Name: ______________________________ (   ) Class: 24 / ______

ANDERSON SERANGOON JUNIOR COLLEGE

2023 JC1 Promotional Exam

PHYSICS Higher 2 9749/02

Paper 2 Structured Questions **Tuesday 26 September 2023**

2 hours

Candidates answer on the Question Paper.
No Additional Materials are required.

READ THESE INSTRUCTIONS FIRST

Write your name, class index number and class in the spaces at the top of this page.
Write in dark blue or black pen on both sides of the paper.
You may use an HB pencil for any diagrams or graphs.
Do not use staples, paper clips, glue or correction fluid.

The use of an approved scientific calculator is expected, where appropriate.
Answer **all** questions.

The number of marks is given in brackets [ ] at the end of each question or part question.

For Examiner's Use	
Paper 1 (20 marks)	
Paper 2 (80 marks)	
1	
2	
3	
4	
5	
6	
7	
8	
9	
Deductions	
Total	

This document consists of **24** printed pages and **0** blank page.

Data

speed of light in free space	$c = 3.00 \times 10^{8}$ m s^{-1}
permeability of free space	$\mu_0 = 4\pi \times 10^{-7}$ H m^{-1}
permittivity of free space	$\varepsilon_0 = 8.85 \times 10^{-12}$ F m^{-1}
	$(1/(36\pi)) \times 10^{-9}$ F m^{-1}
elementary charge	$e = 1.60 \times 10^{-19}$ C
the Planck constant	$h = 6.63 \times 10^{-34}$ J s
unified atomic mass constant	$u = 1.66 \times 10^{-27}$ kg
rest mass of electron	$m_e = 9.11 \times 10^{-31}$ kg
rest mass of proton	$m_p = 1.67 \times 10^{-27}$ kg
molar gas constant	$R = 8.31$ J K^{-1} mol^{-1}
the Avogadro constant	$N_A = 6.02 \times 10^{23}$ mol^{-1}
the Boltzmann constant	$k = 1.38 \times 10^{-23}$ J K^{-1}
gravitational constant	$G = 6.67 \times 10^{-11}$ 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	$p = \rho gh$
gravitational potential	$\phi = -\frac{Gm}{r}$
temperature	$T/\text{K} = T/{}^\circ\text{C} + 273.15$
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.	$v = v_0 \cos \omega t$ $= \pm\omega\sqrt{x_o{}^2 - x^2}$
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	$V = \frac{Q}{4\pi\varepsilon_o r}$
alternating current/voltage	$x = x_0 \sin \omega t$
magnetic flux density due to a long straight wire	$B = \frac{\mu_o I}{2\pi d}$
magnetic flux density due to a flat circular coil	$B = \frac{\mu_o NI}{2r}$
magnetic flux density due to a long solenoid	$B = \mu_o nI$
radioactive decay	$x = x_0 \exp(-\lambda t)$
decay constant	$\lambda = \frac{\ln 2}{t_{\frac{1}{2}}}$

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

1 A child of weight 330 N is at a point X at the top of a slide. The slide is at the edge of a swimming pool, as shown in Fig. 1.1.

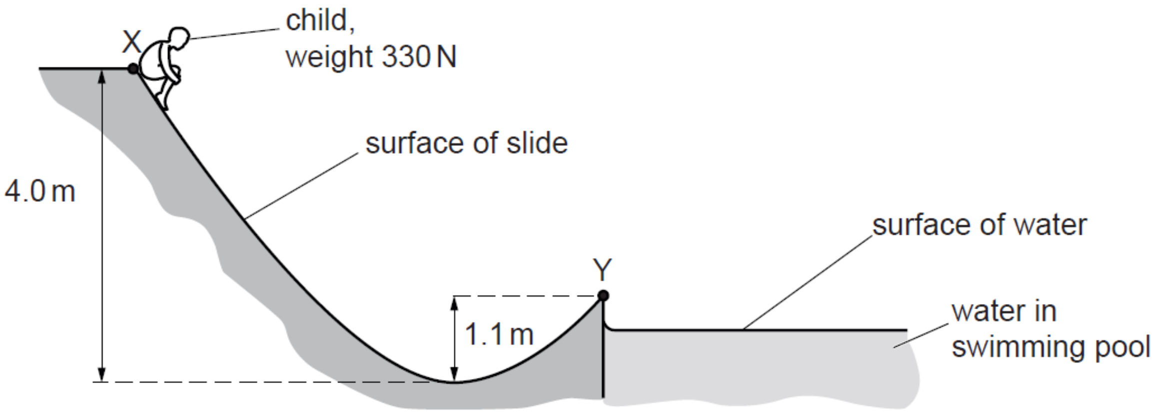

Fig. 1.1 (not to scale)

The child moves from rest to the lowest point of the slide that is a vertical distance of 4.0 m below X. The child continues moving towards point Y which is at the end of the slide and a vertical distance of 1.1 m above the lowest point. The kinetic energy of the child at Y is 540 J.

(a) An average frictional force of 52 N acts on the child when moving from X to Y. By considering changes of energy, determine the distance moved by the child from X to Y.

distance moved = ……………………………m [2]

(b) The child leaves the slide at point Y with a velocity that is at an angle of 41° to the horizontal. The path of the child through the air is shown in Fig. 1.2.

