UNIVERSITY OF CAMBRIDGE

ENGINEERING ADMISSIONS ASSESSMENT

D564/12

2023

60 minutes

SECTION 2

INSTRUCTIONS TO CANDIDATES

Please read these instructions carefully, but do not open this question paper until you are told that you may do so. This paper is Section 2 of 2.

A separate answer sheet is provided for this paper. Please check you have one. You also require a soft pencil and an eraser.

Please complete the answer sheet with your candidate number, centre number, date of birth, and name.

This paper contains 20 multiple-choice questions. There are no penalties for incorrect responses, only marks for correct answers, so you should attempt **all** 20 questions. Each question is worth one mark.

For each question, choose the **one** option you consider correct and record your choice on the separate answer sheet. If you make a mistake, erase thoroughly and try again.

You **must** complete the answer sheet within the time limit.

You can use the question paper for rough working, but **no extra paper** is allowed. Only your responses on the answer sheet will be marked.

Dictionaries and calculators are NOT permitted.

Please wait to be told you may begin before turning this page.

This question paper consists of 21 printed pages and 3 blank pages.

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1 A block of weight W slides down a rough plane at a constant speed.

The plane is at an angle of 30° to the horizontal.

The block is now pulled by a force of $3W$ acting parallel to and up the plane. The block has constant acceleration.

Which expression gives the acceleration of the block?

(gravitational field strength = g)

A $2g$

B $\frac{5}{2}g$

C $3g$

D $\left(3 - \sqrt{3}\right)g$

E $\left(3 - \frac{1}{\sqrt{3}}\right)g$

F $\left(3 - \frac{\sqrt{3}}{2}\right)g$

G $\left(3 - \frac{2}{\sqrt{3}}\right)g$

2 The speed v of an object moving in a straight line is related to time t by the equation

$$v = kt^2$$

where k is a constant.

At $t = 10\,\text{s}$ the speed of the object is $48\,\text{m s}^{-1}$ and the resultant force on the object is 24 N.

What is the mass of the object?

A 0.15 kg

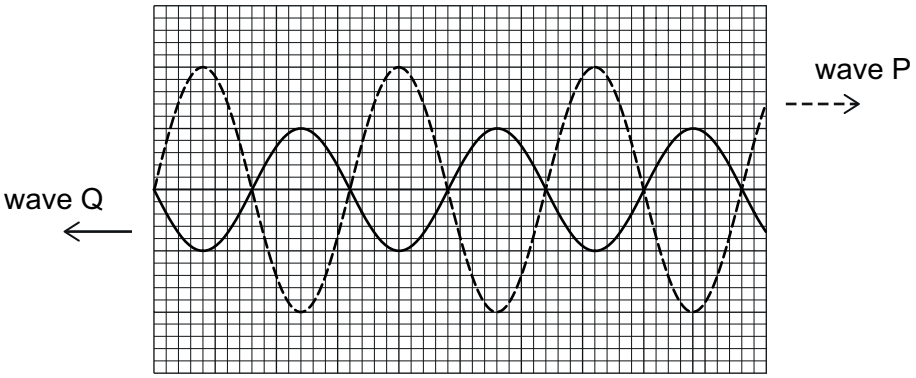
B 0.40 kg

C 1.2 kg

D 2.5 kg

E 6.7 kg

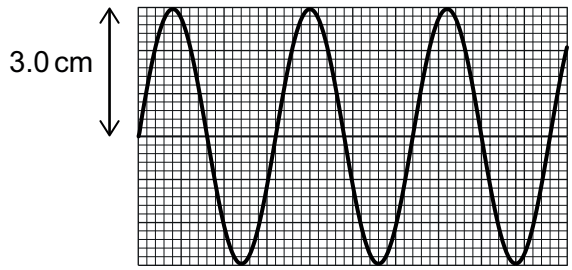
3 Two waves P and Q, which superpose, are shown in the diagram in a particular region at time $t = 0$.



