H

# NATIONAL JUNIOR COLLEGE

## SENIOR HIGH 1 PROMOTIONAL EXAMINATION

Higher 2

CANDIDATE NAME

SUBJECT CLASS

REGISTRATION NUMBER

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**PHYSICS** **9749/02**

Paper 2 Structured Questions
Candidate answers on the Question Paper.

**29 September 2021**
**2 hours**

No Additional Materials are required.

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**READ THE INSTRUCTION FIRST**
Write your subject class, registration number and name on all the work you hand in.
Write in dark blue or black pen on both sides of the paper.
You may use a 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.

Answers **all** questions.

At the end of the examination, fasten all your work securely together.
The number of marks is given in brackets [ ] at the end of each question or part question.

| For Examiner's Use | |
|---|---|
| **1** | **/ 6** |
| **2** | **/ 7** |
| **3** | **/ 7** |
| **4** | **/ 7** |
| **5** | **/ 13** |
| **6** | **/ 10** |
| **7** | **/ 10** |
| **8** | **/ 20** |
| **Total (80m)** | |

This document contains **23** printed pages and **01** blank page.

**Data**

| | |
|---|---|
| speed of light in free space | $c = 3.00 \times 10^{8}\,\mathrm{m\,s^{-1}}$ |
| permeability of free space | $\mu_0 = 4\pi \times 10^{-7}\,\mathrm{H\,m^{-1}}$ |
| permittivity of free space | $\varepsilon_0 = 8.85 \times 10^{-12}\,\mathrm{F\,m^{-1}}$ |
| | $(1/(36\pi)) \times 10^{-9}\,\mathrm{F\,m^{-1}}$ |
| elementary charge | $e = 1.60 \times 10^{-19}\,\mathrm{C}$ |
| the Planck constant | $h = 6.63 \times 10^{-34}\,\mathrm{J\,s}$ |
| unified atomic mass constant | $u = 1.66 \times 10^{-27}\,\mathrm{kg}$ |
| rest mass of electron | $m_e = 9.11 \times 10^{-31}\,\mathrm{kg}$ |
| rest mass of proton | $m_p = 1.67 \times 10^{-27}\,\mathrm{kg}$ |
| molar gas constant | $R = 8.31\,\mathrm{J\,K^{-1}\,mol^{-1}}$ |
| the Avogadro constant | $N_A = 6.02 \times 10^{23}\,\mathrm{mol^{-1}}$ |
| the Boltzmann constant | $k = 1.38 \times 10^{-23}\,\mathrm{J\,K^{-1}}$ |
| gravitational constant | $G = 6.67 \times 10^{-11}\,\mathrm{N\,m^{2}\,kg^{-2}}$ |
| acceleration of free fall | $g = 9.81\,\mathrm{m\,s^{-2}}$ |

**Formulae**

| | |
|---|---|
| uniformly accelerated motion | $s = ut + \frac{1}{2}at^2$<br>$v^2 = u^2 + 2as$ |
| work done on / by a gas | $W = p\Delta V$ |
| hydrostatic pressure | $p = \rho gh$ |
| gravitational potential | $\phi = -Gm/r$ |
| temperature | $T/\mathrm{K} = T/{}^\circ\mathrm{C} + 273.15$ |
| pressure of an ideal gas | $p = \frac{1}{3}\frac{Nm}{V} < c^2 >$ |
| 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. | $v = v_0 \cos\omega t$<br>$= \pm\omega\sqrt{x_0^2 - x^2}$ |
| 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 | $\lambda = \frac{\ln 2}{t_{\frac{1}{2}}}$ |

**[Turn over**

**1** A small wooden block is held stationary on a rough slope at a distance of 2.0 m from the bottom of the slope. At time $t$ = 0, it is projected up the slope with an initial speed of 5.0 m $s^{-1}$ as shown in Fig. 1.1.

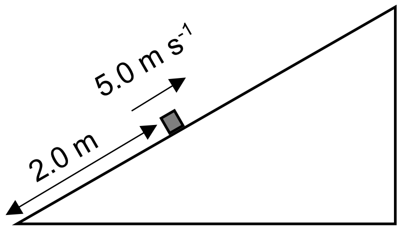


**Fig. 1.1**

The deceleration of the block is 6.0 m $s^{-2}$.

**(a)** Show that the distance travelled by the block, relative to its initial position at t = 0, before it comes to rest momentarily at the top of the slope is 2.1 m.

[1]

**(b)** Determine the time taken for the block to travel to the top of the slope.

time = ...................... s [1]

**(c)** After reaching the top of the slope, the block starts to slide down with an acceleration of 3.8 m $s^{-2}$.

Determine

**(i)** the time taken for the block to travel from the top of the slope to the bottom of the slope.

$t$ = ........................... s [1]

**(ii)** the speed of the block on reaching the bottom of the slope.

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

**(d)** On Fig. 1.2, sketch the variation with time, of the displacement of the block (relative to the start point) for the entire motion starting from $t$ = 0 to the instant the block reaches the bottom of the slope. Take displacement upslope to be positive.