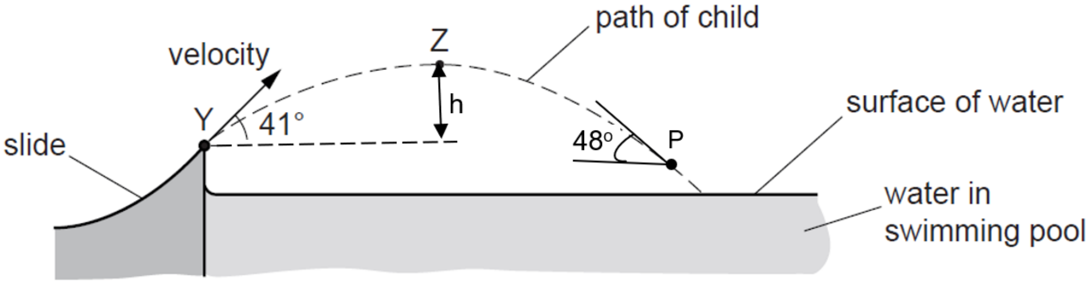

Fig. 1.2 (not to scale)

(i) Calculate the speed of the child at point Y.

speed = ……………………………m s^{-1} [1]

(ii) Show that the speed at point Z is 4.3 m s^{-1}.

[1]

(iii) At point P, along the path of the child, the child is moving at an angle of 48° to the horizontal. Air resistance is negligible.
For the child at point P, determine the vertical distance through which he has fallen from Y.

vertical distance = ……………………m [3]

(iv) On Fig. 1.3, sketch the variation of the kinetic energy of the child with his vertical height above point Y for the movement of the child from Y to Z.
Numerical values are not required.

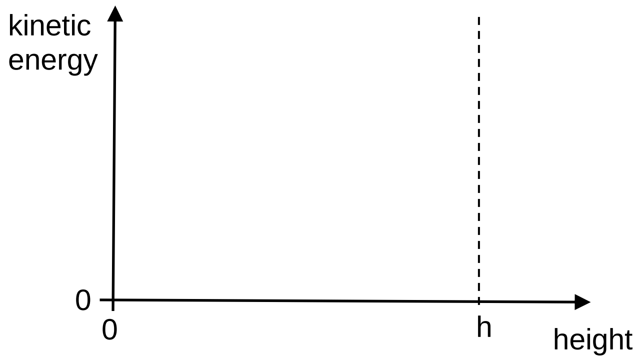

Fig. 1.3

[1]

(c) Use energy considerations to suggest why, if the child causes a large splash on hitting the swimming pool, he will be slowed down in a shorter distance than when no splash is produced.

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....

....

.... [2]

[Total: 10]

2 Two particles A and B, each of mass m, collide elastically, as illustrated in Fig. 2.1.

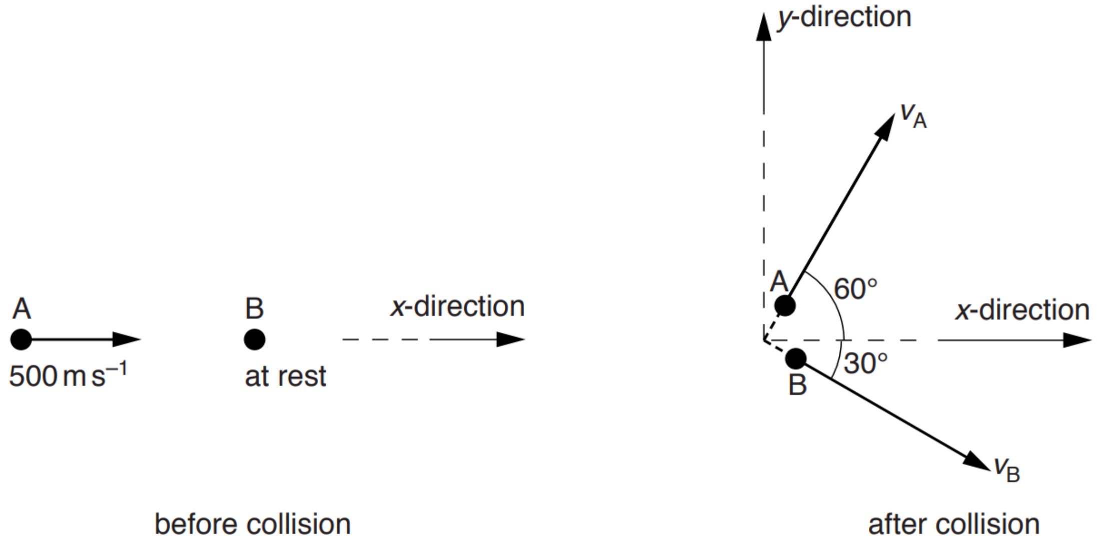

Fig. 2.1

The initial velocity of A is 500 m s^{-1} in the x-direction and B is at rest.

The velocity of A after collision is v_A at 60° to the x-direction. The velocity of B after the collision is v_B at 30° to the x-direction.

(a) **(i)** State an expression in terms of m, for the total initial momentum of A and B.

....[1]

(ii) State an expression in terms of m, v_A and v_B for the total momentum of A and B after the collision

1. in the x-direction,

....

2. in the y-direction.

....

[2]

(iii) By considering the components of momentum in the x and y directions, show that the magnitude of the final velocity of A, v_A is 250 m s^{-1}.

[2]

(b) Determine the magnitude and direction of the change in velocity of A with a diagram indicating the direction of the change in velocity.

magnitude of change in velocity = …………………………….. m s^{-1} [2]

direction of change in velocity = …………………………………[1]

[Total: 8]

3 **(a)** A hollow plastic sphere is attached at one end of a bar. The sphere is partially submerged in water and the bar is attached to a fixed vertical support by a pivot P, as shown in Fig. 3.1.

