Oxford Cambridge and RSA

# AS Level Physics A

## H156/01 Breadth in physics

# Tuesday 24 May 2016 – Morning

## Time allowed: 1 hour 30 minutes

**You must have:**
- the Data, Formulae and Relationships Booklet (sent with general stationery)

**You may use:**
- a scientific calculator
- a ruler (cm/mm)

| | |
|---|---|
| First name | |
| Last name | StemUp Model Solution |

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|---|---|---|---|---|---|---|---|---|---|---|
| Centre number | | | | | | Candidate number | | | | |

**INSTRUCTIONS**
- Use black ink. HB pencil may be used for graphs and diagrams.
- Complete the boxes above with your name, centre number and candidate number.
- Answer **all** the questions.
- Write your answer to each question in the space provided. If additional space is required, you should use the lined page(s) at the end of this booklet. The question number(s) must be clearly shown.
- Do **not** write in the barcodes.

**INFORMATION**
- The total mark for this paper is **70**.
- The marks for each question are shown in brackets **[ ]**.
- This document consists of **28** pages.

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## SECTION A

**You should spend a maximum of 25 minutes on this section.**

Answer **all** the questions.

Write your answer to each question in the box provided.

**1** The watt is the SI unit for power.

Which is the correct definition for the watt? A watt is ....

**A** the rate of work done.

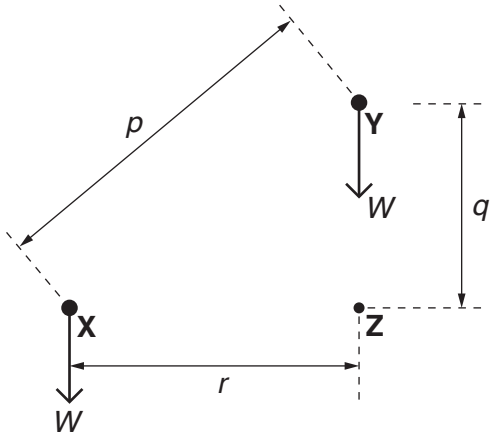
**B** the work done per second.

**C** a joule per second.

**D** a joule per unit time.

Your answer C **[1]**

**2** A crane is used to lift a load directly from point **X** to point **Y**.




The weight of the load is *W*.
*p, q* and *r* are distances between points **X**, **Y** and **Z** as shown in the diagram.

What is the work done against the weight?

**A** $Wp$

**B** $Wq$

**C** $Wr$

**D** $W(q + r)$

Your answer B **[1]**

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**3** A student views the display of a laptop screen through a polarising filter. The intensity of the light changes when the filter is rotated.

Which property of light is demonstrated in this experiment?

**A** It has wavelength of about $5 \times 10^{-7}$ m.

**B** It travels at the speed of light.

**C** It is a transverse wave.

**D** It is a longitudinal wave.

Your answer C **[1]**

**4** Electrons travelling through a thin film of carbon are diffracted.
Which statement is correct?

The electrons behave like ....

**A** photons and are deflected by the carbon atoms.

**B** photons and change direction as their speed changes.

**C** waves and are refracted by the holes in the carbon film.

**D** waves of wavelength similar to the spacing between carbon atoms.

Your answer D **[1]**

**5** In which region of the electromagnetic spectrum is radiation of wavelength 50 μm?

**A** visible

**B** infra-red

**C** microwave

**D** radio

Your answer B **[1]**

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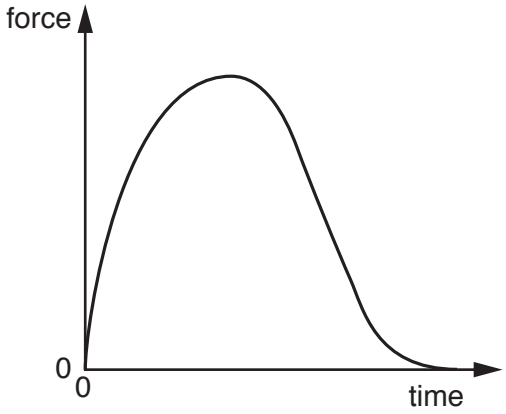
**6** The graph shows the resultant force on a football as it is kicked.




Which of the following graphs relating to this kick would have the same shape as the graph above?

**A** acceleration of the ball against time

**B** kinetic energy of the ball against time

**C** momentum of the ball against time

**D** velocity of the ball against time

Your answer A **[1]**

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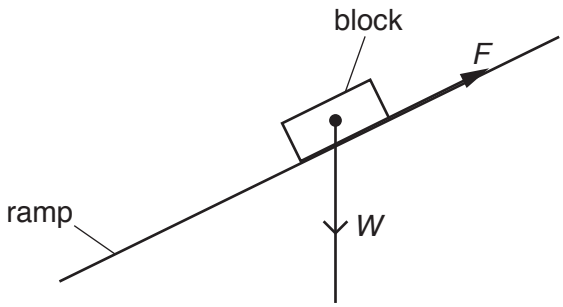
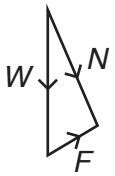
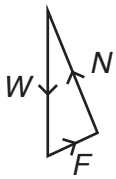
**7** A block of wood is at rest on a ramp.
The weight of the block is *W* and the frictional force on the block is *F*.