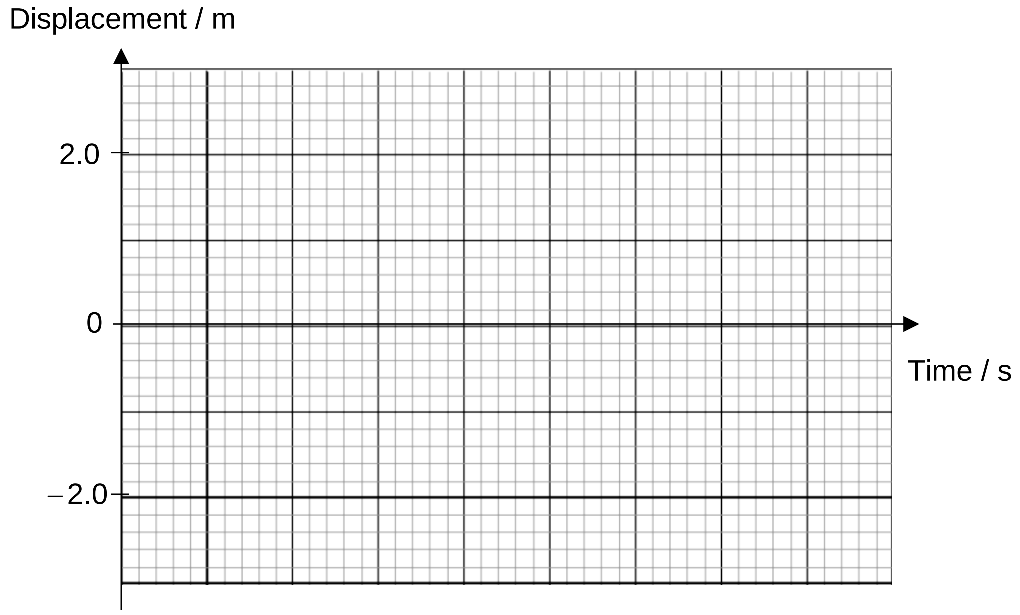


**Fig. 1.2**

[2]

**2** **(a)** Derive, from the definitions of pressure and density, the equation for pressure due to a column of liquid is given by

$$p = h\rho g$$

[3]

**(b)** Fig. 2.1 shows a simplified catapult used to hurl projectiles a long way.

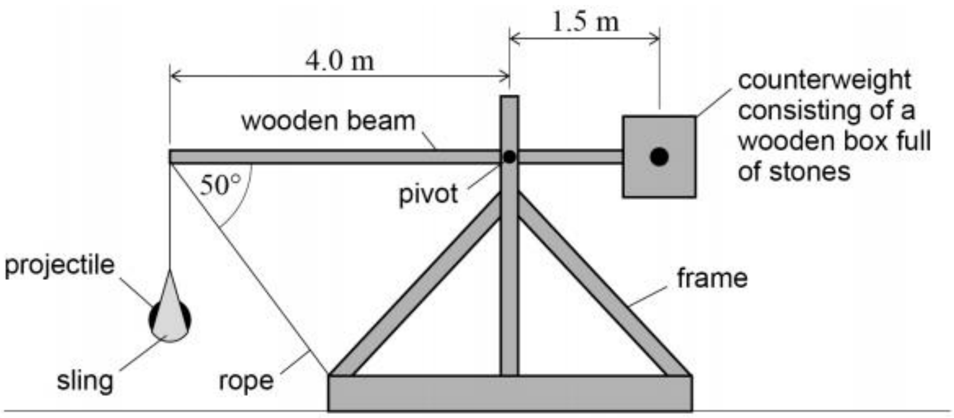


**Fig. 2.1**

The counterweight is a wooden box full of stones to one end of the uniform beam. The projectile, usually a large rock, is in a sling hanging vertically from other end of the beam. The weight of the sling is negligible.

The beam is held horizontal by a rope attached of the frame.

The stones and the wooden box in the counterweight have a total mass of 1000 kg, the mass of the beam is 500 kg and the projectile weighs 250 N.

Calculate the tension in the rope. Explain your working clearly.

tension = ...................................... N [4]

**3** **(a)** Two masses, 2.5 kg and 4.5 kg, are connected by an inextensible cord that runs over a frictionless and massless pulley as shown in Fig. 5.1.

