

**ENGINEERING
ADMISSIONS ASSESSMENT****D564/12****November 2021****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.

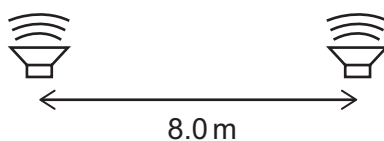
Please wait to be told you may begin before turning this page.

This question paper consists of 22 printed pages and 2 blank pages.



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- 1 Two loudspeakers are positioned 8.0 m apart as shown.



The loudspeakers emit sound waves of the same single frequency. The wave emitted by one loudspeaker is 180° out of phase with the wave emitted by the other loudspeaker.

A point P is in front of the loudspeakers. P is 18.0 m from one loudspeaker and 24.0 m from the other loudspeaker. As a result of superposition of the two waves arriving at P, the amplitude of the sound at position P is a minimum.

The speed of the sound is 336 m s^{-1} .

What is the lowest possible frequency of the sound?

- A 21 Hz
- B 28 Hz
- C 42 Hz
- D 56 Hz
- E 63 Hz
- F 84 Hz

- 2** A block is at rest on a rough inclined plane.

The acute angle between the plane and the horizontal is greater than 45° .

The forces acting on the block are: friction (F), weight (W) and normal contact force (N).

How do the magnitudes of the three forces compare?

A $F < N < W$

B $F < W < N$

C $N < F < W$

D $N < W < F$

E $W < F < N$

F $W < N < F$

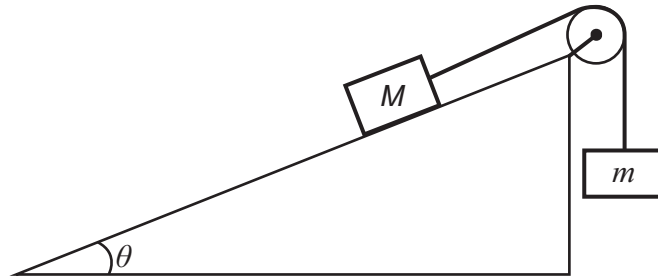
- 3** A dc power supply, a resistor of constant resistance $50\ \Omega$ and a piece of resistance wire are connected in series.

The length of the resistance wire is 20 m and its cross-sectional area is $0.10\ \text{mm}^2$. The wire is made from a material with resistivity $1.0 \times 10^{-7}\ \Omega\text{m}$ and the current in it is 200 mA.

What is the voltage across the terminals of the power supply?

- A** 4.0 V
- B** 6.0 V
- C** 9.9 V
- D** 10.0 V
- E** 10.1 V
- F** 12.0 V
- G** 14.0 V

- 4 Two objects of mass M and m are connected by a rope over a pulley on an inclined plane as shown.



[diagram not to scale]

There is no friction between the plane and the object. The pulley is smooth, and the rope has negligible mass.

The angle θ of the plane to the horizontal is such that $\sin \theta = 0.80$ and $\cos \theta = 0.60$.

The object with mass M accelerates down the slope.

Which expression describes the full range of possible values of M compared with m ?

- A $M > \frac{3}{5}m$
- B $M > \frac{4}{5}m$
- C $M > m$
- D $M > \frac{5}{4}m$
- E $M > \frac{5}{3}m$

