OCR
Oxford Cambridge and RSA

Monday 20 May 2019 – Afternoon

A Level Physics B (Advancing Physics)

H557/01 Fundamentals of Physics

Time allowed: 2 hours 15 minutes

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

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

Please write clearly in black ink. **Do not write in the barcodes.**

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

First name(s) ______________________

Last name ______________________

INSTRUCTIONS
- Use black ink. You may use an HB pencil for graphs and diagrams.
- Answer **all** the questions.
- Where appropriate, your answers should be supported with working. Marks may be given for a correct method even if the answer is incorrect.
- Write your answer to each question in the space provided. If additional space is required, use the lined page(s) at the end of this booklet. The question number(s) must be clearly shown.

INFORMATION
- The total mark for this paper is **110**.
- The marks for each question are shown in brackets **[ ]**.
- Quality of extended responses will be assessed in questions marked with an asterisk (*).
- This document consists of **44** pages.

SECTION A

You should spend a maximum of 40 minutes on this section.

Write your answer for each question in the box provided.

Answer **all** the questions.

1 The unit of electrical conductance is the siemens S, 1 S is the same as

A $1\,J\,C^{-1}$

B $1\,A\,V^{-1}$

C $1\,C\,V^{-1}$

D $1\,\Omega^{-1}\,m^{-1}$

Your answer ☐ **[1]**

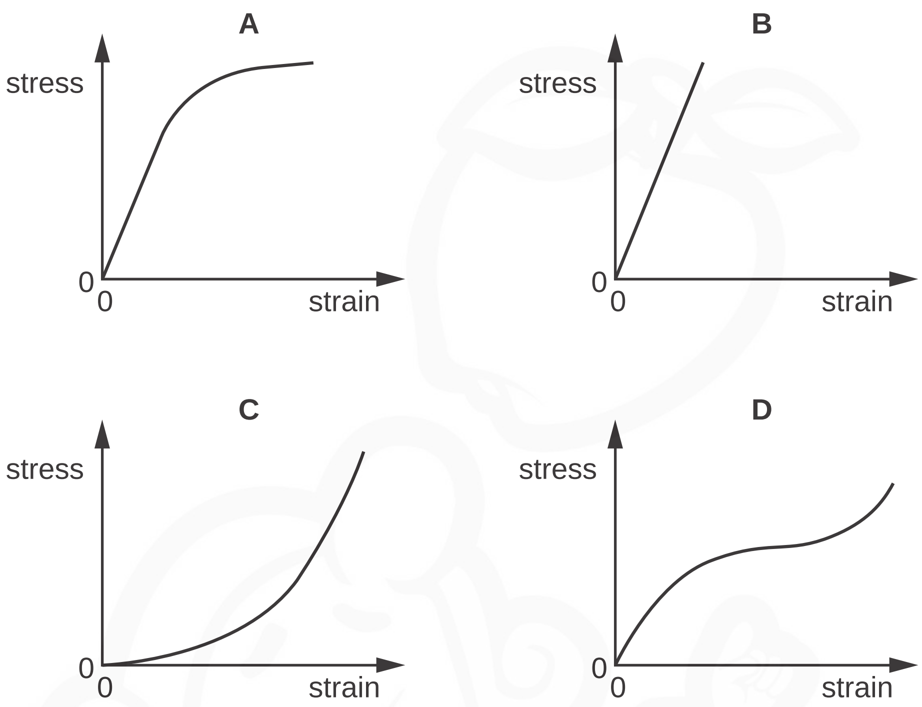
2 Which quantity is followed by a reasonable estimate of its order of magnitude?

A	momentum of a bee in flight	$10^{0}\,kg\,m\,s^{-1}$
B	speed of an air molecule at room temperature	$10^{6}\,m\,s^{-1}$
C	wavelength of red light	$10^{-6}\,m$
D	wavelength of X-rays	$10^{-15}\,m$

Your answer ☐ **[1]**

The following information is for use in questions **3** and **4**.

The stress–strain graphs for four different materials are shown.