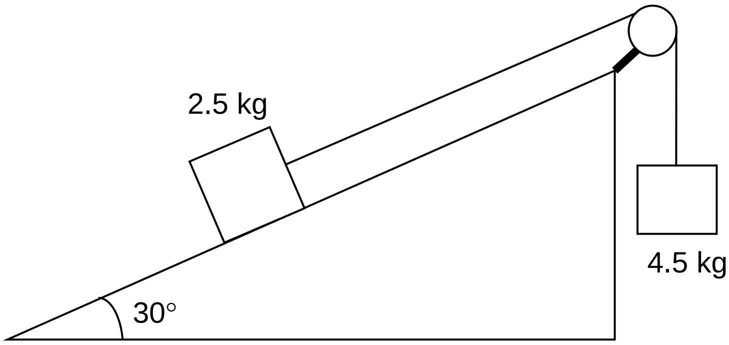


**Fig. 5.1**

Both masses are released from rest and they moved a distance of 0.50 m.

**(a)** Determine the final speed of the system after travelling 0.50 m.

speed = .................... m $s^{-1}$ [3]

**(b)** The power of the engine of a sports car of mass 1500 kg is 200 kW in normal driving mode. It can cruise at speed of 90 km $h^{-1}$.

**(i)** Show that the force that is delivered by the engine to the car is 8000 N.

[2]

**(ii)** When the car suddenly switches to turbocharging mode, the power doubles. Assuming the resistive force remains the same at that instant, determine the acceleration.

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

**4** A circus performer is riding his motorcycle with uniform speed such that its period is 20.0 s in a horizontal circle of radius 83 m on the inner surface of a cylindrical wall, as shown in Fig. 4.1.

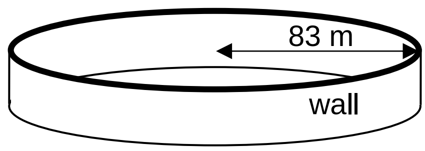


**Fig. 4.1**

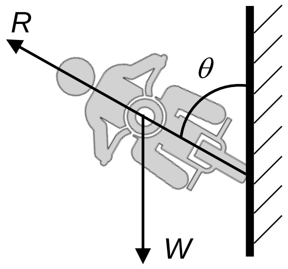


**Fig. 4.2**

The orientation of his motorcycle is shown in Fig. 4.2. The two forces acting on the motorcycle-man system are the reaction force $R$ acting at an angle $\theta$ with the vertical and the weight $W$.

**(a)** $R$ is the resultant of two forces. They are perpendicular to each other. State the two forces.

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

**(b)** One of forces in (a) points to the left of the Fig 4.2, show that this force is

$$F = 0.835\ W$$

[2]

**(c)** Hence, show that the angle $\theta$ is 39.9°

[3]

**(d)** Explain why is it not possible for $\theta$ to be 90°.

.....................................................................................................................................

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

**[Turn over**

**5** **(a)** Define *simple harmonic motion.*

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

**(b)** Fig. 5.1 shows the variation of amplitude of oscillation of a system with the frequency of an external source. The system is critically damped.

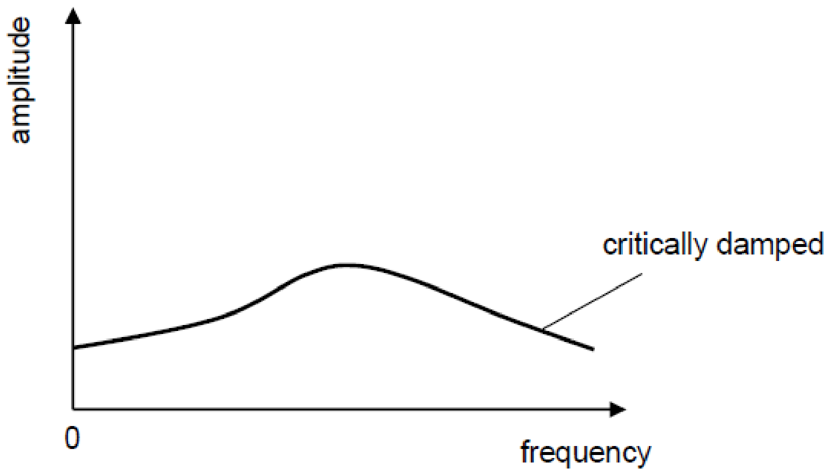


**Fig. 5.1**

**(i)** State the name of the phenomenon illustrated in Fig. 5.1.

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

**(ii)** Sketch, on Fig. 5.1, the variation of the amplitude with frequency for the same system that is lightly damped.

[3]

**(c)** A motor car with a defective suspension system is driven at a steady speed over a series of road bumps. The road surface may be assumed to vary sinusoidally. At this speed the car's vertical oscillation becomes very large.

The following data is available.

Mass of car with passengers = 1850 kg

Mass of passengers = 320 kg

Vertical rise of car when passengers get out of car = 1.5 cm

Separation of two adjacent peaks of the road surface = 13 m.