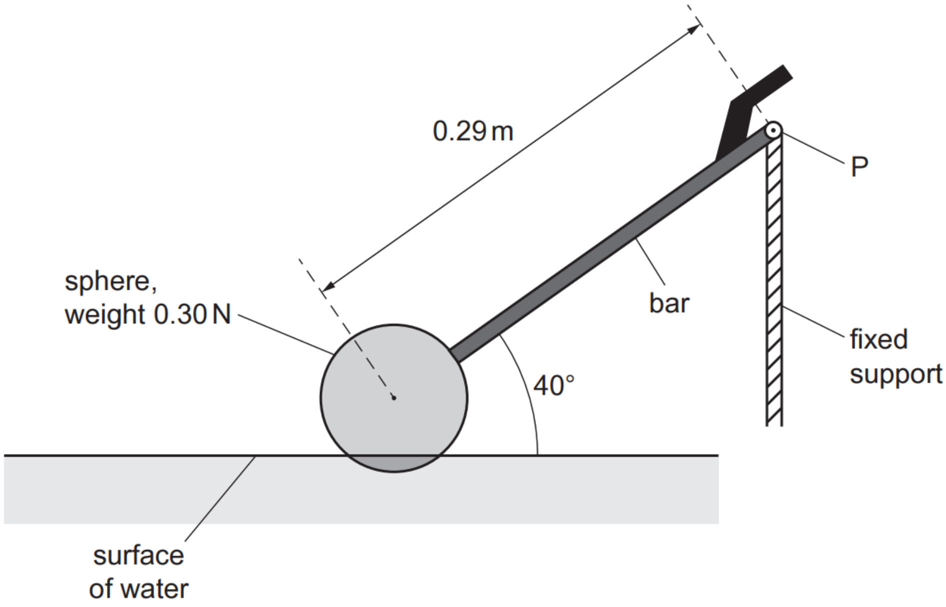

Fig. 3.1 (not to scale)

The sphere has weight 0.30 N. The distance from P to the centre of gravity of the sphere is 0.29 m. Assume that the weight of the bar is negligible.

Calculate the moment of the weight of the sphere about P.

moment = …………………………….N m [2]

(b) The system shown in Fig. 3.1 is part of a mechanism that controls the amount of water in a tank.

Water enters the tank and causes the sphere to rise. This results in the bar becoming horizontal. Fig. 3.2 shows the system in its new position.

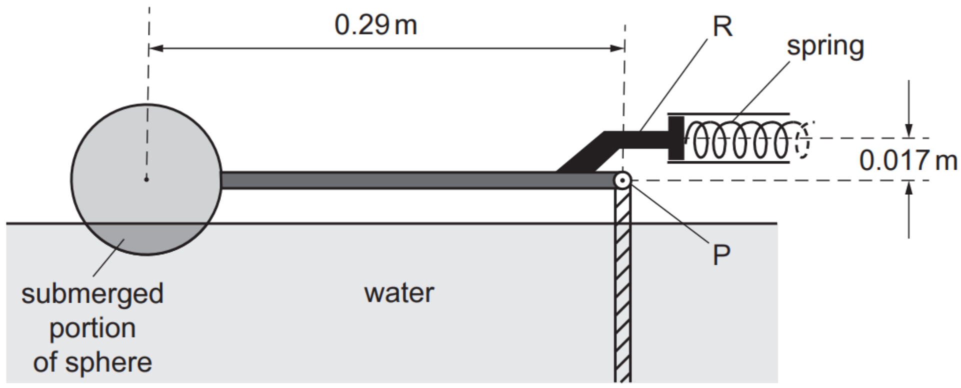

Fig. 3.2 (not to scale)

In this position the rod R exerts a force to compress a horizontal spring that controls the water supply to the tank. R is positioned at a perpendicular distance of 0.017 m above P.

The variation of the force F applied to the spring with compression x of the spring is shown in Fig. 3.3.

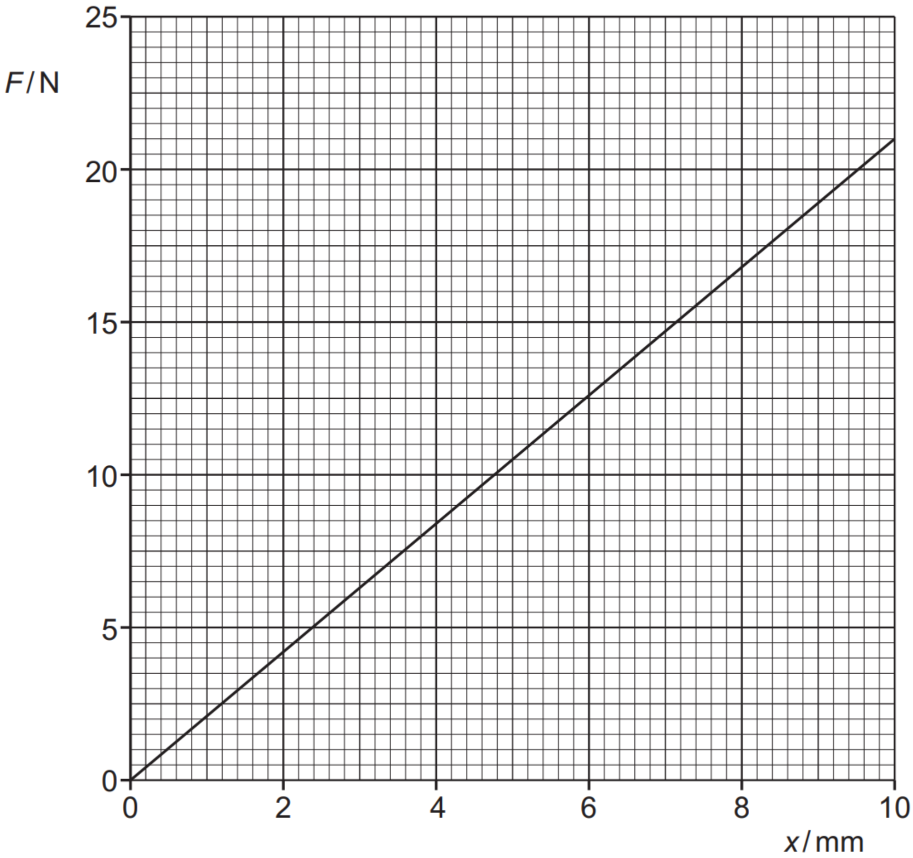

Fig. 3.3

(i) At the position shown in Fig. 3.2, the system is stationary and in equilibrium.