Both waves have period *T* and are moving in the directions shown by the arrows. Wave P has amplitude 2.0 cm and wave Q has amplitude 1.0 cm.

Which diagram represents the resultant wave formed in the same region by waves P and Q at time $t = \frac{T}{2}$?

A



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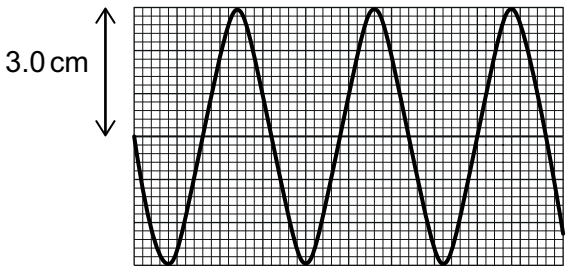

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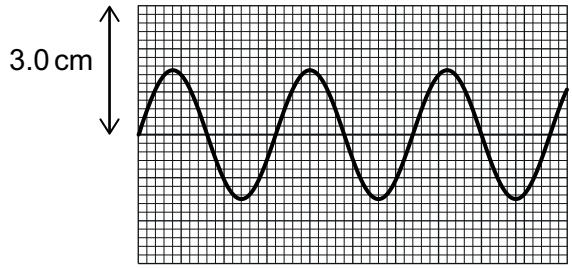

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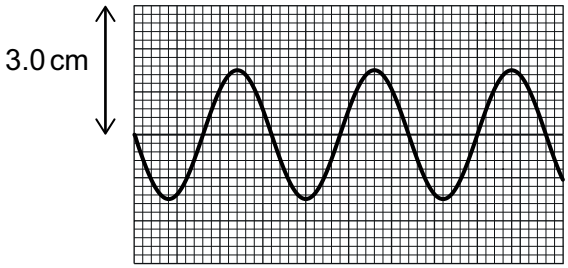

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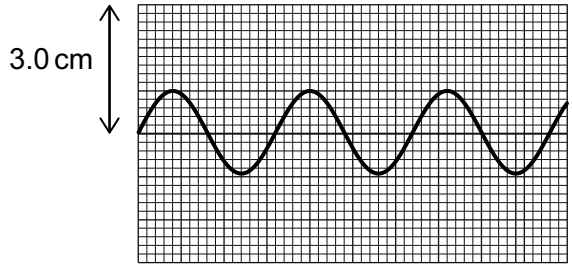

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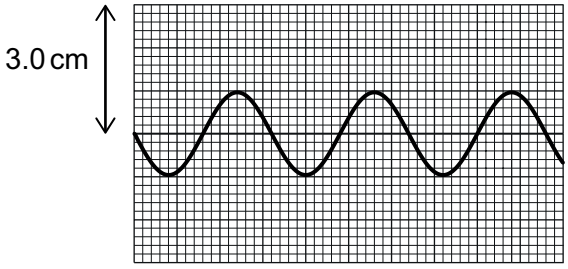

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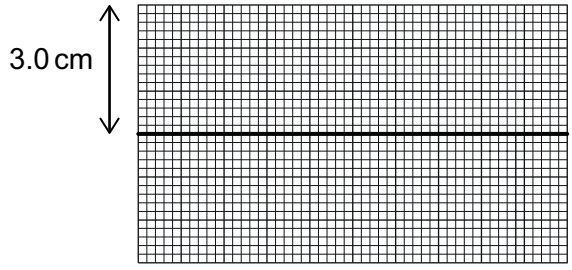
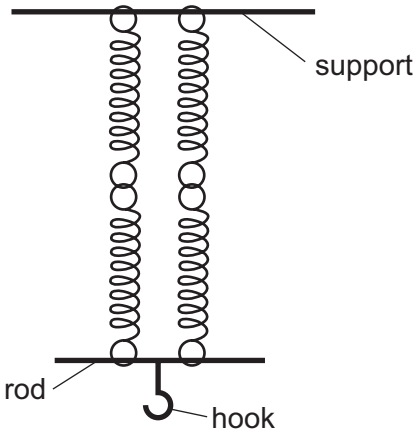