The natural frequency *f* of the car is given by the following expression.

$$f = \frac{1}{2\pi}\sqrt{\frac{k}{m}}$$

where *k* is the spring constant and *m* is the mass of car and passengers.

**(i)** Determine the natural frequency of the car.

natural frequency = ………………… Hz [2]

**(ii)** Explain why the vertical oscillations of this car becomes very large.

..........................................................................................................................

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..........................................................................................................................

.......................................................................................................................... [3]

**(iii)** Determine the speed of the car when the vertical oscillations is very large.

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

**6** **(a)** A wave of frequency $f$ and wavelength $\lambda$ has speed $v$.

Using the definition of speed, deduce the equation $v = f\lambda$.

[2]

**(b)** Fig. 6.1 shows the variation with time of the displacements $X_A$ and $X_B$ at a point P due to sinusoidal sound waves A and B.

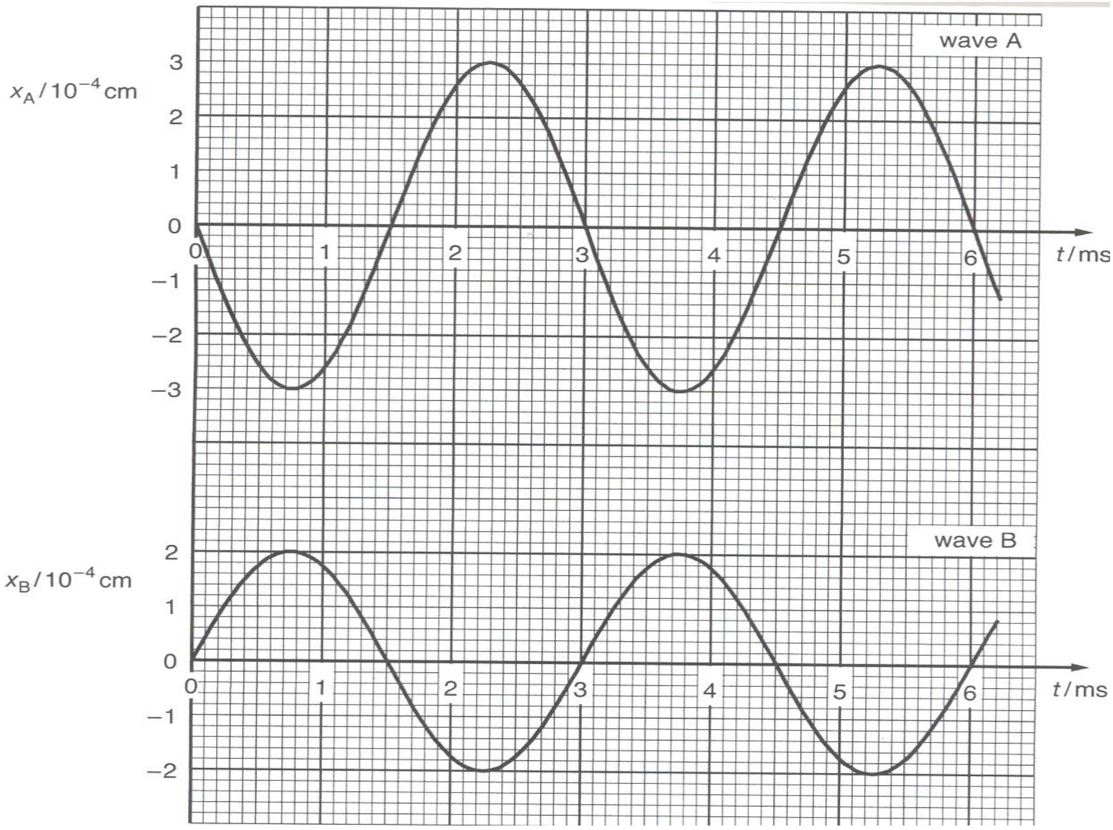



**Fig. 6.1**

**(i)** By reference to Fig. 6.1, state one similarity and one difference between these two waves.

**Similarity:** ……………………………………………………………………………………………...

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

**Difference:**……………………………………………………………………………………………...

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

**(ii)** The intensity of wave A alone at point P is $I$ .

**1.** Show that the intensity of wave B alone at P is $\frac{4}{9}I$ .

[1]

**[Turn over**

**2.** Calculate the resultant intensity, in terms of $I$, of the two waves at point P.

Resultant intensity = ………………………………… [2]

**(iii)** Determine the resultant displacement for the two waves at point P at time t = 4.0 ms.

Resultant displacement = ………………………………… cm [1]

**(c)** A 10 W light bulb emits visible light uniformly in all directions. A person can see the light from a distance of $20 \times 10^3$ m on a dark night.