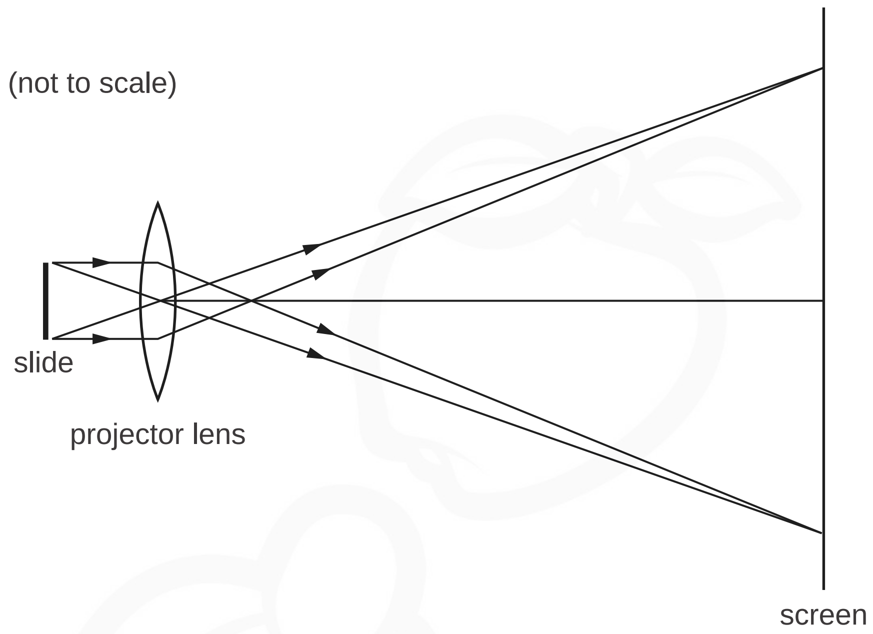
3 Which diagram shows the stress–strain graph for a ductile metal?

Your answer ☐ **[1]**

4 Which diagram shows the stress–strain graph for a rubber polymer?

Your answer ☐ **[1]**

5 A slide projector has a lens of focal length *f*. It is set up to give a large, magnified focused image on a screen. The screen is further than 2*f* from the lens centre.



Where is the slide (object) placed?

A further than 2*f* from the lens centre

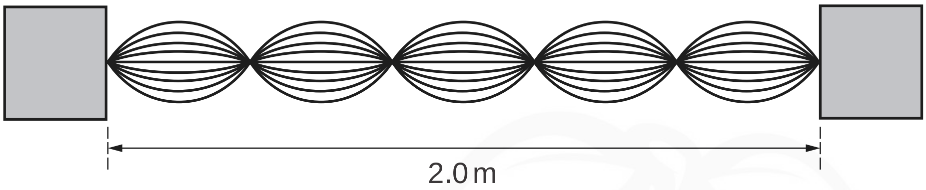
B at 2*f* from the lens centre

C between 2*f* and *f* from the lens centre

D at *f* from the lens centre

Your answer ☐ **[1]**

The diagram is for use in questions **6** and **7**.
The diagram shows a sketch of a wave pattern on a vibrating string.



6 Which description of this wave is correct?

A The wave is longitudinal, has a wavelength of 40 cm and is stationary.

B The wave is transverse, has a wavelength of 40 cm and is stationary.

C The wave is transverse, has a wavelength of 80 cm and is progressive.

D The wave is transverse, has a wavelength of 80 cm and is stationary.

Your answer ☐ **[1]**

7 The frequency of the wave shown in the diagram is 3.0 Hz.

What is the wave speed on the string?

A $1.2\,m\,s^{-1}$

B $2.4\,m\,s^{-1}$

C $3.8\,m\,s^{-1}$

D $7.5\,m\,s^{-1}$

Your answer ☐ **[1]**

8 A signal is digitised by sampling at 22 kHz.
The total voltage variation is 2.0 V and the noise voltage variation is 1.0 mV.

Which statement is correct?

A The highest frequency accurately sampled will be 11 kHz.

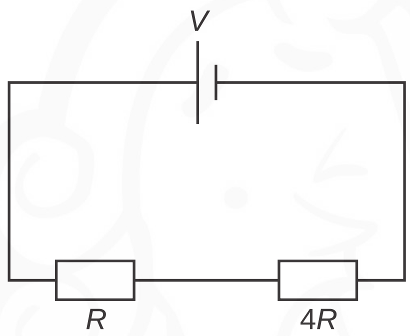
B The recommended number of bits per sample is 8.

C The voltage resolution of the sampling should be about 0.1 mV.

D $\frac{V_{total}}{V_{noise}} \approx 11 \times 10^3$

Your answer ☐ **[1]**

9 The circuit shows a potential divider with resistors of R and $4R$.



What is the ratio $\frac{\text{power dissipated in resistor } R}{\text{power dissipated in resistor } 4R}$?