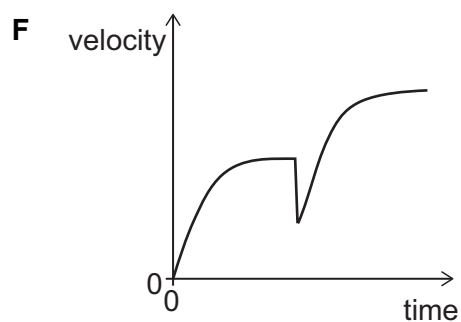
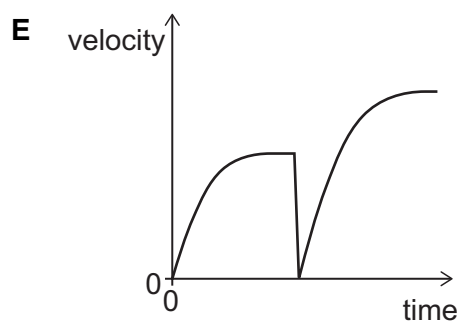
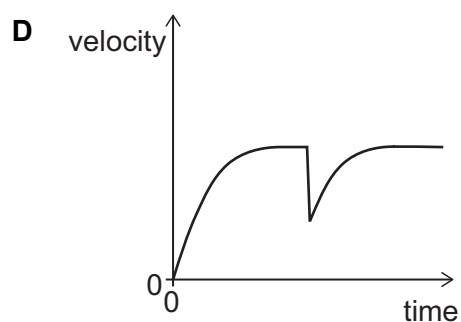
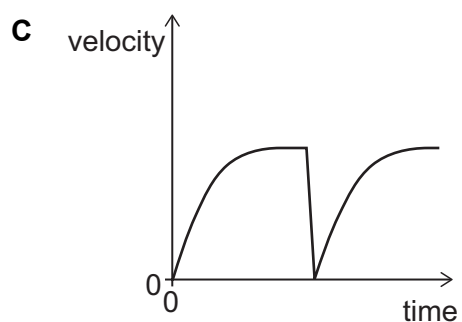
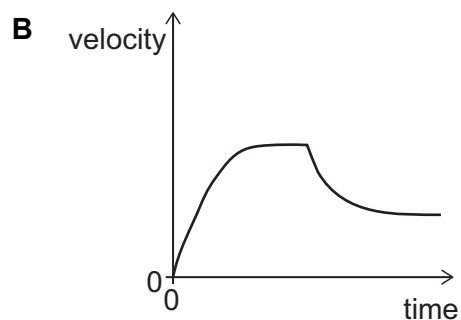
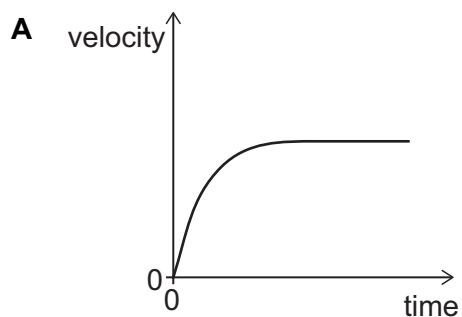
- 5 An object P falls vertically from rest through air and reaches terminal velocity.

An identical object Q is projected vertically upwards from the ground.

When Q reaches its maximum height, P collides with it. The two objects join together in such a way that there is no change to the area of cross section passing through the air.

The two combined objects then fall through the air as one object.

Which sketch graph shows the variation of velocity with time for object P before and after the collision?



- 6 A lorry of mass m has an engine that develops a constant mechanical output power P .

The lorry is accelerated from rest by the engine in a horizontal straight line. The lorry experiences a total resistive force that is always proportional to the square of its speed.

The process is repeated for different values of P , and the maximum speed of the lorry is found to be proportional to P^n , where n is a constant.

What is the value of n ?

- A $\frac{1}{3}$
- B $\frac{1}{2}$
- C 1
- D 2
- E 3

- 7 A battery pack consists of 6 cells, each with an emf of 1.50 V and each with an internal resistance of $0.20\ \Omega$.

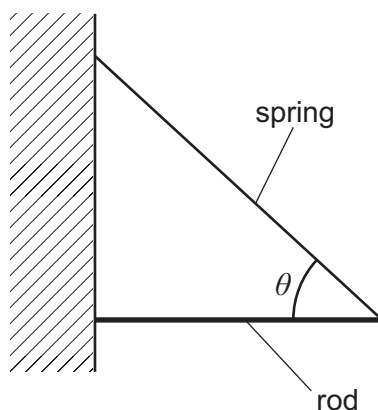
The cells are arranged in two rows connected in parallel. Each row contains 3 cells connected in series.

The battery pack is connected to an external resistor of resistance $1.20\ \Omega$.

What is the electrical power transferred in the external resistor?