If the area of the pupil in the person's eye is 0.50 $cm^2$, calculate the power of light received by one eye.

power = ………………………………… W [2]

**7** A stationary sound wave is formed in a tube with one closed end as illustrated in Fig. 7.1.

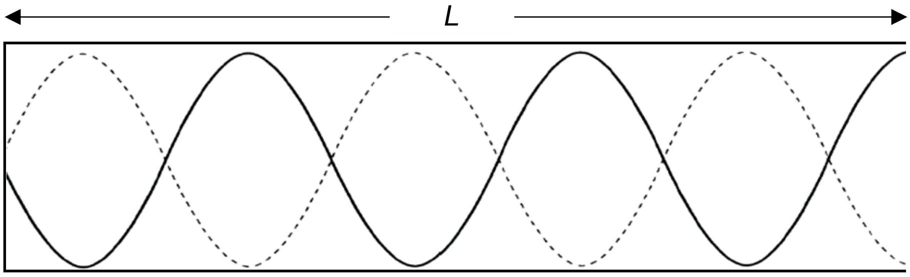



**Fig. 7.1**

The length of the tube is $L$.

The solid line represents the wave at time $t = 0$ and the dotted line represents the wave at time $t = \frac{T}{2}$, where $T$, the period of the wave, is $5.0 \times 10^{-4}$ s. The speed of sound is 330 m $s^{-1}$.

**(a)** Calculate

**(i)** the frequency of the sound wave.

frequency = ........................ Hz [1]

**(ii)** the wavelength of the sound wave.

wavelength = ......................... m [1]

**(iii)** the length $L$ of the tube.

length = ......................... m [2]

**(iv)** On Fig. 7.1, label a point with the letter "A" where the amplitude of vibration of the air molecules is maximum.

[1]

**(b)** On Fig. 7.1, sketch the shape of the stationary wave when

**(i)** $t = \frac{T}{4}$. Label this wave X. [1]

**(ii)** $t = \frac{7T}{8}$. Label this wave Y. [2]

**[Turn over**

**(c)** Determine another resonant frequency that is higher than the one shown in Fig. 7.1.

frequency = ..................... Hz [2]

**8** When Ball 1 of mass $m_1$ and velocity $u$ collides elastically with a stationary Ball 2 of mass $m_2$, the motion of the balls after the collision depends on the direction of impact. This can be solved completely by applying the laws of conservation of energy and linear momentum.

Fig. 8.1 shows the oblique collision of the two balls.

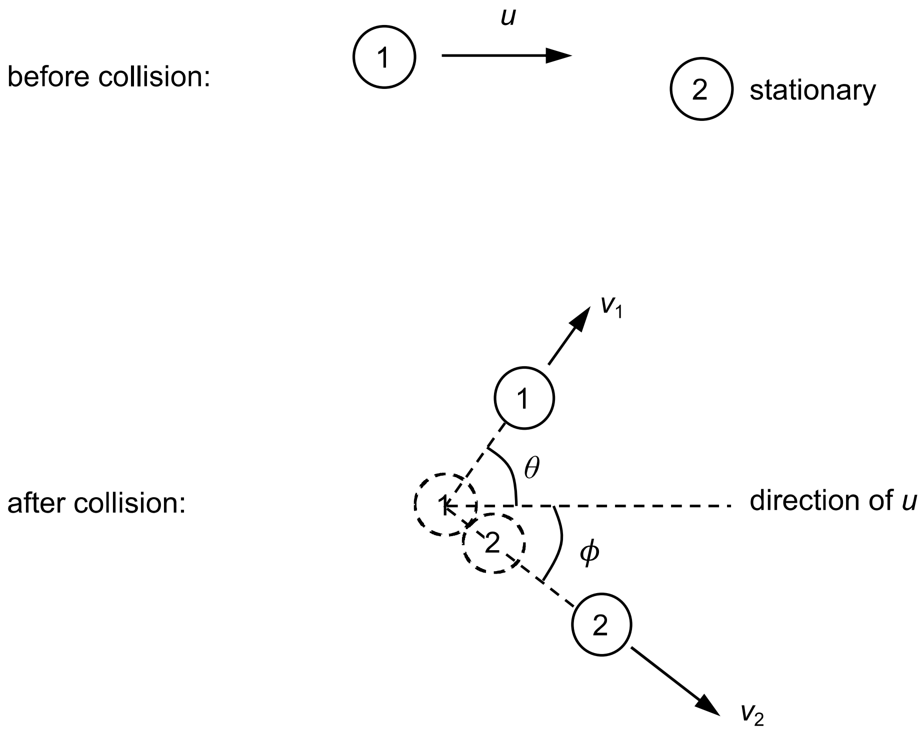



**Fig. 8.1**

After the collision, Ball 1 acquires velocity $v'$ at angle $\theta$ to $u$ and Ball 2 acquires velocity $v$ at angle $\phi$ to $u$.