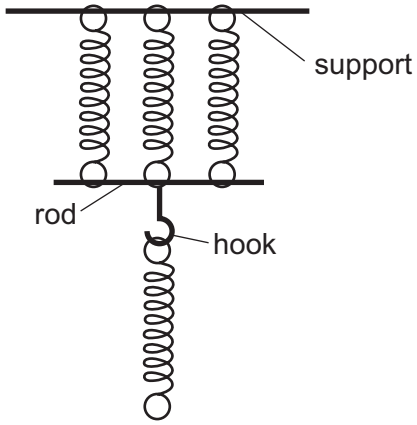
4 Four identical springs are arranged as shown and suspended from a support.



The mass of the springs, rod and hook are negligible.

A load of weight 8.4 N is attached to the hook at the lower end of the springs and this causes a total extension of the system of 24 mm.

The arrangement is then changed to:



The load of 8.4 N is attached to the bottom of the lower spring.

What is the total extension of the system at equilibrium in the second arrangement?

(The springs obey Hooke's law.)

A 3 mm

B 12 mm

C 16 mm

D 24 mm

E 32 mm

F 48 mm

G 64 mm

5 A student and a child are standing on trolleys X and Y, respectively, which are close to each other but not touching. The trolleys are initially stationary on a straight, horizontal frictionless track. The student is initially holding a ball of mass 5.0 kg.

The total mass of the student, the ball and trolley X is 80 kg.

The total mass of the child and trolley Y is 20 kg.

The student on trolley X throws the ball to the child on trolley Y. The ball travels at a horizontal speed of 12 m s^{-1} relative to the ground. The child then catches the ball.

What is the speed of separation of the trolleys after the child has caught the ball?

(Assume that air resistance is negligible.)

A 1.6 m s^{-1}

B 2.4 m s^{-1}

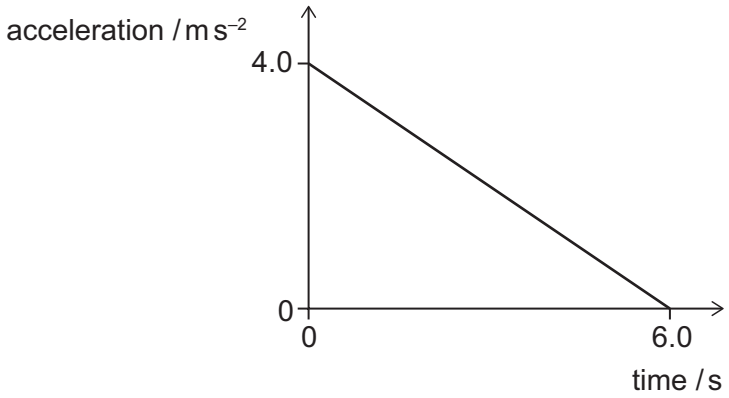
C 3.2 m s^{-1}

D 3.8 m s^{-1}

E 24 m s^{-1}

6 The variation of the acceleration with time of an object moving in a straight line is shown on the graph.

At time = 0 s the velocity of the object is 8.0 m s^{-1}.



What is the maximum velocity of the object between time = 0 s and time = 6 s?

