [1]

(ii) Explain, without calculation, how the balance length would change if the cross-sectional area of the potentiometer wire is uniform throughout with a value of 5.7×10^{-8} m^2 and the resistance of the variable resistor is unchanged.

....

.... [1]

[Total: 9]

7 Potassium-40 ($^{40}_{19}K$) is an isotope of potassium with a half-life of 1.25×10^9 years.

(a) **(i)** Explain the term isotopes.

....

.... [1]

(ii) Define half-life of a radioactive isotope.

....

.... [1]

(b) Most of the isotope potassium-40 undergoes beta decay to form the stable isotope calcium-40 ($^{40}_{20}Ca$).

(i) Complete the nuclear decay equation. Include all the decay products.

$$^{40}_{19}K \rightarrow$$

[3]

(ii) Data for the atomic masses are given in Table 7.1.

Table 7.1

	mass / *u*
$^{40}_{19}K$	39.963998
$^{40}_{20}Ca$	39.962591

Determine the energy released in each decay of potassium-40 to calcium-40.

energy released = ... MeV [4]

(c) 90% of the potassium-40 decays to form calcium-40 while the remaining 10% decays to form the stable isotope argon-40.

In a particular sample of rock, the ratio of the number of potassium atoms to the number of argon atoms is found to be 2:1.

Estimate the age of the rock. Assume that originally there was no argon present.

age of rock = ... years [3]

[Total: 12]

8 Read the passage below and answer the questions that follow.

Skiing is a popular recreational activity involving using skis to move across snow. Ski resorts in snowy mountain regions have ski lifts to transport skiers uphill. The chairs in ski lifts move on a continuously circulating wire rope. Fig. 8.1 shows a two-person chair that is commonly used in ski lifts.

Fig. 8.1

A particular ski lift uses 48 two-person chairs, evenly spaced along the wire rope, to transport skiers up a height of 300 m from the lower station to the upper station. Each chair has a mass of 80 kg and moves at a constant speed of 2.5 m s^{-1}. The distance between the two stations is 900 m as shown in Fig. 8.2.

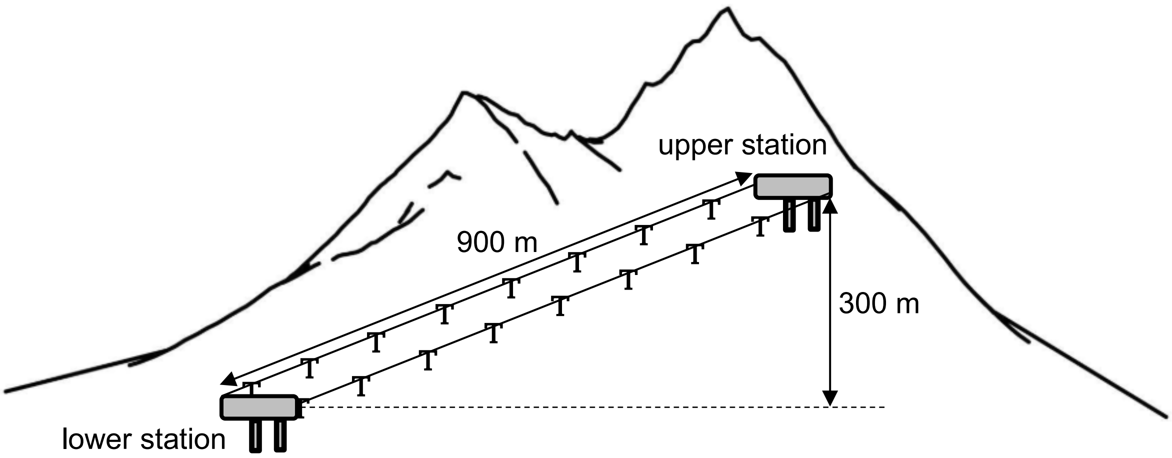

Fig. 8.2 (not to scale)

Ski resorts offer ski lessons where skiers new to skiing can learn the two basic techniques: sliding and carving.