The variation with cos $\phi$ of the ratio $\frac{v}{u}$ of Ball 2 for the different ratios of the masses $\frac{m_2}{m_1}$ of Ball 1 and Ball 2 are shown in Fig. 8.2.

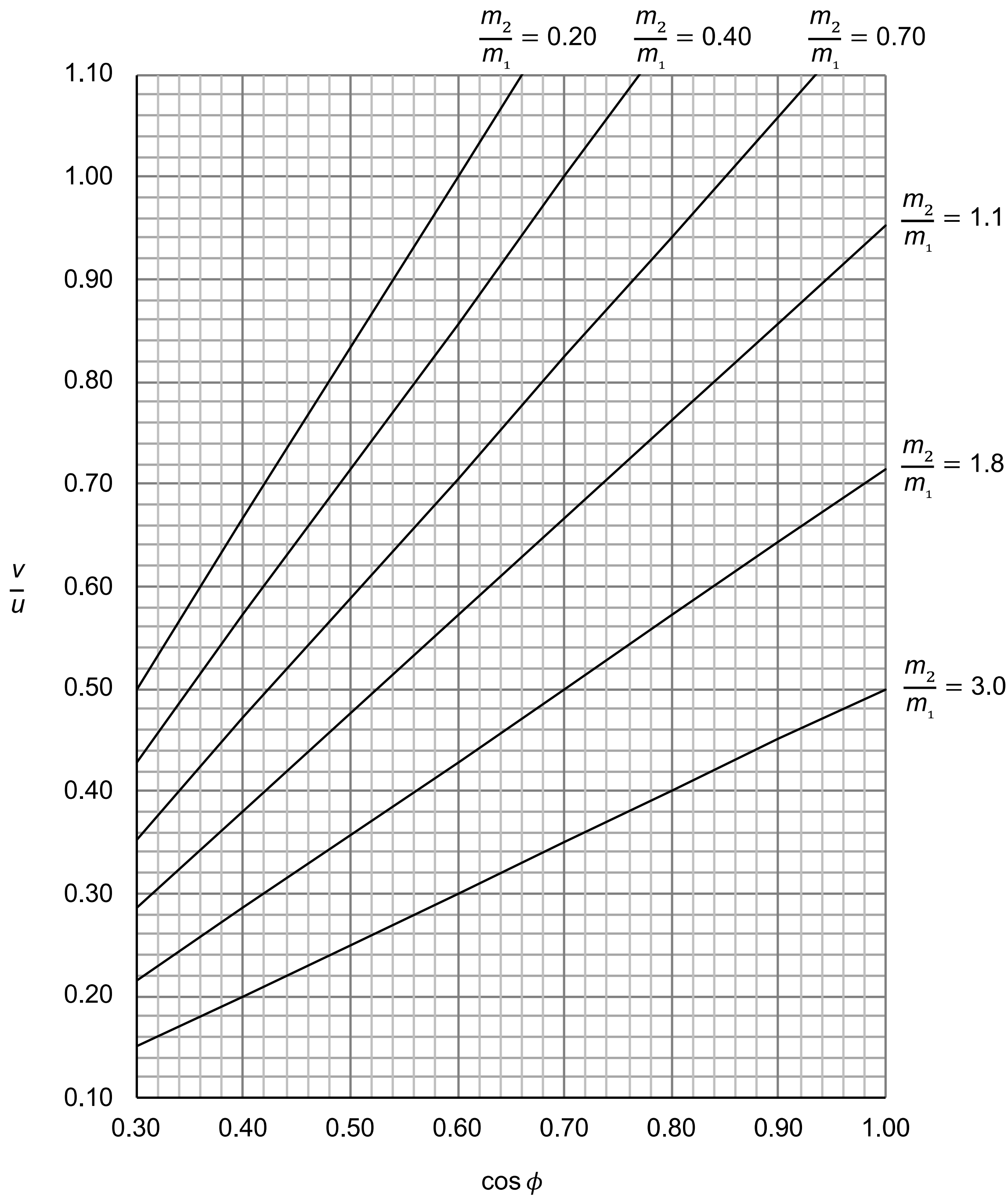



**Fig. 8.2**

**(a)** The graphs in Fig. 8.2 are described by the expression

$$\frac{v}{u} = k \cos \phi \qquad \text{(equation 8.1)}$$

where $k$ is a constant.

Without drawing a graph, use the data for $\frac{m_2}{m_1} = 0.70$ to verify the expression.

[2]

**(b)** The constant $k$ in **(a)** is related to the ratio of the masses by

$$\frac{2}{k} = \alpha \frac{m_2}{m_1} + \beta \qquad \text{(equation 8.2)}$$

where $\alpha$ and $\beta$ are integers.