- A 2.7 W
- B 3.6 W
- C 7.5 W
- D 10.8 W
- E 13.5 W
- F 43.2 W

- 8 A light spring is used to support a uniform rod horizontally against a wall as shown. The angle between the spring and the rod is θ .



The spring constant of the spring is 20 N m^{-1} and the weight of the rod is 16 N .

The angle θ is such that $\cos \theta = \frac{3}{5}$ and $\sin \theta = \frac{4}{5}$.

How much energy is stored in the spring?

- A 1.6 J
- B 2.5 J
- C 3.2 J
- D 4.4 J
- E 5.0 J
- F 6.4 J
- G 10 J
- H 40 J

- 9** An object of mass 2.0 kg moves in a straight line under the action of a resultant force.

The displacement x of the object from its position at time $t = 0$ is given by

$$x = 4.0 t^3$$

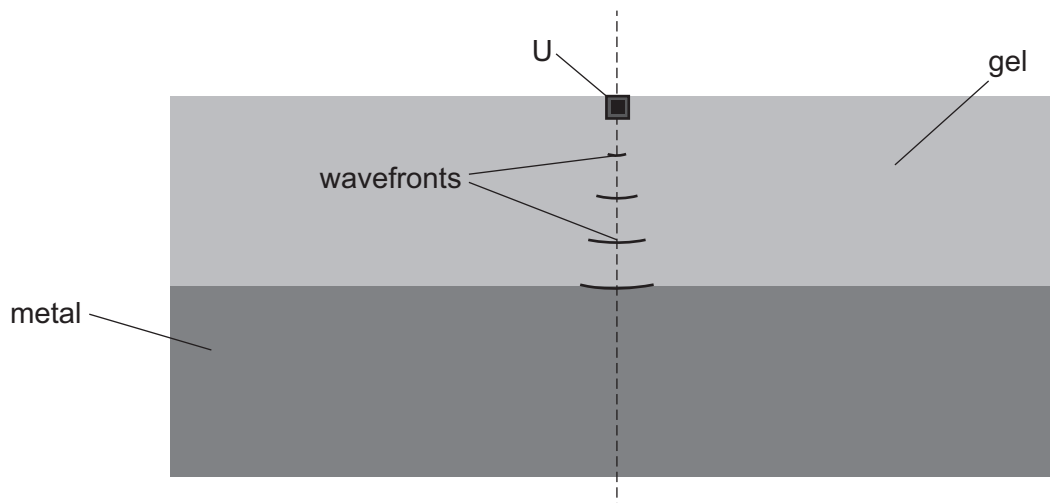
where x is in metres and t is in seconds.

At $t = 5.0$ s, what is the rate of change of momentum of the object?

- A** 6.7 kg m s⁻²
- B** 66.7 kg m s⁻²
- C** 120 kg m s⁻²
- D** 240 kg m s⁻²
- E** 600 kg m s⁻²

- 10** In an industrial process to test the purity of a metal, a narrow beam of ultrasound passes into a block of the metal. The ultrasound generator U is immersed in a gel that is in contact with the metal. The ultrasound passes from the gel into the metal.

The arcs of circles shown in the gel are lines that represent the positions of the compressions (known as wavefronts) of the ultrasound wave that comes from U.



Ultrasound travels faster in the metal than in the gel.

The wavefronts in the metal are circular arcs with their centre at a point X that is on the dashed line.

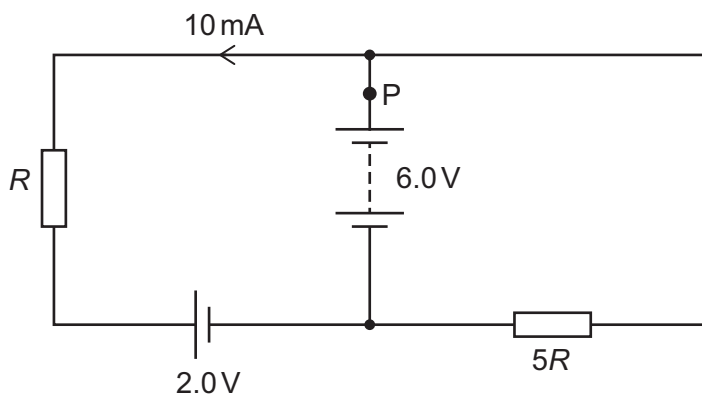
Where on the dashed line is X?