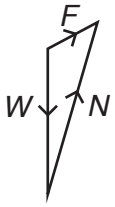


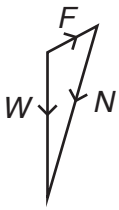

A triangle of forces diagram can be used to determine the magnitude and the direction of the normal contact force *N*.

Which is the correct diagram for this triangle?

**A**



**B**



**C**



**D**



Your answer B **[1]**

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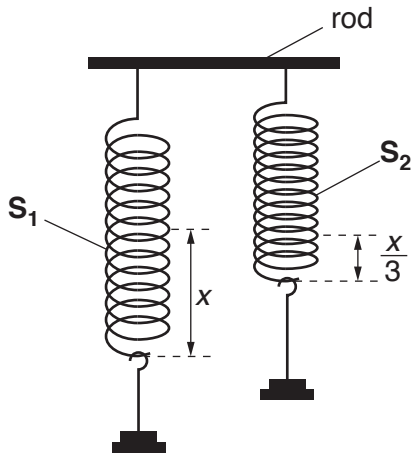
**8** The top ends of two springs, $\mathbf{S_1}$ and $\mathbf{S_2}$, are attached to a rod.




A mass is hung from the bottom end of $\mathbf{S_1}$. The extension of $\mathbf{S_1}$ is $x$. The elastic potential energy in the spring is $E$. The same mass is hung from the bottom end of $\mathbf{S_2}$. The extension of $\mathbf{S_2}$ is $\frac{x}{3}$.

What is the elastic potential energy in the spring $\mathbf{S_2}$?

**A** $\frac{E}{9}$

**B** $\frac{E}{3}$

**C** $3E$

**D** $9E$

Your answer B **[1]**

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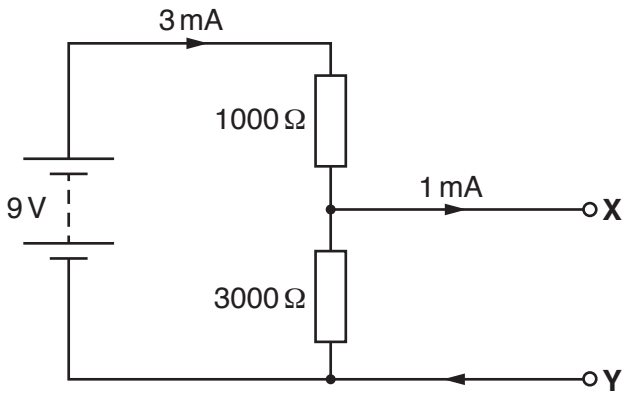
**9** A 9 V battery is connected to two resistors as shown. The terminals **X** and **Y** are connected to another circuit that draws a current of 1 mA. The current from the battery is 3 mA.




What is the power supplied to the circuit connected between **X** and **Y**?

**A** 6 mW

**B** 12 mW

**C** 18 mW

**D** 27 mW

Your answer A **[1]**

**10** A trolley **M** collides head-on with a trolley **L**. The mass of trolley **M** is greater than the mass of trolley **L**. The trolleys join together after the collision.

Which statement is correct?

**A** The momentum of each trolley is conserved.

**B** Trolley **M** experiences a greater force than trolley **L** during the collision.

**C** The total force acting on the two-trolley system during the collision is zero.

**D** Kinetic energy is conserved.

Your answer C **[1]**

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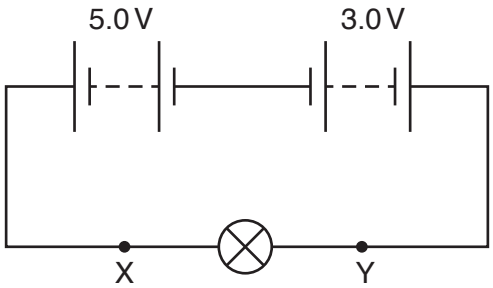
**11** Two batteries are connected in a circuit with a lamp as shown.

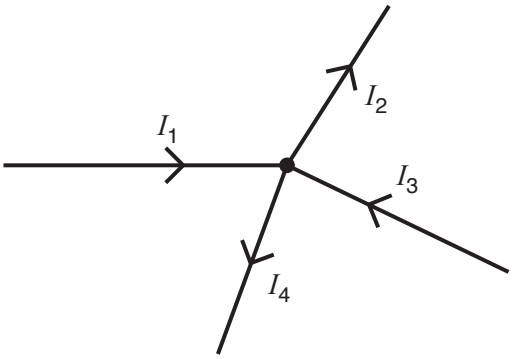



The batteries have e.m.f. 5.0 V and 3.0 V.
Which row is correct?

| | Direction of conventional current | Magnitude of current |
|---|---|---|
| **A** | clockwise | greater at Y than at X |
| **B** | clockwise | same at Y and X |
| **C** | anticlockwise | greater at X than at Y |
| **D** | anticlockwise | same at X and Y |

Your answer D **[1]**

**12** The diagram shows the conventional currents entering and leaving a junction in an electric circuit. $I_1$, $I_2$, $I_3$ and $I_4$ are all positive.




Which statement is always true?