Fig. 8.3 shows the tables of values of $\frac{m_2}{m_1}$, $k$ and $\frac{2}{k}$.

| $\frac{m_2}{m_1}$ | $k$ | $\frac{2}{k}$ |
|---|---|---|
| 0.20 | 1.67 | 1.20 |
| 0.40 | 1.43 | 1.40 |
| 0.70 | 1.17 | 1.71 |
| 1.1 | | |
| 1.8 | 0.714 | 2.80 |
| 3.0 | 0.500 | 4.00 |

**Fig. 8.3**

**(i)** Complete Fig. 8.3 for $\frac{m_2}{m_1} = 1.1$

[1]

**(ii)** Fig. 8.4 is a graph of some of the data of Fig. 8.3.

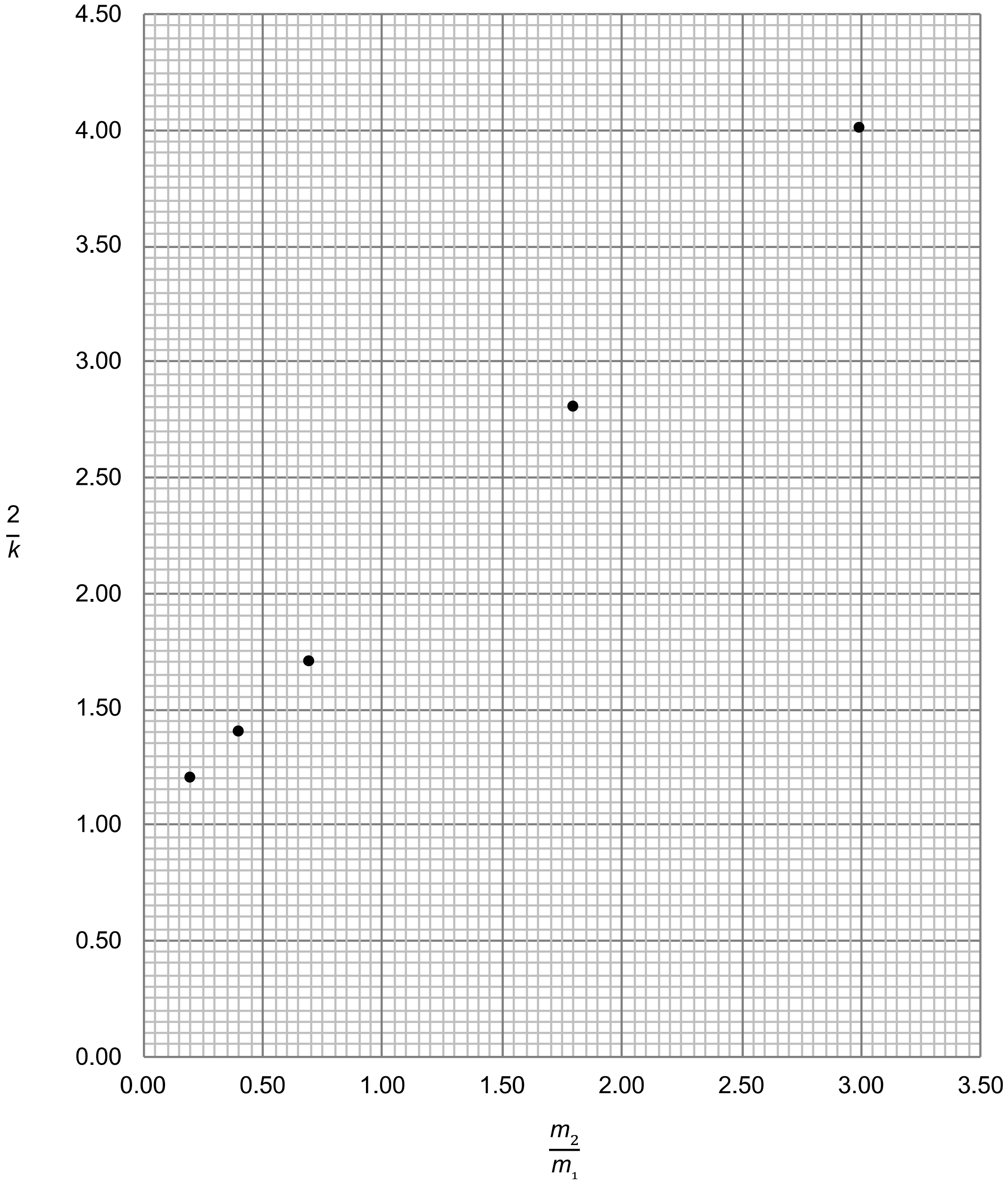



**Fig. 8.4**

On Fig. 8.4,

**1.** plot the point corresponding to $\dfrac{m_2}{m_1} = 1.1$,

**2.** draw the line of best fit for all the points.

[2]

**(iii)** Determine $\alpha$ and $\beta$ from Fig. 8.4.

$\alpha =$ ……………………………………

$\beta =$ ……………......……………… [4]

**(iv)** By using equation 8.1 and equation 8.2 in **(a)** and **(b)**, write down an expression for the speed $v$ of Ball 2 in terms $u$, $\frac{m_2}{m_1}$ and cos $\phi$.