- A** above U
- B** at U
- C** in the gel below U
- D** on the boundary between the gel and the metal
- E** in the metal

- 11 The diagram shows a circuit containing two power supplies with negligible internal resistance and two resistors with resistances R and $5R$.

The emfs of the power supplies and the magnitude and direction of the current in one part of the circuit are shown.

One point in the circuit is labelled P.

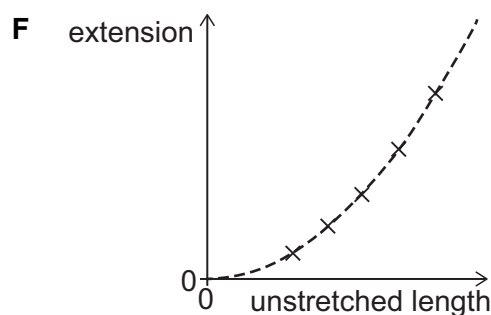
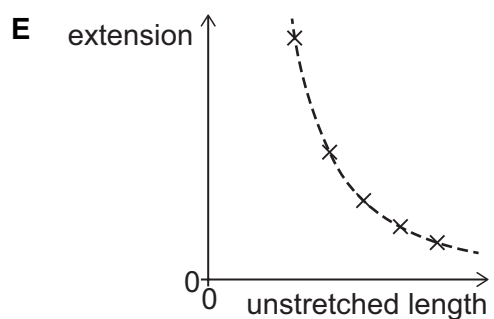
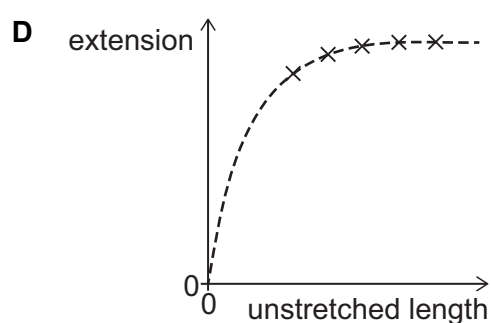
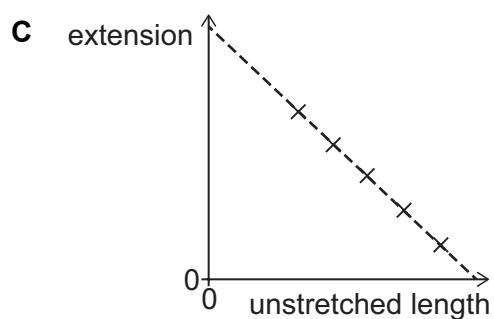
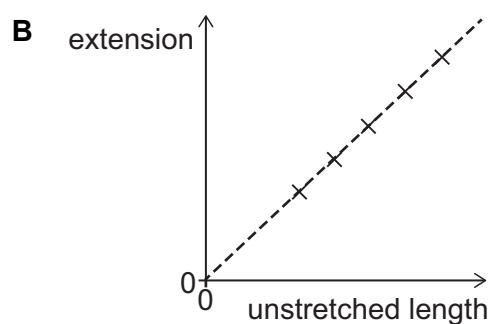
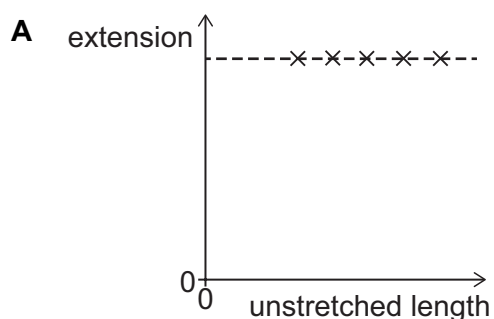


What is the magnitude of the current at P?