The radius of the sphere is 0.0480 m and 26.0% of the volume of the sphere is submerged.

The density of water is 1.00×10^{3} kg m^{-3}.

Show that the upthrust on the sphere is 1.18 N.

[1]

(ii) By taking moments about P, determine the force exerted on the spring by the rod R.

force = ……………………………… N [2]

(iii) Use Fig. 3.3 to calculate the elastic potential energy E_P of the compressed spring.

E_P = …………………………….J [2]

(c) When the sphere moves from the position shown in Fig. 3.1 to the position shown in Fig. 3.2, the upthrust on the sphere does work. Assume that resistive forces are negligible.

State and explain whether the work done by the upthrust is equal to the gain in elastic potential energy of the compressed spring.

……………………………………………………………………………………………………..

……………………………………………………………………………………………………..

…………………………………………………………………………………………….........[2]

[Total: 9]

4 **(a)** A large bowl is made from part of a hollow sphere.

A small spherical ball is placed inside the bowl and is given a horizontal speed. The ball follows a horizontal circular path of constant radius, as shown in Fig. 4.1.

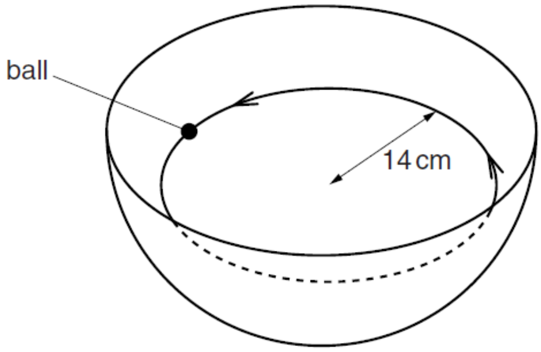

Fig. 4.1

The forces acting on the ball are its weight W and the normal reaction force R of the bowl on the ball, as shown in Fig. 4.2.

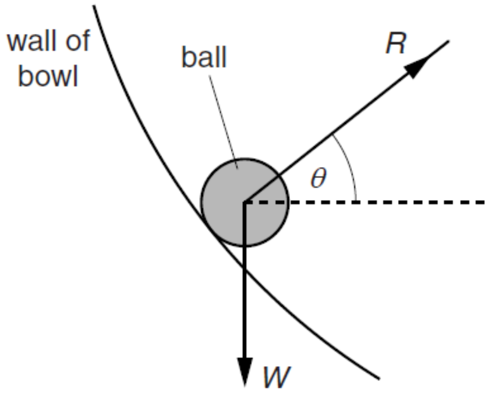

Fig. 4.2

The normal reaction force R is at an angle θ to the horizontal.

(i) By resolving the reaction force R into two perpendicular components, show that the resultant force F acting on the ball is given by the expression

$$W = F \tan \theta.$$

[2]

(ii) State the significance of the force F for the motion of the ball in the bowl.

……………………………………………………………………………………………..................

……………………………………………………………………………………………... [1]

(iii) The ball moves in a circular path of radius 14 cm. For this radius, the angle θ is 28°. Calculate the speed of the ball.

speed = …………………………….m s^{-1} [3]

(iv) Explain how the resultant force F acts on the ball to cause acceleration, but there is no change to the kinetic energy of the ball.

……………………………………………………………………………………………..................

……………………………………………………………………………………………..................

……………………………………………………………………………………………... [2]

(b) A smooth track loops around to form a vertical circle of diameter 0.40 m as shown in Fig. 4.3. Point Y is at the top of the track. A ball of mass 42 g is fired horizontally on the track. The initial speed at which the ball enters the loop at point X is 3.7 m s^{-1}.

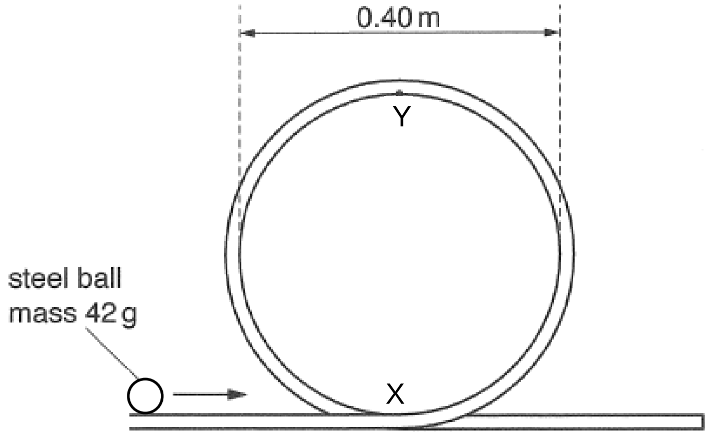

Fig. 4.3

(i) Determine whether the ball is in contact with the track at point Y. Show your working.

[3]

(ii) Suggest with a reason whether your conclusion in **(b)(i)** would be different for a ball of a greater mass moving with the same initial speed.

....

....[1]

[Total: 12]

5 **(a)** State what is meant by a *gravitational field*.

……………………………………………………………………………………………………..

……………………………………………………………………………………………………..

…………………………………………………………………………………………........[2]

(b) The gravitational potential ϕ at a distance r from an isolated point mass m is given by the expression

$$\phi = -\frac{GM}{r}$$

where G is the gravitational constant.

Explain why gravitational potential is negative.

……………………………………………………………………………………………………..

……………………………………………………………………………………………………..

……………………………………………………………………………………………………..