**A** $I_1 + I_2 = I_3 + I_4$

**B** $I_1 - I_2 + I_3 - I_4 = 0$

**C** $I_1 = I_2$ and $I_3 = I_4$

**D** $I_1 + I_2 + I_3 + I_4 = 0$

Your answer B **[1]**

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**13** A student determines the resistance $R$ of a filament lamp by measuring the potential difference $V$ across it and the current $I$ in it. The values recorded by the student are:

$V = (5.00 \pm 0.20)$ V and $I = (40.0 \pm 1.0)$ mA.

What is the percentage uncertainty in the value of $R$?

**A** 1.5%

**B** 1.6%

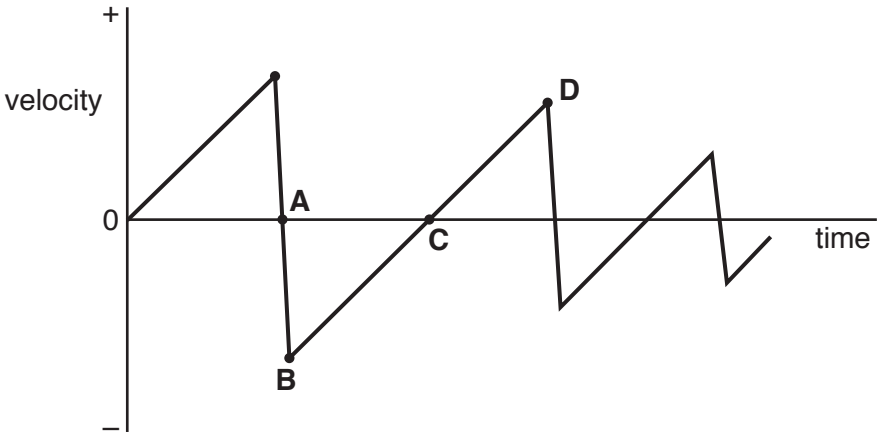
**C** 6.5%

**D** 20%

Your answer C **[1]**

**14** A golf ball is dropped from rest onto a hard floor.
The graph shows how the velocity of the ball varies with time as it bounces, from the time of release.

At which point does the ball reach its maximum height after the first bounce?




Your answer C **[1]**

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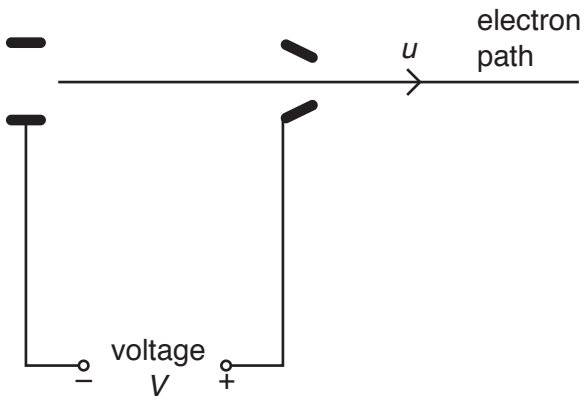
**15** An electron gun is used to accelerate electrons from rest through a voltage $V$. The electrons emerge with a speed $u$.




The voltage in the gun is halved to $\frac{V}{2}$. At what speed do the electrons emerge?

**A** $\frac{u}{4}$

**B** $\frac{u}{2}$

**C** $\frac{u}{\sqrt{2}}$

**D** $u\sqrt{2}$

Your answer C **[1]**

**16** Photons of energy $4.8 \times 10^{-19}$ J are incident on the surface of a clean metal plate of work function $3.2 \times 10^{-19}$ J.

What is the maximum speed of emitted electrons?

**A** $5.9 \times 10^{5}\,\mathrm{m\,s^{-1}}$

**B** $8.4 \times 10^{5}\,\mathrm{m\,s^{-1}}$

**C** $1.0 \times 10^{6}\,\mathrm{m\,s^{-1}}$

**D** $1.3 \times 10^{6}\,\mathrm{m\,s^{-1}}$

Your answer A **[1]**

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**17** Two guitar strings of equal length, but of different thickness, are under the same tension. The strings are made of the same material.

The thinner string has a diameter of 0.20 mm and the thicker string has a diameter of 0.80 mm.

What is the value of the ratio $\frac{\text{elastic potential energy in the thinner string}}{\text{elastic potential energy in the thicker string}}$ ?

**A** 0.125

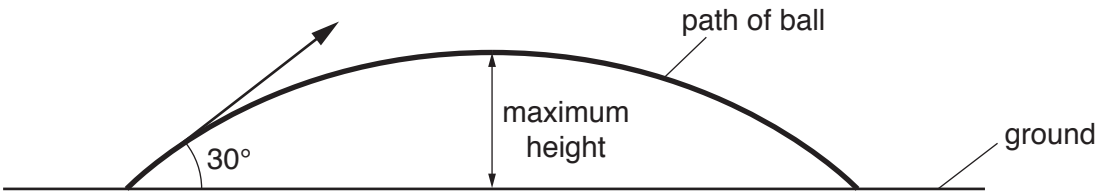
**B** 0.25

**C** 4.0

**D** 16

Your answer D **[1]**

**18** A ball is thrown at an angle of 30° to the horizontal. The initial kinetic energy of the ball is *K*. Air resistance has negligible effect on the motion of the ball.




What is the kinetic energy of the ball at the maximum height?