A $\frac{1}{16}$

B $\frac{1}{4}$

C $\frac{4}{5}$

D 4

Your answer ☐ **[1]**

10 A student is calculating the charge carrier number density of a metal.
She knows how many free electrons each atom contributes, the density of the metal and the molar mass of the metal.

Which further piece of information does she need to calculate the charge carrier number density?

A the Avogadro constant

B the charge on the electron

C the crystal structure of atomic packing

D the electrical conductivity of the metal

Your answer ☐ **[1]**

11 A nickel wire has conductance of 0.43 S, a length of 2.0 m and a cross-sectional area of $5.0 \times 10^{-7}\,\text{m}^2$.

What is the conductivity of nickel in S m^{-1}?

A 1.1×10^{-7}

B 5.9×10^{-7}

C 1.7×10^{6}

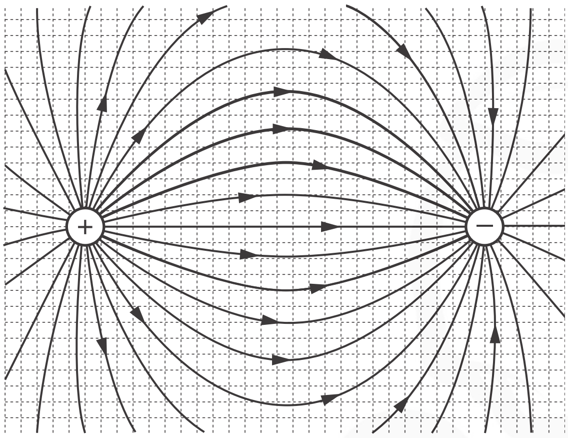
D 9.3×10^{6}

Your answer ☐ **[1]**

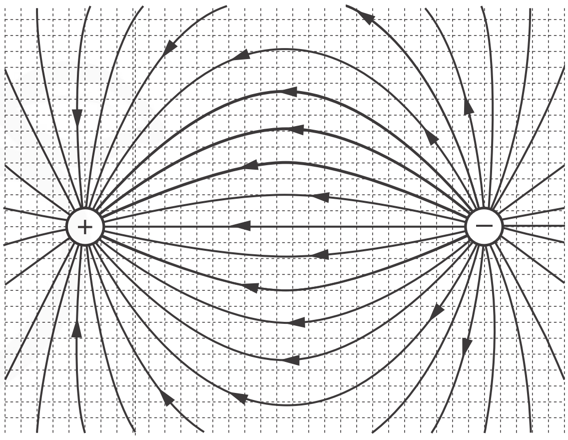
12 A positive and a negative charge of equal magnitude are placed near each other.

Which diagram best represents the electric field of the two charges?