…………………………………………………………………………………………........[2]

(c) A moon of radius 1.25×10^6 m orbits a planet of radius 2.50×10^6 m. At a particular time, the distance between their centres is 28.8×10^6 m, as shown in Fig. 5.1.

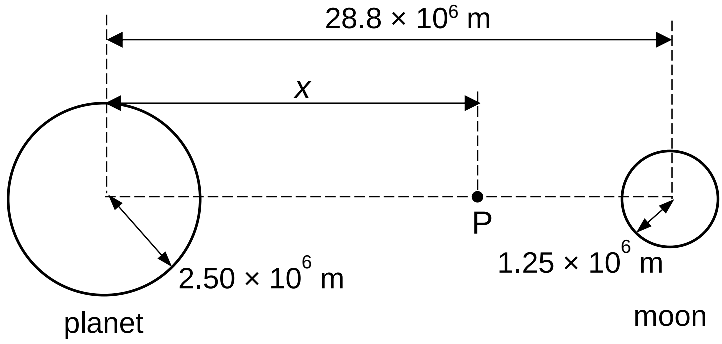

Fig. 5.1

Point P is a point along the line between the centres of the planet and the moon, at a variable distance x from the centre of the planet.

The variation with x of the gravitational potential ϕ at point P, for points between surfaces of the planet and the moon, is shown in Fig. 5.2.

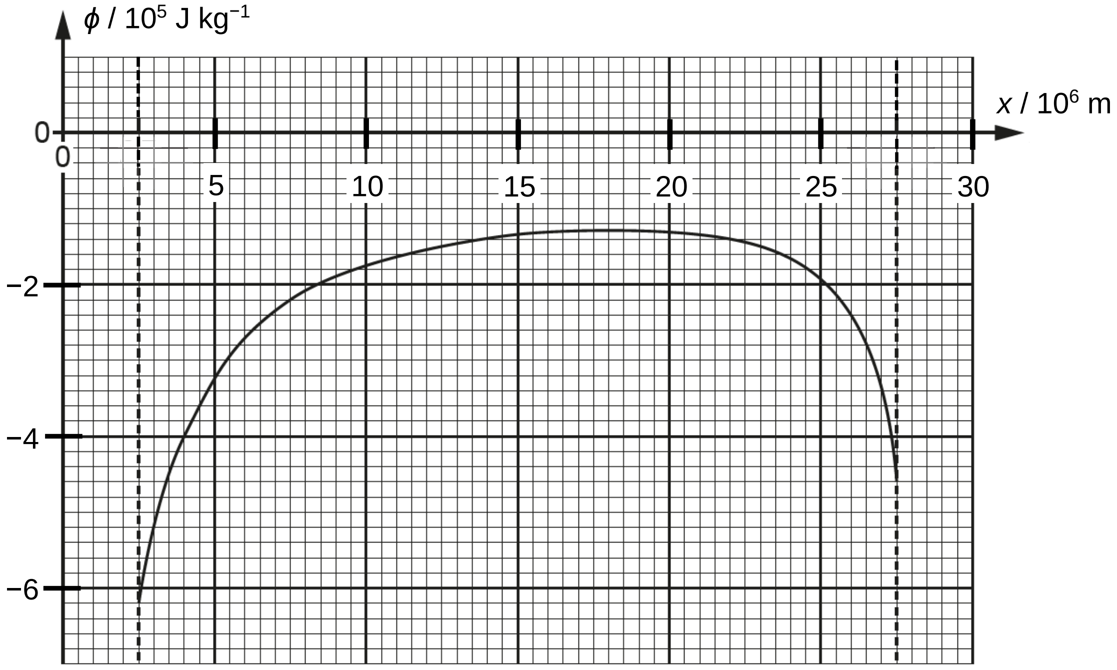

Fig. 5.2

At this particular time, a rock passes between the planet and the moon at a distance $x = 6.75 \times 10^6$ m. The rock has mass 3.97 kg and speed 550 m s^{-1}.

Use Fig. 5.2 to

(i) determine the resultant gravitational force from the planet and the moon acting on the rock,

resultant gravitational force = ……………………………. N

direction = ………………..……………………………… [3]

(ii) determine quantitatively whether the rock could travel off into space.
Explain your working.

[3]

[Total: 10]

6 An object is suspended from a spring that is attached to a fixed point as shown in Fig. 6.1.

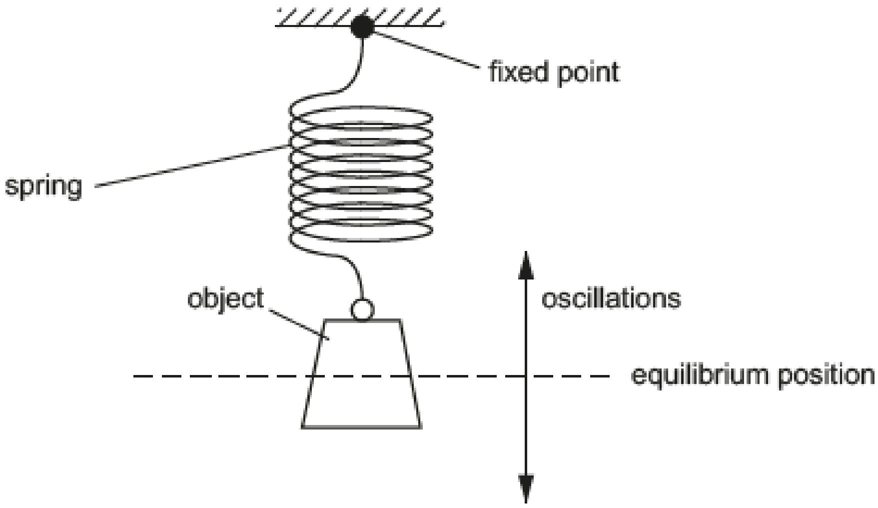

Fig. 6.1

The object oscillates vertically with simple harmonic motion about its equilibrium position.