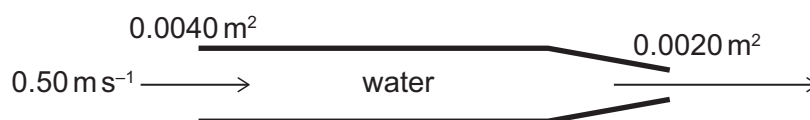
- A 3.0mA
- B 7.0mA
- C 8.5mA
- D 11.5mA
- E 13mA
- F 25mA

- 12** A selection of five wires made from the same metal have different unstretched lengths but equal masses. The wires are all subjected to the same small tension force and each wire extends within its limit of proportionality.

Which graph shows the relationship between the extension of the wires and the unstretched length of the wires?



- 13** Water enters a horizontal pipe of cross-sectional area 0.0040 m^2 at constant speed 0.50 m s^{-1} . At the end of the pipe the cross-sectional area reduces to 0.0020 m^2 and the water leaves the pipe as shown. The density of water is 1000 kg m^{-3} .

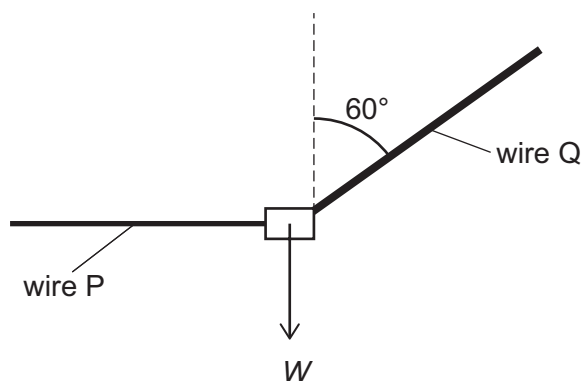


How much power must be supplied to the water to maintain the flow in this section of the pipe?

(Assume that the water is incompressible and that frictional forces can be neglected.)

- A** 0.25 W
- B** 0.50 W
- C** 0.75 W
- D** 1.0 W
- E** 1.25 W
- F** 1.5 W
- G** 3.75 W

- 14 Two light wires P and Q support a load of weight W in equilibrium as shown. Wire P is horizontal and wire Q is at an angle of 60° to the vertical. The wires are made from the same material.



The radius of wire Q is twice the radius of wire P.

What is the ratio

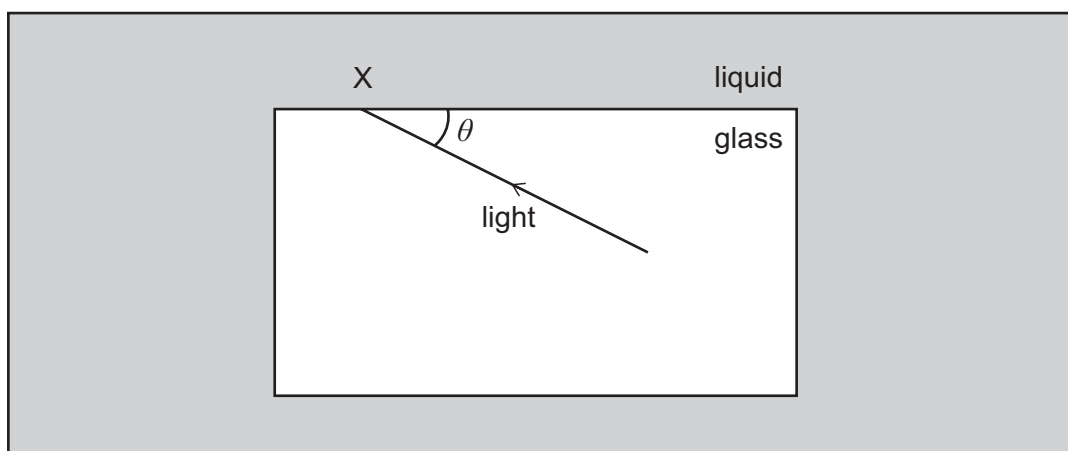
$$\frac{\text{strain in wire P}}{\text{strain in wire Q}} ?$$

(The wires do not exceed their limits of proportionality.)