A 5.0 m s^{-1}

B 8.0 m s^{-1}

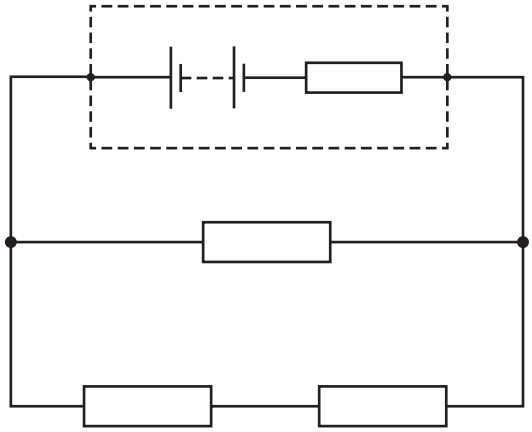
C 12 m s^{-1}

D 20 m s^{-1}

E 32 m s^{-1}

F 44 m s^{-1}

7 The diagram shows a circuit that includes a battery with an emf of 18 V and internal resistance r.



The three identical resistors in the external circuit each have resistance *R*.

The terminal potential difference across the battery is 16 V.

Which expression gives *R* in terms of r?

A $R = \frac{10r}{3}$

B $R = \frac{16r}{3}$

C $R = 6r$

D $R = 12r$

E $R = \frac{27r}{2}$

F $R = 24r$

G $R = \frac{51r}{2}$

8 Three identical bar magnets, each of mass m, and two identical trolleys, X and Y, also each of mass m, are arranged with the bar magnets fixed to the trolleys as shown. The trolleys are held at rest a short distance apart on a smooth horizontal track.

The trolleys are released at the same time. They move towards each other and collide.

Find the value of the ratio

$$\frac{\text{kinetic energy of X immediately before collision}}{\text{kinetic energy of Y immediately before collision}}$$

A $\frac{4}{9}$

B $\frac{1}{2}$

C $\frac{2}{3}$

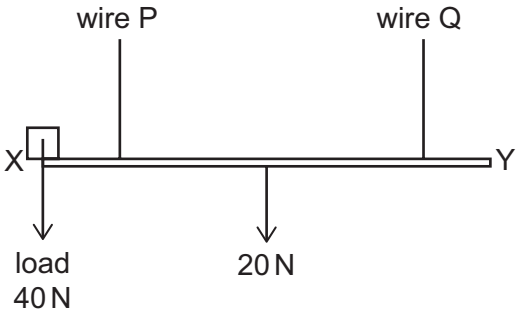
D 1

E $\frac{3}{2}$

F 2

G $\frac{9}{4}$

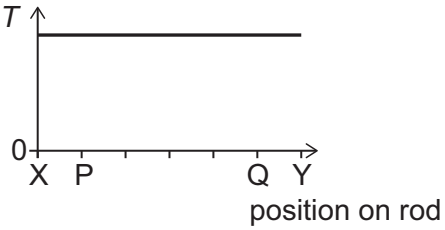
9 A uniform rod XY of length 3.0 m has a weight of 20 N. The rod is supported by two light wires, P and Q, as shown. P and Q are attached 0.50 m from ends X and Y, respectively.



A 40 N load is moved from end X to end Y. The rod remains horizontal at all times.

Which graph shows the variation of the tension *T* in wire P with the position of the load as it is moved along the rod?

A



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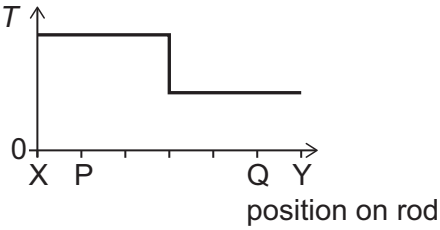

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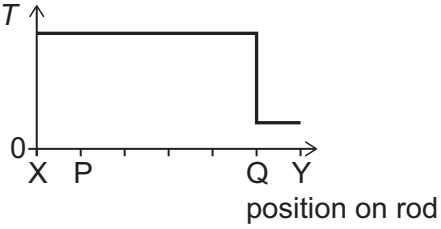

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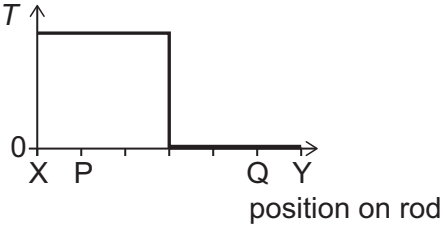