(a) State the defining equation for simple harmonic motion. Identify the meaning of each of the symbols used to represent physical quantities.

……………………………………………………………………………………………………..

……………………………………………………………………………………………………..

……………………………………………………………………………………………………[2]

(b) The variation with displacement x from the equilibrium position of the velocity v of the object is shown in Fig. 6.2.

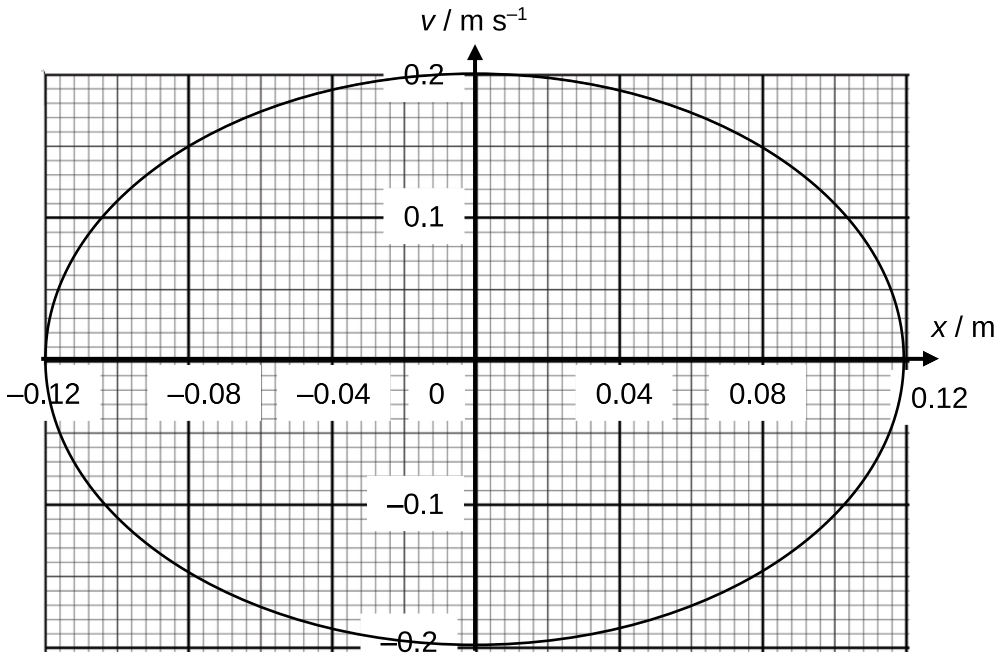

Fig. 6.2

The variation with x of the potential energy E_p of the oscillations of the object is shown in Fig. 6.3.

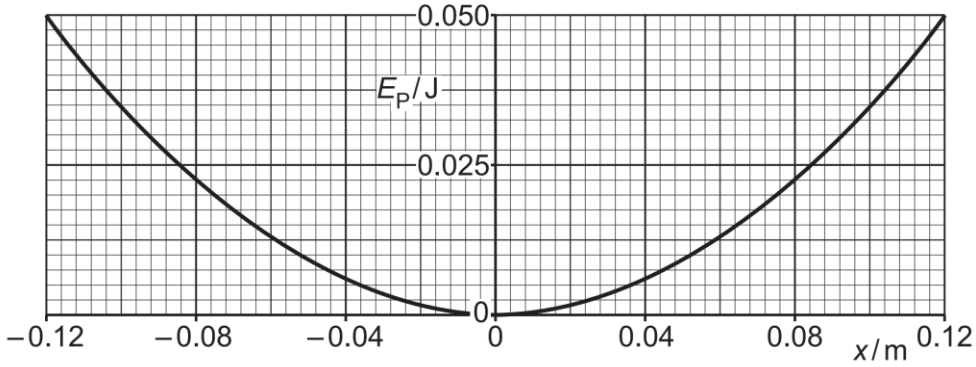

Fig. 6.3

Use Fig. 6.2 and Fig. 6.3 to:

(i) show that the angular frequency of the oscillations is 1.7 rad s^{-1},

[2]

(ii) determine the mass M of the object.

M = ………………………………….. kg [2]

(c) The oscillations of the object are now lightly damped.

(i) State what is meant by damping.

…………………………………………………………………………………………..

…………………………………………………………………………………………..

………………………………………………………………………………………… [2]

(ii) Assume that the damping does not change the angular frequency of the oscillations.

On Fig. 6.2, sketch the variation with x of v when the amplitude of the oscillations is 0.060 m. [2]

[Total: 10]

7 Fig. 7.1 shows transverse wave P moving to the left.

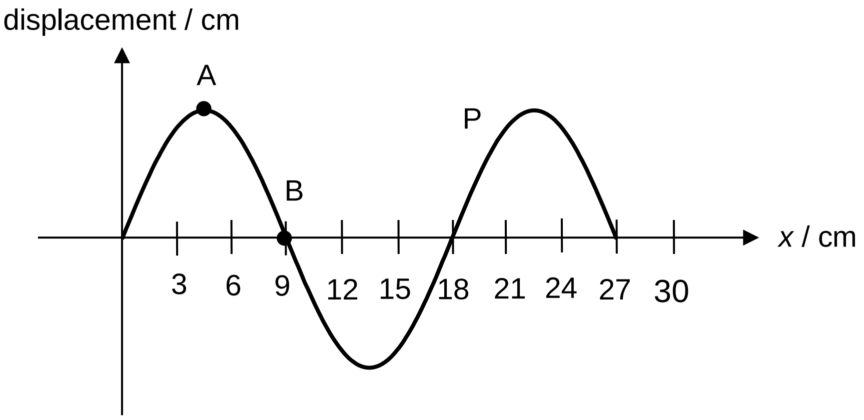

Fig. 7.1

(a) State the directions of the velocities of particles at points A and B.