Sliding occurs when a skier moves down a slope in a straight path. This movement results from the interaction between two forces: the skier's weight and the friction between the skier and snow surface.

When skis press against snow, the increased pressure beneath the skis causes localised melting, creating a microscopic layer of water. This water layer significantly reduces friction, facilitating smoother ski movements. The type of snow plays a crucial role in this process, directly affecting both the skier's control and velocity.

The friction f between the skis and the snow is related to the normal contact force N acting on the skier due to the snow by the equation:

$$f = \mu N$$

where μ is the coefficient of friction.

(a) **(i)** On a crowded day, each chair carries two skiers uphill and no skiers downhill. The average mass of a skier is 75 kg.

Calculate the mechanical power required to drive the ski lift.

power = ... W [3]

(ii) Suggest a reason why your answer in **(a)(i)** is an underestimation.

....

.... [1]

(b) Table 8.1 shows the values of μ for various types of snow.

Table 8.1

type of snow	μ
hard snow	0.050
medium snow	0.080
soft snow	0.12
wet / icy snow	0.030

To maintain control and regulate speed while sliding, skiers will adjust their direction of motion relative to the downhill direction. The angle between the direction of motion and the downhill direction, known as the ski angle α, is shown on Fig. 8.3.

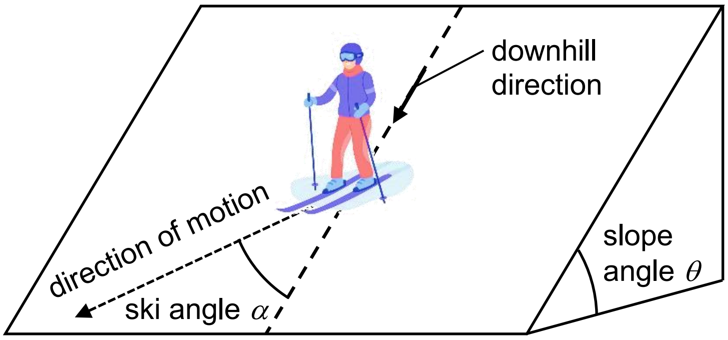

Fig. 8.3

Skiers typically ski across the face of the slope in a zig-zag pattern for optimal control. The acceleration a_g in the direction of motion due to gravity varies depending on the slope angle θ and ski angle α.

Fig. 8.4 shows the variation with α of a_g at various values of θ.