**A** 0

**B** 0.25 *K*

**C** 0.75 *K*

**D** 0.87 *K*

Your answer C **[1]**

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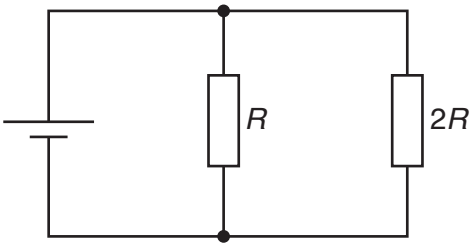
**19** A resistor of resistance $R$ is connected in parallel with a resistor of resistance $2R$. The combination of resistors is connected to a cell.




What is the ratio $\dfrac{\text{power dissipated in resistor of resistance } R}{\text{power dissipated in resistor of resistance } 2R}$ ?

**A** $\frac{1}{4}$

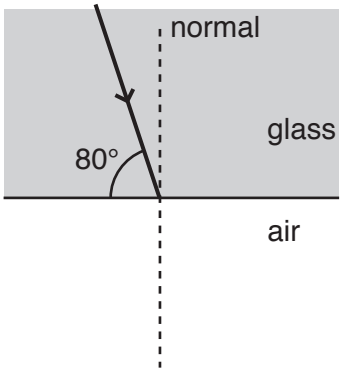
**B** $\frac{1}{2}$

**C** 1

**D** 2

Your answer D **[1]**

**20** The speed of light in air is $3.0 \times 10^8\,\text{m s}^{-1}$ and the speed of light in glass is $2.0 \times 10^8\,\text{m s}^{-1}$. A ray of monochromatic light in glass strikes the glass-air boundary at an angle of 80° to the boundary.




What is the angle made to the normal by the ray of light leaving the boundary?

**A** 6.6°

**B** 15°

**C** 41°

**D** 49°

Your answer B **[1]**

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## SECTION B

Answer **all** the questions.

**21** **(a)** Physical quantities can be added together. Velocity and mass are examples of two different types of physical quantities.
Discuss how the addition of two velocities differs from the addition of two masses.

Mass is a scalar quantity but velocity is a vector quantity.

Masses are simply added arithmetically, but adding velocities depends on their directions; they must be added as vectors (vector triangle or resolving), so two velocities can even cancel out. **[2]**

**(b)** Fig. 21 shows a stationary trolley on a smooth ramp.

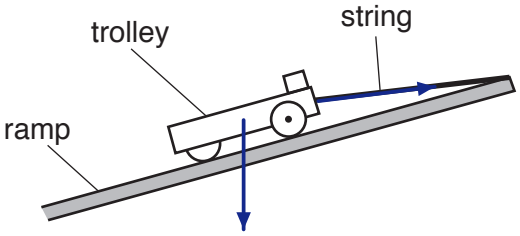


**Fig. 21**

A short length of string is attached between the end of the trolley and the top of the ramp.
Assume that the frictional force acting on the trolley is negligible when it is stationary or when it is moving.

**(i)** Other than the normal contact force, there are two other forces acting on the stationary trolley.
On **Fig. 21**, draw arrows to show these two forces. You do not need to name these forces. **[1]**

**(ii)** The string is cut at time $t = 0$. The trolley travels down the ramp with a constant acceleration of $3.0\,\mathrm{m\,s^{-2}}$.
Calculate the time $t$ taken by the trolley to travel a distance of 0.80 m down the ramp.

$s = ut + \frac{1}{2}at^2$, with $u = 0$

$0.80 = \frac{1}{2} \times 3.0 \times t^2$

$t^2 = 0.533$, so $t = 0.730$ s

$t =$ 0.73 s **[2]**

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**22** A group of engineers are testing a new car. They are investigating how the braking distance $x$ of the car varies with its initial speed $u$ when a constant braking force is applied.
Fig. 22 shows the data points plotted on a $u^2$ against $x$ graph. The straight line of best fit has been drawn through the data points.