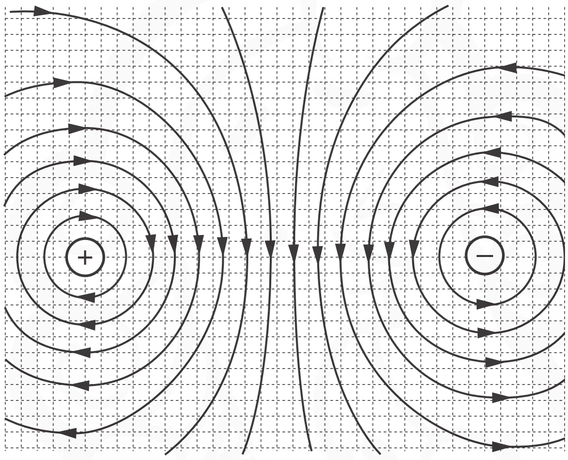
A



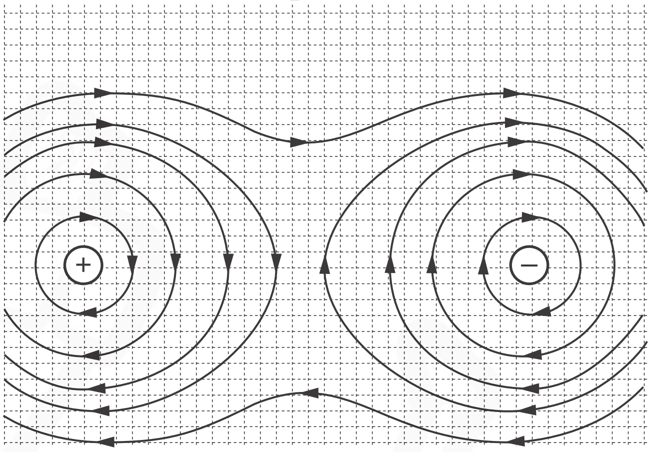
B



C

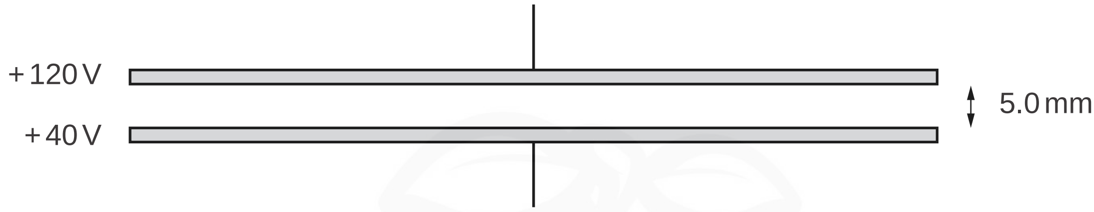


D



Your answer ☐ **[1]**

13 Two horizontal metal plates are 5.0 mm apart.
The plates are at potentials of +120 V and +40 V.



What is the force experienced by an electron in the electric field between the plates?

A 2.6×10^{-18} N

B 5.1×10^{-18} N

C 2.6×10^{-15} N

D 5.1×10^{-15} N

Your answer ☐ **[1]**

14 The resistance *R* of an unknown resistor is found by measuring the potential difference *V* across the resistor and the current *I* through it, using the equation

$R = \frac{V}{I}$.

The voltmeter reading has a 2% uncertainty and the ammeter reading has a 3% uncertainty.
What is the best estimate of the uncertainty in the calculated resistance?

A 0.7%

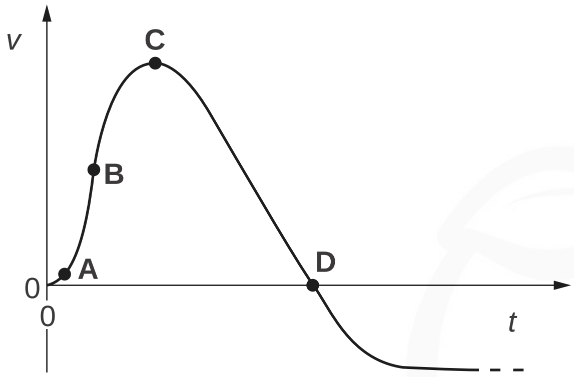
B 3%

C 5%

D 6%

Your answer ☐ **[1]**

The following information is for use in questions **15** and **16**.



The graph shows how the vertical velocity *v* of a firework rocket changes with time *t*.

15 At which point labelled on the graph does the rocket have the greatest acceleration?

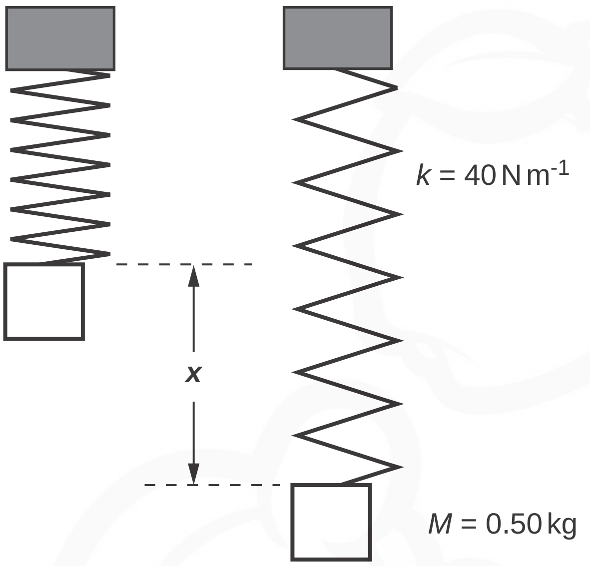
Your answer [ ] **[1]**

16 At which point labelled on the graph does the rocket have the greatest altitude?

Your answer [ ] **[1]**

17 The spring in this diagram has a spring constant k of 40 N m^{-1}.
The mass M of 0.50 kg is attached to the end of the suspended spring and then dropped under gravity.

acceleration due to gravity g = 10 m s^{-2}



What is the maximum extension x of the spring in metres when the mass first comes to rest?