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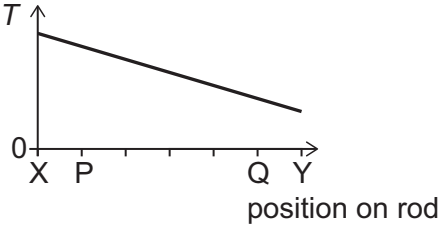

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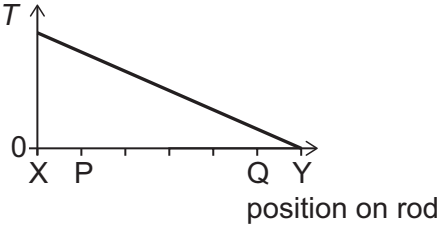
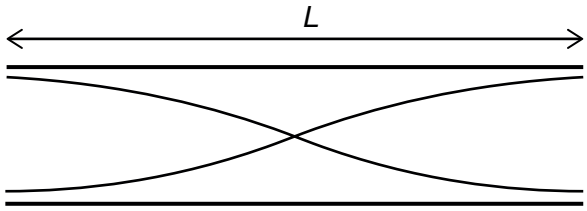


10 A pipe of length *L* open at both ends contains a stationary sound wave with 1 node, as shown in the diagram.



The frequency of the stationary wave in this pipe is $4f$.

A second pipe is open at one end and closed at the other end. A stationary sound wave in this pipe contains one more node than the stationary wave shown in the diagram.

The frequency of the stationary wave in the second pipe is f.

The speed of sound is the same in both pipes.

What is the length of the second pipe?

A 4*L*

B 6*L*

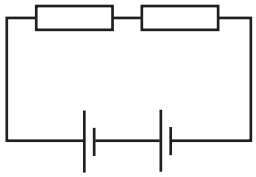
C 8*L*

D 10*L*

E 12*L*

11 The resistors in the following four circuits are identical.

1



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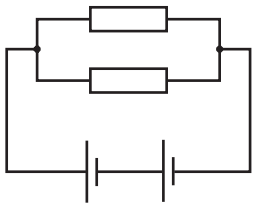

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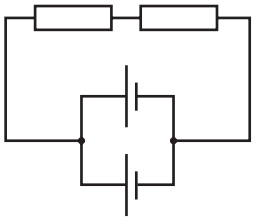

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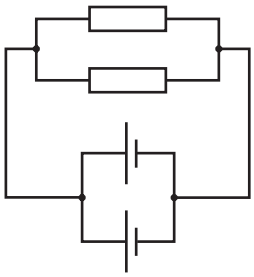


The cells are identical and have no internal resistance. Each cell can supply the same total amount of energy at a constant voltage before becoming exhausted.

t_1, t_2, t_3 and t_4 are the lengths of time after which the cells in circuits **1**, **2**, **3** and **4**, respectively, become exhausted.

Which comparison of t_1, t_2, t_3 and t_4 is correct?

A $t_1 = t_2 < t_3 = t_4$

B $t_1 = t_3 < t_2 = t_4$

C $t_2 < t_1 = t_4 < t_3$

D $t_2 = t_4 < t_1 = t_3$

E $t_3 < t_1 = t_4 < t_2$

F $t_3 = t_4 < t_1 = t_2$

12 A particle of mass m is accelerated from rest by a resultant force of varying magnitude that acts in a constant direction. The kinetic energy E of the particle increases with time t according to the equation

$$E = kt$$

where k is a constant.

Which expression gives the resultant force on the particle at time T?