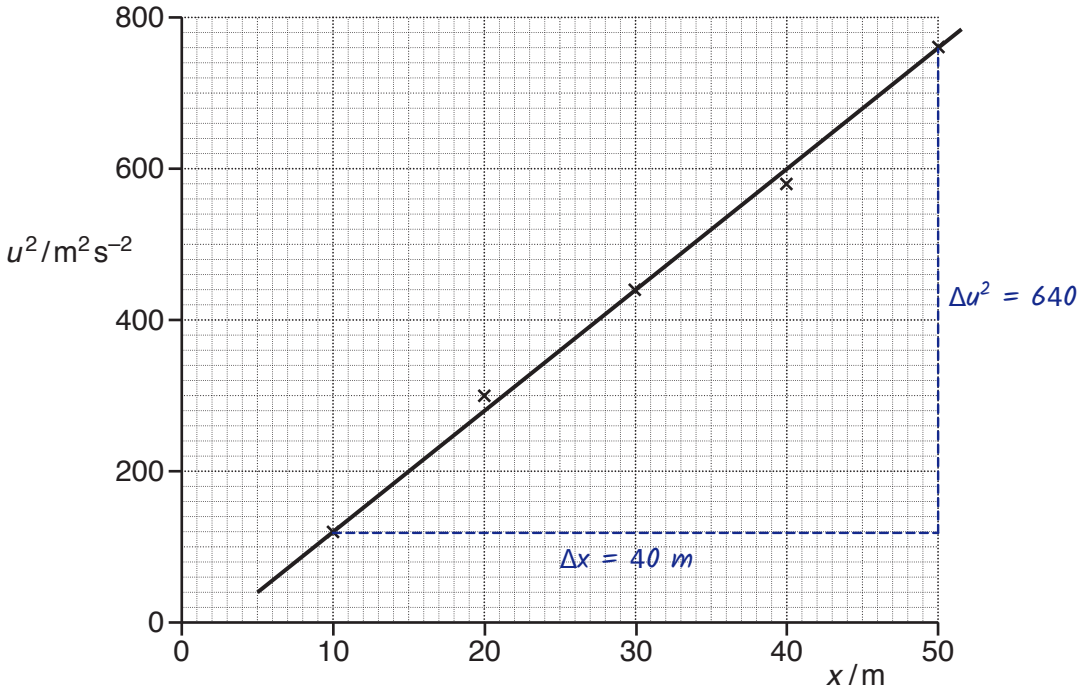


**Fig. 22**

The theoretical relationship between $u$ and $x$ for the car is

$$u^2 = 2ax$$

where $a$ is the magnitude of the deceleration of the car.

**(a)** Fig. 22 shows that the straight line does not pass through the origin because of a systematic error in the measurement of the braking distance $x$. The $u^2$ values are accurate.
Suggest why a systematic error in $x$ does not introduce any difference between the actual value and the experimental value for the deceleration of the car.

The systematic error shifts the line along the x-axis by the same amount, so the gradient of the line (which gives a) remains the same. **[1]**

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**(b)** The mass of the car is 920 kg.
Use the gradient of the line drawn in **Fig. 22** to determine the braking force $F$ acting on the car.

gradient = $\Delta u^2/\Delta x$ = (770 − 130) ÷ (50 − 10) = 640 ÷ 40 = 16 m $s^{-2}$

$u^2$ = 2ax, so gradient = 2a

a = 16 ÷ 2 = 8.0 m $s^{-2}$

F = ma = 920 × 8.0 = 7360 N

F = 7.4 × $10^3$ N

$F$ = .....7.4 × $10^3$..... N **[3]**

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**23** **(a)** Fig. 23.1 shows a metal cylinder of diameter of about 5 cm placed on a horizontal table.

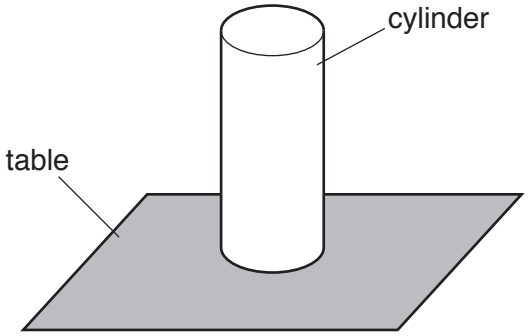


**Fig. 23.1**

Describe how you can use instruments available in a physics laboratory to determine the pressure exerted by the cylinder on the table. State how you would make your results as precise as possible.

pressure = force ÷ area = weight of cylinder ÷ area of its base.

Measure the mass m of the cylinder with a top-pan balance and calculate the weight W = mg ($g = 9.81\ m\ s^{-2}$), or measure W directly with a newtonmeter.

Measure the diameter d of the base with vernier callipers in several places and average; area $A = \pi r^2 = \pi d^2/4$.

Pressure p = W ÷ A. For precision use vernier callipers or a micrometer (high resolution) for d, and a balance with smaller divisions (e.g. 0.01 g) for m, to reduce the percentage uncertainty.

..... **[4]**

**(b)** **(i)** State *Archimedes' principle*.

The upthrust on an object in a fluid is equal to the weight of the fluid displaced.

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

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**(ii)** Fig. 23.2 shows the metal cylinder from **(a)** hung from a newtonmeter.

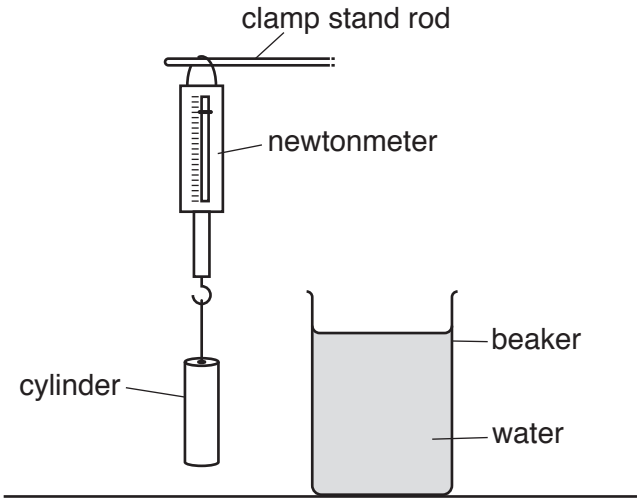


**Fig. 23.2**

The reading on the newtonmeter is 9.0 N.
The cylinder is slowly lowered into water in a beaker until it is completely submerged. The cylinder does not touch the side or the bottom of the beaker. The newtonmeter reading now is 7.8 N. The density of water is 1000 kg m$^{-3}$.
Calculate the density $\rho$ of the metal of the cylinder.

upthrust = 9.0 − 7.8 = 1.2 N = weight of water displaced

volume V = 1.2 ÷ (1000 × 9.81) = 1.223 × $10^{-4}$ $m^3$

mass of cylinder = 9.0 ÷ 9.81 = 0.917 kg

ρ = m ÷ V = 0.917 ÷ 1.223 × $10^{-4}$ = 7500 kg $m^{-3}$

$\rho$ = .....$7.5 \times 10^3$..... kg m$^{-3}$ **[3]**

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**24** **(a)** State *Newton's second law.*

The resultant force on an object is directly proportional to (equal to) the rate of change of its momentum.