....

.... [1]

(b) Fig. 7.2 shows the graph of the displacement of particle A with time.

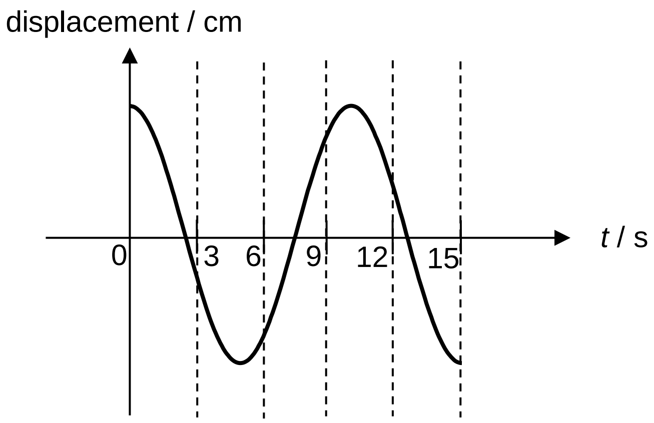

Fig. 7.2

Calculate the speed of wave P.

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

Fig. 7.3 shows transverse waves P and Q moving to the left.

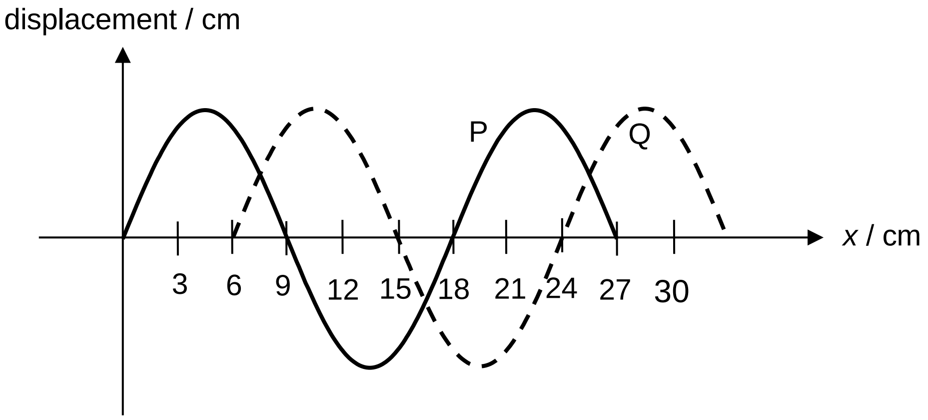

Fig. 7.3

(c) Determine the phase difference between waves P and Q.

phase difference = ... rad [2]

[Total: 5]

8 **(a)** A laser is used to produce an interference pattern on a screen, as shown in Fig. 8.1.

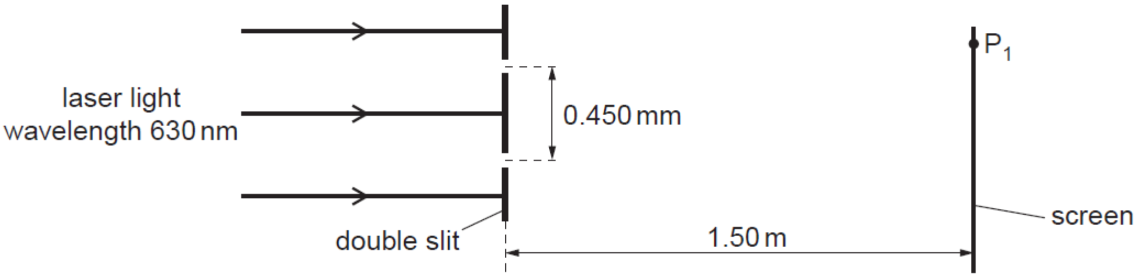

Fig. 8.1 (not to scale)

The laser emits light of wavelength 630 nm. The slit separation is 0.450 mm. The distance between the slits and the screen is 1.50 m. A maximum is formed at P_1.

Interference fringes are observed only when the light from the slits is coherent.

(i) Explain what is meant by *coherence*.

....

.... [1]

(ii) Explain how an interference maximum is formed at P_1.

....

....

.... [2]

(iii) Calculate the fringe separation.

fringe separation = ... m [2]

(b) Suggest changes to the appearance of the fringes when the amplitude of the waves incident on the double slits is increased by the same amount.

....

....

....

.... [3]

[Total: 8]

[Turn Over

9 A student investigates the trajectory of a small marble as it rolls off a surface which is inclined to the horizontal.

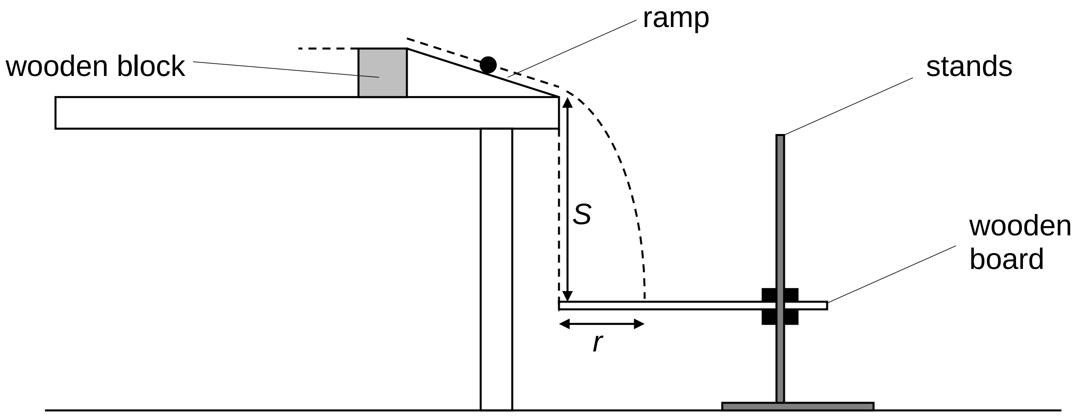

Fig. 9.1

Fig. 9.1 shows the path the marble follows after leaving the ramp. The student records the horizontal distance r and the vertical distance S of the marble's trajectory in Fig. 9.2.