A k

B $2mk$

C $\sqrt{2mkT}$

D $\sqrt{\frac{mk}{2T}}$

E $\sqrt{\frac{mk}{8T}}$

F $\sqrt{\frac{2mk}{T}}$

G $\sqrt{\frac{k}{2mT}}$

13 A light horizontal wire of cross-sectional area A is fixed at two points a distance $2L$ apart. The initial tension in the wire is zero.

An object of weight W is fixed directly to the centre of the wire. The wire stretches so that the object rests in equilibrium at a vertical distance of $\frac{3L}{4}$ below the original position of the wire.

What is the Young modulus of the wire?

(Assume that the wire does not exceed its limit of proportionality.)

A $\frac{2W}{A}$

B $\frac{4W}{A}$

C $\frac{5W}{2A}$

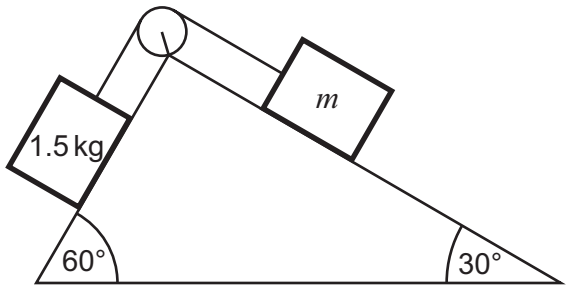
D $\frac{2W}{3A}$

E $\frac{10W}{3A}$

F $\frac{20W}{3A}$

G $\frac{5W}{6A}$

14 A triangular ramp with angles to the horizontal of 60° and 30° is placed with its largest face horizontal. A block of mass 1.5 kg and a block of mass m are joined by a light, inextensible string and placed on the ramp as shown.



The string passes over a light, frictionless pulley.

The maximum force of friction between the block of mass 1.5 kg and the surface of the ramp is 3.5 N.

The maximum force of friction between the block of mass m and the surface of the ramp is 5.0 N.

What is the maximum value of m that allows the blocks to remain stationary on the surfaces?

(gravitational field strength = 10 N kg^{-1})

A 1.5 kg

B 1.65 kg

C 2.35 kg

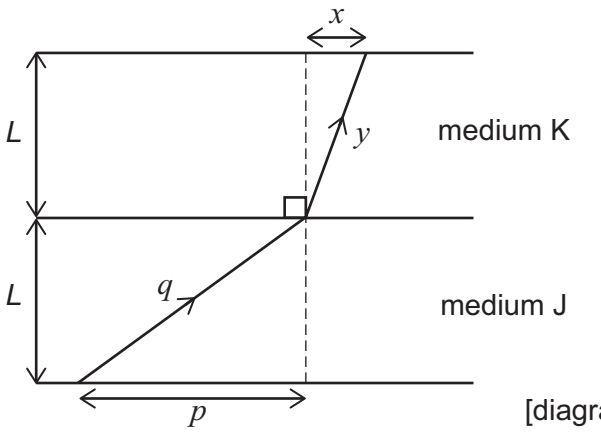
D $\left(\frac{16\sqrt{3}}{15}\right)$ kg

E $(0.60\sqrt{3})$ kg

F $(0.30 + 1.5\sqrt{3})$ kg

G $(1.7 + 1.5\sqrt{3})$ kg

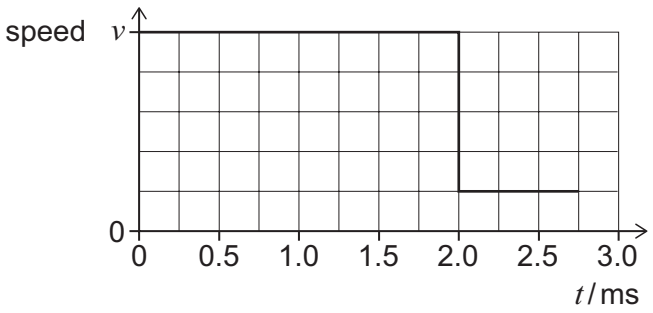
15 A sound wave travels through medium J, reaches a boundary, and then travels through medium K as shown. The thickness of each medium is *L*.