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

**(b)** A comet makes an inelastic collision with a small asteroid in space.

**(i)** State **two** physical quantities conserved in this collision.

**1** momentum

**2** total energy

**[1]**

**(ii)** Fig. 24.1 shows how the force *F* acting on the **comet** varies with time *t* during the collision.

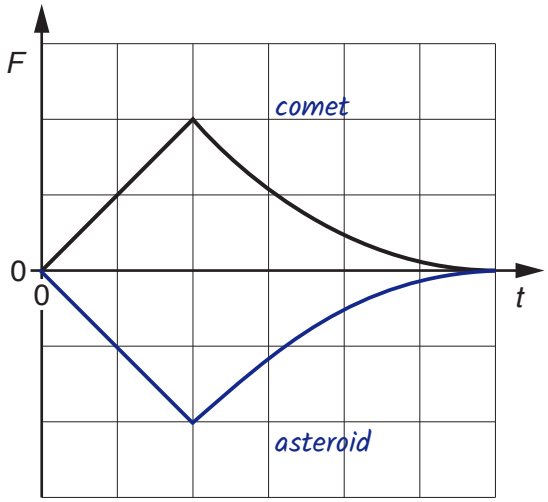


**Fig. 24.1**

Describe and explain how the force acting on the **asteroid** varies with time during this collision. You may sketch a suitable graph on **Fig. 24.1** to support your answer.

By Newton's third law, the force on the asteroid has the same magnitude as the force on the comet at every instant t, but it acts in the opposite direction (negative), as sketched.

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

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**(c)** A hydrogen atom travelling at $500\,m\,s^{-1}$ makes a head-on collision with a stationary carbon atom. The collision is perfectly elastic. After the collision the hydrogen atom bounces back with a speed of $420\,m\,s^{-1}$. Fig. 24.2 shows the atoms before and after the collision.

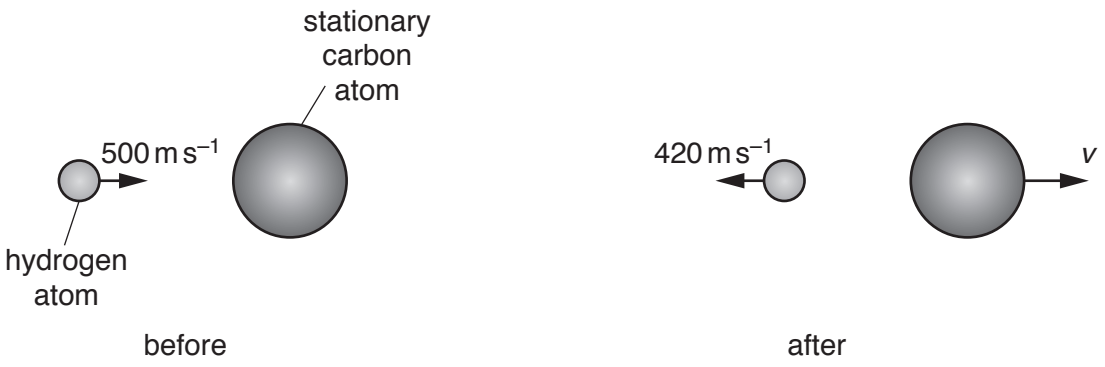


**Fig. 24.2**

The mass of the hydrogen atom is $1.7 \times 10^{-27}$ kg and the mass of the carbon atom is $2.0 \times 10^{-26}$ kg.
Calculate the speed $v$ of the carbon atom after the collision.

Momentum is conserved (taking right as positive):

$1.7 \times 10^{-27} \times 500 = 1.7 \times 10^{-27} \times (-420) + 2.0 \times 10^{-26} \times v$

$8.5 \times 10^{-25} + 7.14 \times 10^{-25} = 2.0 \times 10^{-26}\ v$

$v = 1.564 \times 10^{-24} \div 2.0 \times 10^{-26} = 78\ m\ s^{-1}$

$v$ = .....78..... $m\,s^{-1}$ **[3]**

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**25** **(a)** A chemical cell is connected across a resistor.

**(i)** The terms electromotive force (e.m.f.) and potential difference (p.d.) are terms associated with the circuit.

State **one** similarity and **one** difference between e.m.f. and p.d.

similarity:

Both have the same unit, the volt (both are energy transferred per unit charge).

difference:

For e.m.f., energy is transformed from chemical (other forms) to electrical energy; for p.d., energy is transformed from electrical energy to heat (other forms). **[2]**

**(ii)** The resistor is cylindrical in shape. It has cross-sectional area $1.2 \times 10^{-6}\,m^2$ and length $6.0 \times 10^{-3}\,m$. In this resistor there are $9.6 \times 10^{16}$ free electrons.
Calculate the mean drift velocity $v$ of the electrons when the current in the resistor is 3.0 mA.