- A $\frac{\sqrt{3}}{8}$
- B $\frac{\sqrt{3}}{4}$
- C $\frac{\sqrt{3}}{2}$
- D $\sqrt{3}$
- E $2\sqrt{3}$
- F $\frac{4}{\sqrt{3}}$
- G $\frac{8}{\sqrt{3}}$

- 15** The speed of light in a block of glass is $2.0 \times 10^8 \text{ m s}^{-1}$. The block of glass is immersed in a liquid of refractive index 1.2.

The diagram shows a ray of light travelling in the glass block striking the side of the block at the point labelled X. The acute angle between the ray and the side of the block is θ .

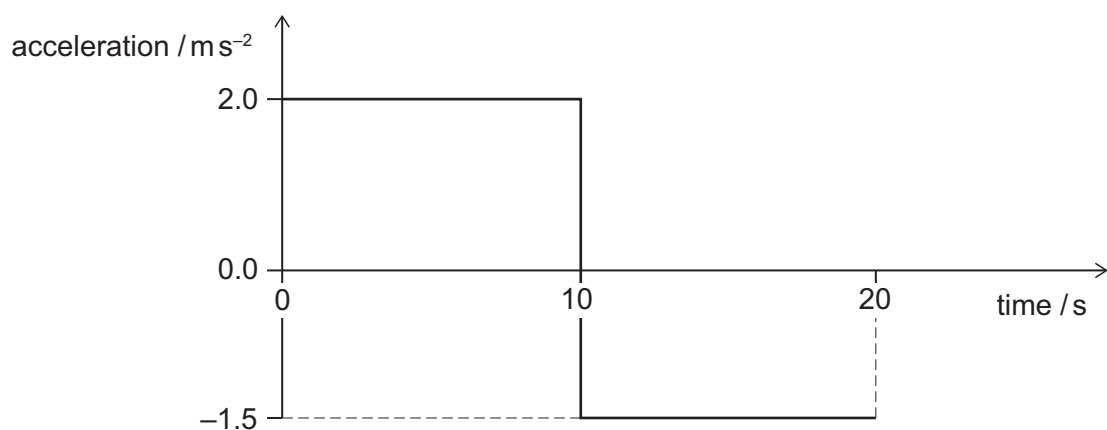


What is the full range of values of the acute angle θ for which light is refracted at X?

(The speed of light in a vacuum is $3.0 \times 10^8 \text{ m s}^{-1}$.)

- A** $0^\circ < \theta < \cos^{-1}\left(\frac{2}{3}\right)$
- B** $0^\circ < \theta < \cos^{-1}\left(\frac{\sqrt{5}}{3}\right)$
- C** $0^\circ < \theta < \cos^{-1}\left(\frac{3}{5}\right)$
- D** $0^\circ < \theta < \cos^{-1}\left(\frac{4}{5}\right)$
- E** $\cos^{-1}\left(\frac{2}{3}\right) < \theta < 90^\circ$
- F** $\cos^{-1}\left(\frac{\sqrt{5}}{3}\right) < \theta < 90^\circ$
- G** $\cos^{-1}\left(\frac{3}{5}\right) < \theta < 90^\circ$
- H** $\cos^{-1}\left(\frac{4}{5}\right) < \theta < 90^\circ$

- 16** A car is at rest on a straight horizontal road. At time $t = 0$ s the car starts to move along the road. The graph shows how its acceleration varies from $t = 0$ s to $t = 20$ s.

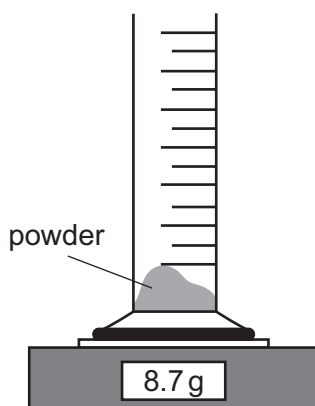


What is the displacement of the car from its starting position when $t = 20$ s?