The wave travels a distance q in medium J and a distance y in medium K.

The horizontal distance travelled in medium J is p. The horizontal distance travelled in medium K is x.

The wave travels at speed v in medium J. The graph shows how the speed of the wave varies with time t as it travels distances q and y, and that the wave leaves medium K at $t = 2.75$ ms.



What is the value of $\frac{x}{p}$?

A $\frac{3}{200}$

B $\frac{3}{40}$

C $\frac{8}{75}$

D $\frac{3}{8}$

E $\frac{8}{15}$

F $\frac{8}{3}$

G $\frac{200}{3}$

16 The drag force F acting on a sphere of radius r falling at constant speed v though air is given by

$$F = krv$$

where k is a constant.

For a sphere of uniform density and mass m falling at a constant speed, the drag force heats the surrounding air at a constant rate P.

Another sphere of the same material but with mass $8m$ falls through the air at a different constant speed.

What is the rate at which the drag force on the heavier sphere heats the surrounding air?

A $2P$

B $4P$

C $8P$

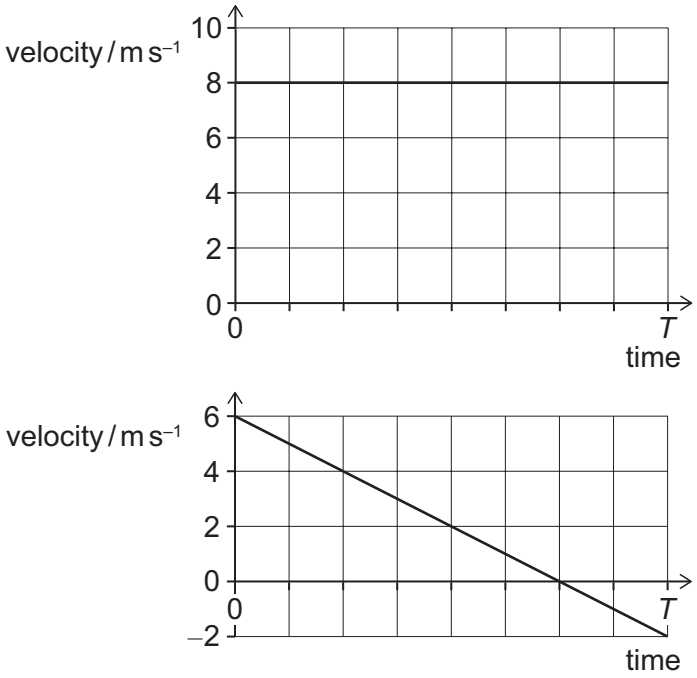
D $16P$

E $32P$

F $64P$

17 A projectile is launched from an inclined plane.

The graphs show the variation of the horizontal and vertical components of the velocity of the projectile with time from when it is launched until it hits the plane at time *T*.



What is the angle of the plane to the horizontal?

(gravitational field strength = 10 N kg^{-1})