$n$ = number of free electrons ÷ volume

$n = 9.6 \times 10^{16} \div (1.2 \times 10^{-6} \times 6.0 \times 10^{-3}) = 1.33 \times 10^{25}\ m^{-3}$

$I = Anev$, so $v = I \div (Ane)$

$v = 3.0 \times 10^{-3} \div (1.2 \times 10^{-6} \times 1.33 \times 10^{25} \times 1.60 \times 10^{-19})$

$v = 1.17 \times 10^{-3}\ m\ s^{-1}$

$v$ = $1.2 \times 10^{-3}$ $m\,s^{-1}$ **[3]**

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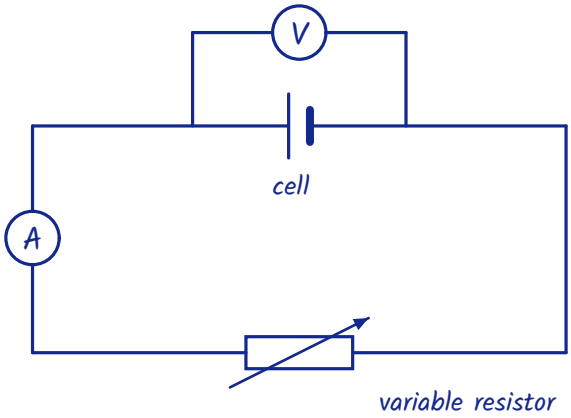
**(b)** A student is given a chemical cell, an ammeter, a voltmeter, a variable resistor and a number of connecting wires.
Design a laboratory experiment to determine the internal resistance *r* of the chemical cell using a graph. Start with a circuit diagram.
In your description pay particular attention to

- the circuit used
- the measurements taken
- how the data is analysed using a graph.




Cell in series with ammeter and variable resistor; voltmeter across the cell terminals.

Measure the current I (ammeter) and terminal p.d. V (voltmeter).

Change the resistance of the variable resistor to get at least 6 sets of I and V.

E = V + Ir, so V = −rI + E. Plot V against I: a straight line with gradient = −r. **[4]**

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**26** **(a)** Fig. 26.1 shows the variation of displacement $y$ with position $x$ of a progressive transverse wave on a stretched string at a particular instant.

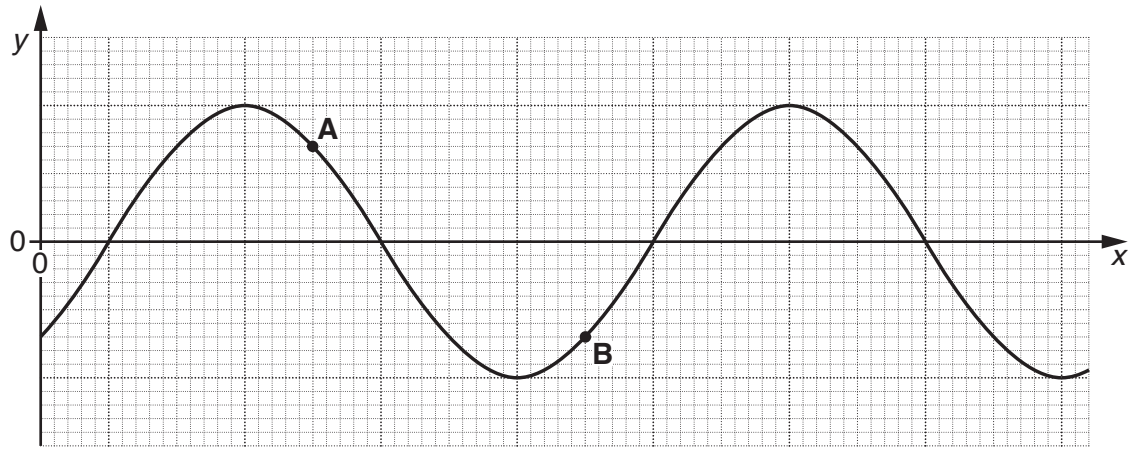


**Fig. 26.1**

The motions of particles **A** and **B** of the string is analysed over a short period of time. The distance between the positions of **A** and **B** is half a wavelength of the wave. The particles **A** and **B** have the same speed.

**(i)** State **one** difference between the motions of these particles.

A and B move in opposite directions (A moves up while B moves down);

they are in antiphase. **[1]**

**(ii)** The particle **A** oscillates with frequency 75 Hz.
The distance between the positions of **A** and **B** is (40.0 ± 2.0) cm.
Calculate the speed $v$ of the transverse wave on the string and the absolute uncertainty in this value.

A to B is half a wavelength, so $\lambda = 2 \times 0.400 = 0.80$ m

$v = f\lambda = 75 \times 0.80 = 60$ m s$^{-1}$

% uncertainty = $(2.0 \div 40.0) \times 100 = 5.0$ %

absolute uncertainty = $0.050 \times 60 = 3.0$ m s$^{-1}$

$v$ = 60 ± 3.0 m s$^{-1}$ **[3]**

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**(b)** A stretched rubber cord has its ends fixed at points **X** and **Y**. The middle of the cord is lifted vertically and then released. A stationary wave pattern with one loop is formed by the vibrating cord, see Fig. 26.2.