- A** 5.0 m
- B** 25 m
- C** 35 m
- D** 175 m
- E** 225 m
- F** 375 m

- 17 An empty measuring cylinder is placed on a balance, and the balance reading is then set to zero.

A mass of 8.7 g of a powder is poured into the measuring cylinder as shown in the diagram.



Liquid is poured into the cylinder to cover the powder completely. The powder does not dissolve. The reading on the measuring cylinder and the reading on the balance are recorded.

More liquid is added and a second pair of readings is recorded.

The table shows the two pairs of readings.

<i>reading on measuring cylinder / cm³</i>	<i>reading on balance / g</i>
10.0	15.0
25.0	27.6

What is the density of the material from which the powder is made?

- A 0.414 g cm⁻³
- B 1.16 g cm⁻³
- C 1.31 g cm⁻³
- D 1.45 g cm⁻³
- E 2.00 g cm⁻³
- F 2.50 g cm⁻³
- G 3.48 g cm⁻³
- H 6.00 g cm⁻³

- 18** A stone of mass 100 g is fired horizontally from an 80 m high vertical cliff. The ground below the cliff is horizontal.

The kinetic energy of the stone when it hits the ground is 125 J.

What is the distance from the bottom of the cliff to the point where the stone hits the ground?

(gravitational field strength = 10 N kg^{-1} ; ignore air resistance and any effect of wind)

- A** 60 m
- B** 80 m
- C** 120 m
- D** 160 m
- E** 200 m

- 19** An electrical component is connected to a switch and a power supply which has a constant terminal potential difference V . The switch is initially open. At time $t = 0$ the switch is closed.

When the switch is closed, the current I in the component increases with time t as given by the equation

$$I = kt^2$$

where k is a positive constant.

When the current reaches a value I_F the component fails and the current falls instantly to zero.

How much electrical energy has been transferred to the component by the time it fails?

(All quantities are in standard SI units.)

A $\frac{Vk}{3} \left(\frac{I_F}{k} \right)^{\frac{3}{2}}$

B $Vk \left(\frac{I_F}{k} \right)^{\frac{3}{2}}$

C $3Vk \left(\frac{I_F}{k} \right)^{\frac{3}{2}}$

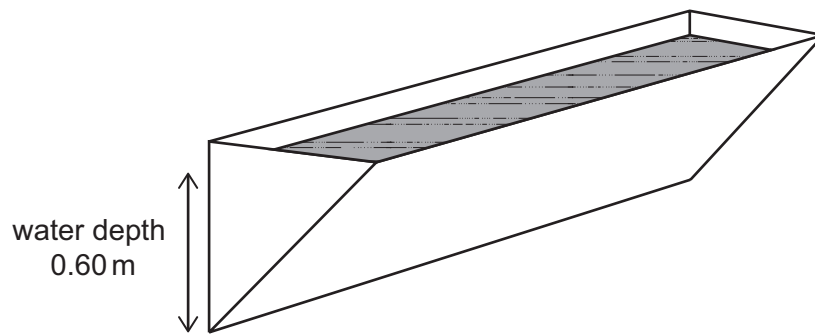
D $\frac{Vk}{3} \left(\frac{I_F}{k} \right)$

E $Vk \left(\frac{I_F}{k} \right)$

F $3Vk \left(\frac{I_F}{k} \right)$

- 20** A water trough has the shape of a prism, with a cross section that is a right-angled isosceles triangle.

One rectangular face and the two triangular ends of the trough are vertical, as shown.



[diagram not to scale]

The trough contains water of depth 0.60 m measured on the vertical rectangular face.

What is the force exerted by the water on one triangular end of the trough?

(density of water = 1000 kg m^{-3} ; gravitational field strength = 10 N kg^{-1})

- A** 180 N
- B** 270 N
- C** 360 N
- D** 540 N
- E** 720 N
- F** 1080 N
- G** 6000 N
- H** 12 000 N

END OF TEST