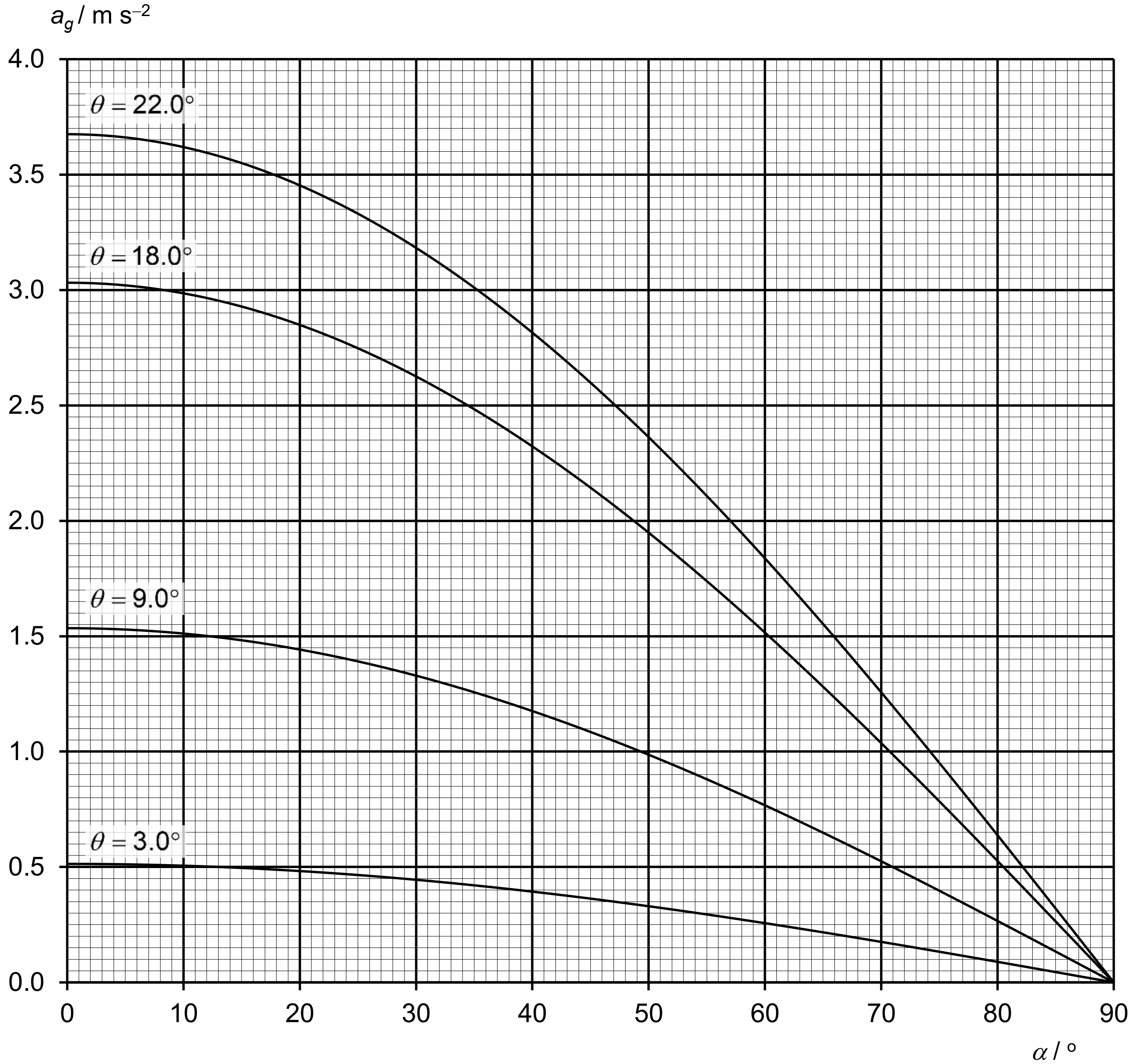

Fig. 8.4

A skier of mass 75 kg moves down the slope with slope angle $\theta = 9.0°$ and ski angle $\alpha = 0°$. The slope is covered with medium snow. Assume that air resistance is negligible.

(i) Show that the normal contact force N acting on the skier is 730 N.

[1]

(ii) Determine the friction acting on the skier.

friction = ... N [2]

(iii) Determine the acceleration of the skier.

acceleration = ... m s^{-2} [2]

(c) The skier moves down a new slope of slope angle $\theta = 22.0°$. The new slope is covered with soft snow. To maintain a constant speed, the skier adjusts his direction of motion to a ski angle α.

(i) Determine the friction acting on the skier on the new slope.

friction = ... N [1]

(ii) Use Fig. 8.4 to determine the ski angle α.

α = ... ° [3]

(iii) State how the skier can increase his speed.

....

.... [1]

(d) Carving occurs when skiers tilt their skis to execute controlled turns as shown in Fig. 8.5.

Fig. 8.5

The angle between the skis and the snow surface known as the edge angle β is shown in Fig. 8.6.

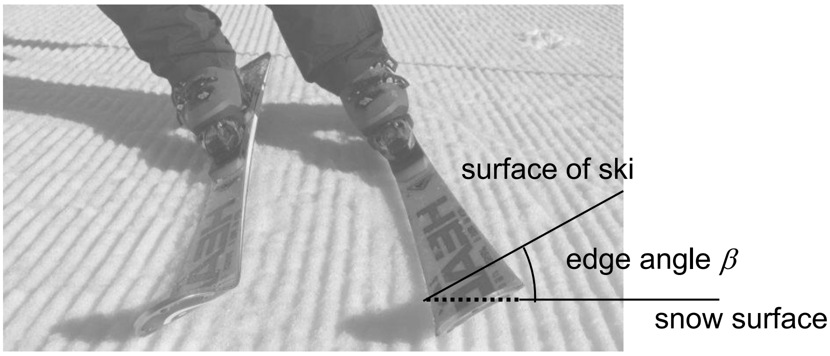

Fig. 8.6

Unlike sliding, carving involves following a circular arc in the plane of the slope. The edge angle β determines the turn radius r.