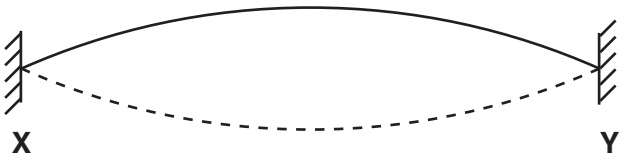


**Fig. 26.2**

**(i)** Explain how a stationary wave pattern is produced in **this** arrangement.

Progressive waves travel along the cord and are reflected at the fixed ends X and Y.

The incident and reflected waves (same frequency and speed, travelling in opposite directions) superpose (interfere) to produce the stationary wave. **[2]**

**(ii)** The stationary wave pattern shown in Fig. 26.2 is produced in the laboratory. Describe how the wavelength of the transverse wave on the stretched cord can be determined.

Measure the length XY of the cord with a metre rule. One loop is half a wavelength, so $\lambda = 2 \times XY$.

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

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**27** Fig. 27.1 shows the $I$-$V$ characteristic of an LED designed to emit blue light.

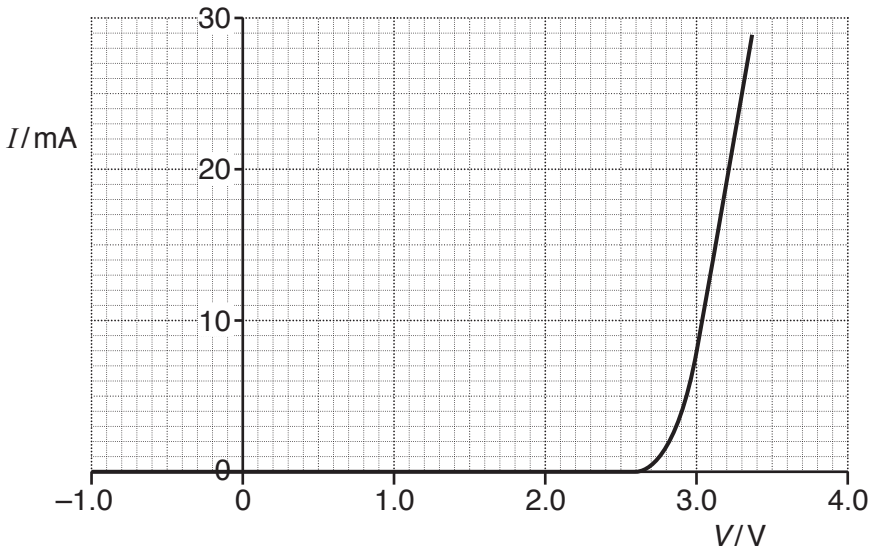


**Fig. 27.1**

**(a)** Describe and justify the variation of resistance $R$ of the LED as the potential difference $V$ across the LED is increased from

- –1.0 V to 2.6 V

I = 0 (negligible) so the resistance R is infinite (very large), e.g. at 2.0 V: R = V/I = 2.0 ÷ 0 = ∞.

- 2.6 V to 3.0 V

R decreases rapidly as I increases sharply. At 3.0 V, I = 8.0 mA, so R = V/I = 3.0 ÷ 8.0 × $10^{-3}$ = 380 Ω.

- 3.0 V to 3.4 V.

R continues to decrease, but more slowly. At 3.3 V, I = 25 mA, so R = 3.3 ÷ 25 × $10^{-3}$ = 130 Ω.

**[4]**

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**(b)** A student uses the LED with the characteristic shown in Fig. 27.1 to construct the circuit shown in Fig. 27.2.

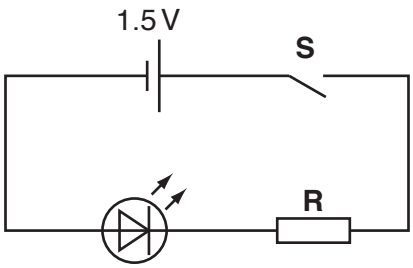


**Fig. 27.2**

A suitable resistor **R** is used in the circuit. The cell has electromotive force (e.m.f.) of 1.5 V and negligible internal resistance.
The LED fails to emit any light when the switch **S** is closed.
Explain why the circuit does not work and modify the design of the circuit so that the LED is lit when **S** is closed.

The LED is reverse biased (the polarity of the cell is wrong), so there is no current.

Also the e.m.f. of 1.5 V is too small; the p.d. across the LED must be greater than 2.6 V for it to conduct and emit light.

Modification: reverse the LED (or the cell) so it is forward biased, and use two 1.5 V cells in series (a 3.0 V supply), so the p.d. across the LED is greater than 2.6 V. **[3]**

**(c)** The wavelength of light from the LED is 480 nm. The radiant power emitted from the LED is 1.2 mW.
Calculate the number of photons *N* emitted from the LED per second.

$E = hc/\lambda = 6.63 \times 10^{-34} \times 3.00 \times 10^{8} \div 480 \times 10^{-9}$

$E = 4.14 \times 10^{-19}$ J

$N = P \div E = 1.2 \times 10^{-3} \div 4.14 \times 10^{-19}$

$N = 2.9 \times 10^{15}$ $s^{-1}$

*N* = $2.9 \times 10^{15}$ $s^{-1}$ **[3]**

**END OF QUESTION PAPER**

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## ADDITIONAL ANSWER SPACE

If additional space is required, you should use the following lined page(s). The question number(s) must be clearly shown in the margin(s).

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