A $\tan^{-1}\frac{1}{32}$

B $\tan^{-1}\frac{1}{8}$

C $\tan^{-1}\frac{1}{4}$

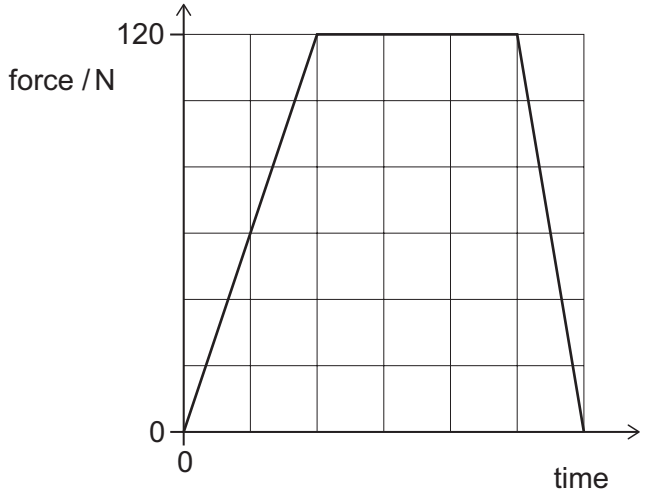
D $\tan^{-1}\frac{5}{16}$

E $\tan^{-1}\frac{1}{3}$

F $\tan^{-1}\frac{4}{3}$

18 A tennis ball of mass 0.060 kg travels horizontally and strikes a vertical wall at 30 m s^{-1}. It leaves the wall in the opposite direction at 20 m s^{-1}.

The graph shows how the resultant horizontal force acting on the ball varies with time during this collision.



What is the duration of the collision?

A $\frac{1}{200}$ s

B $\frac{1}{150}$ s

C $\frac{1}{100}$ s

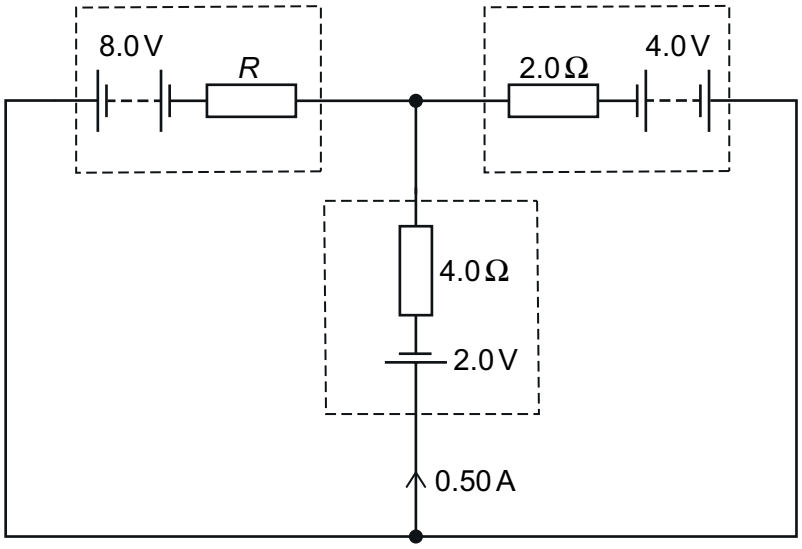
D $\frac{1}{40}$ s

E $\frac{1}{30}$ s

F $\frac{1}{20}$ s

19 A battery with an emf of 8.0 V and internal resistance *R* and another battery with an emf of 4.0 V and internal resistance 2.0 Ω are connected to a cell with an emf of 2.0 V and internal resistance 4.0 Ω in the circuit shown.

The current in the 2.0 V cell is 0.50 A in the direction shown in the diagram.



What is the resistance *R*?

A 1.6 Ω

B 2.7 Ω

C 3.2 Ω

D 8.0 Ω

E 16 Ω

20 A model for how the resistivity ρ of damp soil varies with depth x from the surface is given by

$$\rho = \rho_0\left(1 - \frac{kx^2}{h^2}\right)$$

where h is the maximum depth, and k and ρ_0 are other constants.

What is the resistance of a vertical column of damp soil of cross-sectional area *A* and depth h?

A $\frac{\rho_0 h}{A}$

B $\frac{\rho_0 h}{A}(1-k)$

C $\frac{\rho_0 h}{2A}(2-k)$

D $\frac{\rho_0 h}{A}(1-3k)$

E $\frac{\rho_0 h}{A}\left(1-\frac{k}{3}\right)$

F $\frac{\rho_0}{A}\left(1-\frac{kh}{3}\right)$

G $\frac{\rho_0 h^2}{A}\left(\frac{1}{2}-\frac{k}{4}\right)$

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