Fig. 8.7 shows the variation with β of r for different types of snow when the skier moves at a speed of 5.0 m s^{-1} and a ski angle $\alpha = 0°$.

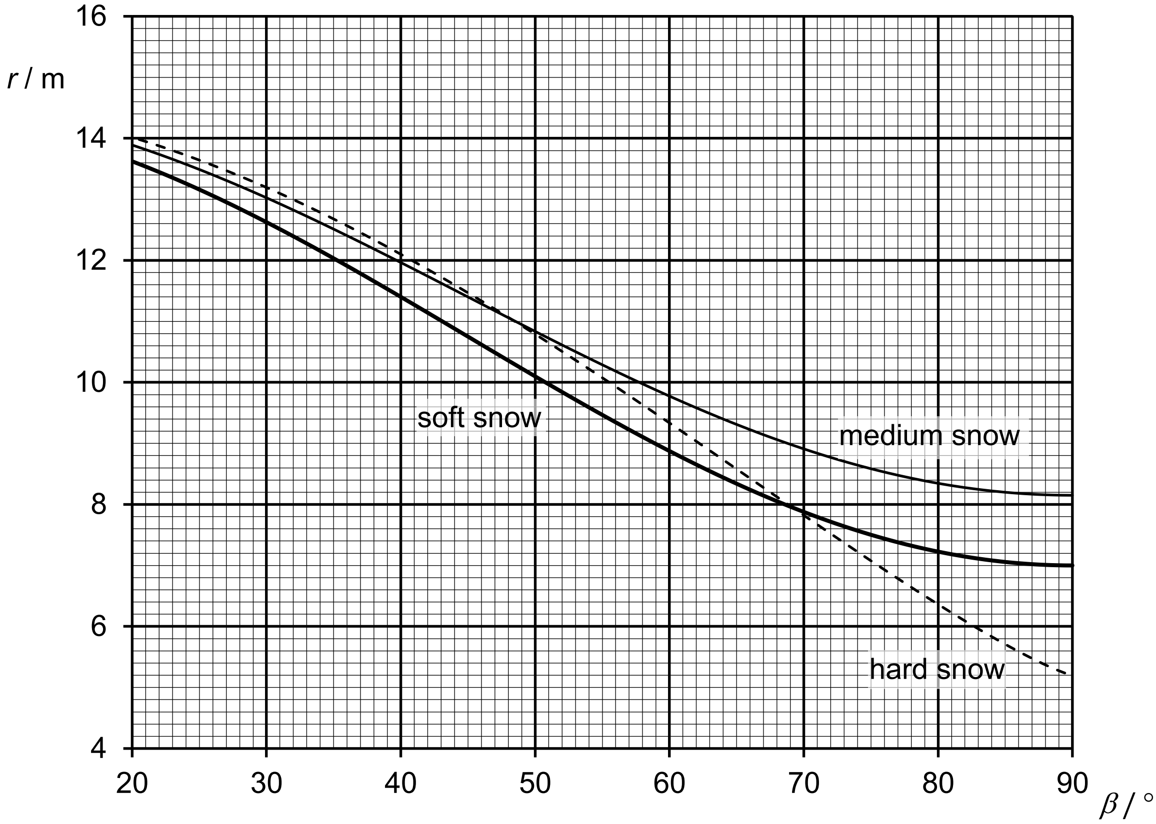

Fig. 8.7

(i) Determine the centripetal force acting on the skier for edge angle of 61° on hard snow.

centripetal force = ... N [3]

(ii) With reference to the forces acting on the skier and the stability of the skier, explain why a larger edge angle is required to generate a higher centripetal force.

....

....

....

....

....

.... [3]

[Total: 20]