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

**(c)** Fig. 8.5 shows Ball 1 colliding head–on ($\phi = 0°$) with the stationary Ball 2.

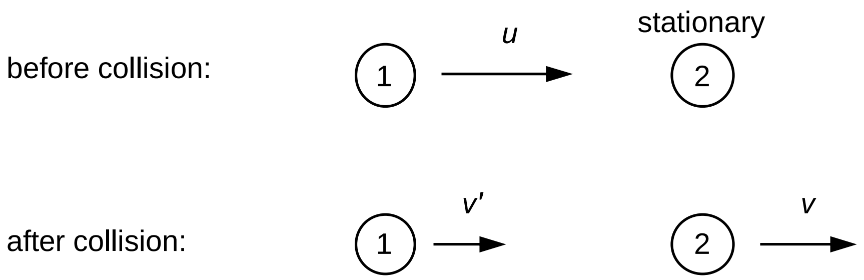
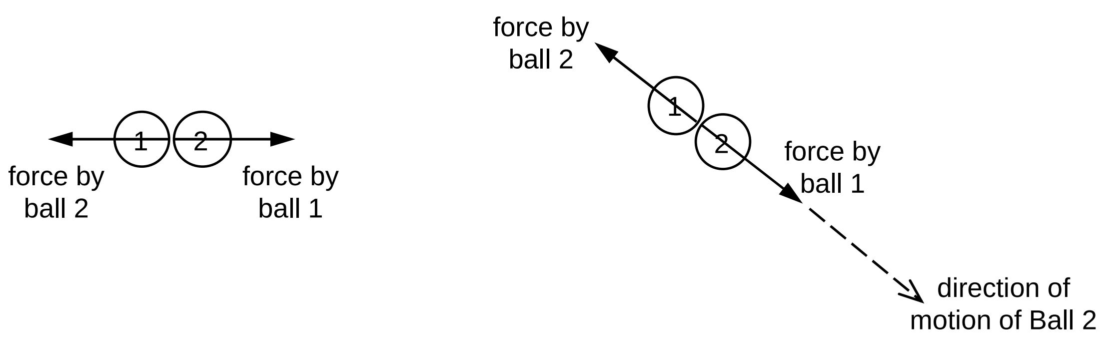



**Fig. 8.5**

By using information in **(a)** and **(b)**, show that $v = u$ and $v' = 0$ when the masses of the balls are equal.

[2]

**(d)** During the time of impact, each ball exerts a normal force on the other. The normal forces on each ball are equal and oppositely directed. Through the action of these forces, momentum is exchanged between the two balls. Fig. 8.6 shows these forces when the balls collide head–on or obliquely.




**(a)** **(b)**

**Fig. 8.6**

Fig. 8.6(a) shows the forces lying along the line connecting the centres of the balls during a head–on collision.

Fig. 8.6(b) shows the forces parallel to the velocity of Ball 2 in an oblique collision.

**(i)** Explain why in a head–on collision, shown in Fig. 8.6(a), the direction of the velocities of the balls before and after the collision lie on the line connecting the centres of the balls.

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

**(ii)** Fig 8.7 shows the instant just before the oblique collision between two balls.

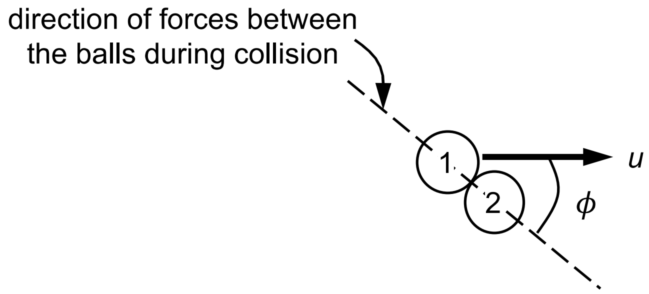


**Fig. 8.7**

The direction of the forces experienced by the balls during the collision is shown in the figure at angle $\phi$ to the initial velocity $u$ of Ball 1.

**1.** Write down the component of the initial velocity $u$, in terms of $u$ and $\phi$,

along the direction of the forces: ……………………………………………………..........

perpendicular to the direction of the forces: ……………………………………........…[1]

**2.** Explain why the velocities of Ball 1 and Ball 2 after the collision are perpendicular when the masses of the balls are equal.

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

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…………………………………………………………………………………….................. [3]

**3.** Explain whether your answer to **(d)(ii)2.** will be different if the masses of the balls are not equal.

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

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

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