S / m	r_1 / m	r_2 / m	$r = \frac{r_1 + r_2}{2}$ r / m	$\frac{S}{r}$
0.600	0.236	0.235	0.236	2.54
0.500	0.216	0.217	0.217	2.30
0.400	0.197	0.198	0.198	2.02
0.300	0.164	0.163	0.164	1.83
0.200	0.129	0.131		
0.100	0.090	0.088		

Fig. 9.2

Theory suggests that r and S are related by the expression

$$S = \frac{P}{Q}r + \frac{k}{Q^2}r^2$$

where k, P and Q are constants and $k = 4.9 \text{ m s}^{-2}$.

(a) Complete the table in Fig.9.2. [1]

(b) Plot the two points calculated in **(a)** on Fig. 9.3 and draw the best fit line. [2]

(c) Comment on any anomalous data or results you may have obtained. Explain your answer.

....

.... [1]

(d) Determine the gradient and *y*-intercept of the graph.

gradient = ……………………………………………

y-intercept = ……………………………………[2]

(e) Determine the values of *P* and *Q*.

P = ……………………………………………

Q = ……………………………………[2]

[Total: 8]

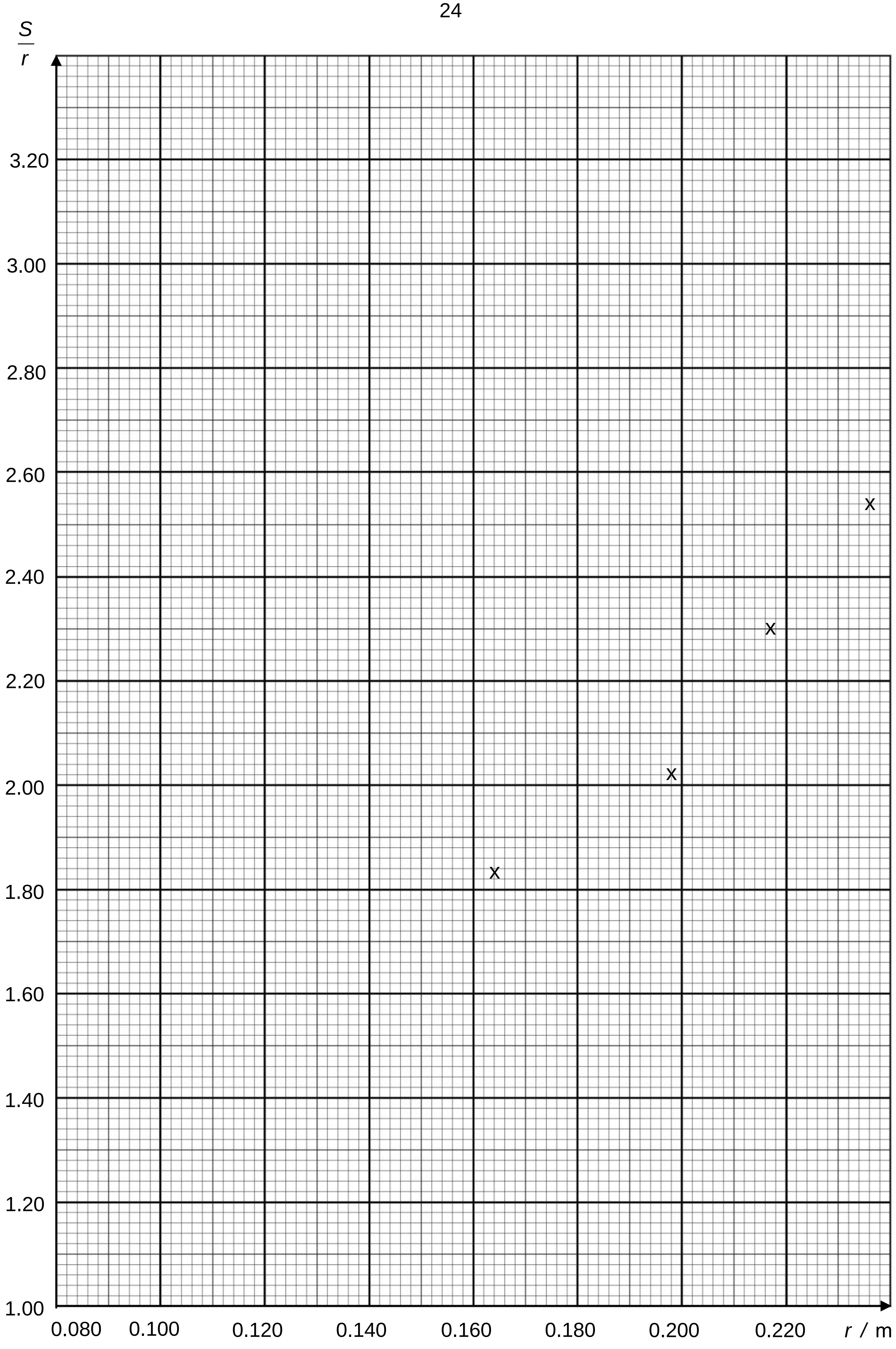
S/r
3.20
3.00
2.80
2.60
2.40
2.20
2.00
1.80
1.60
1.40
1.20
1.00
0.080
0.100
0.120
0.140
0.160
0.180
0.200
0.220
r / m

Fig.9.3