(Use ideas about energy conservation.)

A $\frac{1}{8}$

B $\frac{1}{4}$

C $\frac{1}{2}$

D 1

Your answer ☐ **[1]**

18 A fixed mass of gas occupies a volume *V*. The temperature of the gas is increased so that the mean square speed of the molecules is doubled.

What is the new volume of the gas, if the pressure remains constant?

A $\frac{V}{2}$

B $\frac{V}{\sqrt{2}}$

C $2V$

D $4V$

Your answer ☐ **[1]**

19 Protons consist of quarks.

The 'up' anti-quark has a charge of $-\frac{2e}{3}$ and the 'down' anti-quark has a charge of $+\frac{1e}{3}$, where *e* is the charge on an electron.

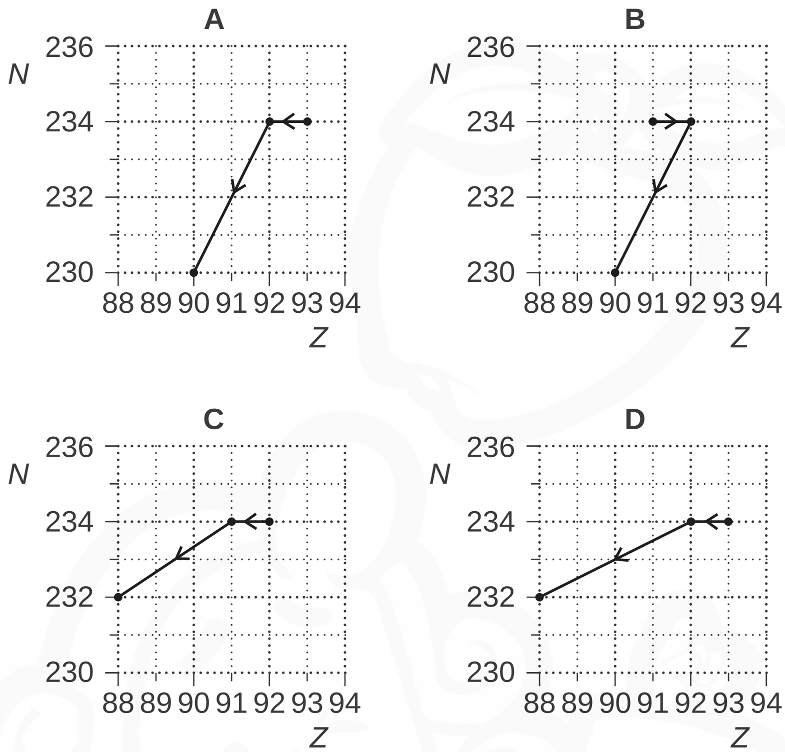
What does an **anti-proton** contain?

	Up anti-quarks	Down anti-quarks
A	0	3
B	1	1
C	1	2
D	2	1

Your answer ☐ **[1]**

20 A radioactive nucleus is formed by β-decay. This nucleus then decays by α-emission.

Which graph of nucleon number *N* plotted against proton number *Z* shows the β-decay followed by the α-emission?



Your answer ☐ **[1]**

The following information is for use in questions **21** and **22**.

Two radioactive sources of equal mass are freshly prepared.
One is ^{225}Ra, which has a half-life of 15 days.
The other is ^{225}Ac, which has a half-life of 10 days.

21 After 30 days which ratio gives $\dfrac{\text{number of } ^{225}\text{Ra atoms remaining}}{\text{number of } ^{225}\text{Ac atoms remaining}}$?

A $\frac{1}{2}$

B $\frac{3}{4}$

C $\frac{4}{3}$

D 2

Your answer ☐ **[1]**

22 After 30 days which ratio gives $\dfrac{\text{activity of the } ^{225}\text{Ra source}}{\text{activity of the } ^{225}\text{Ac source}}$?

A $\frac{1}{2}$

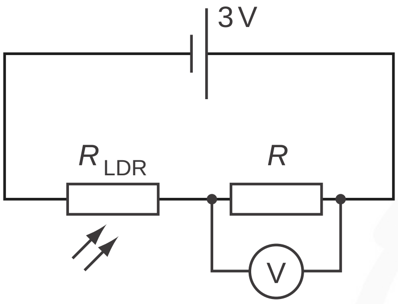
B $\frac{3}{4}$

C $\frac{4}{3}$

D 2

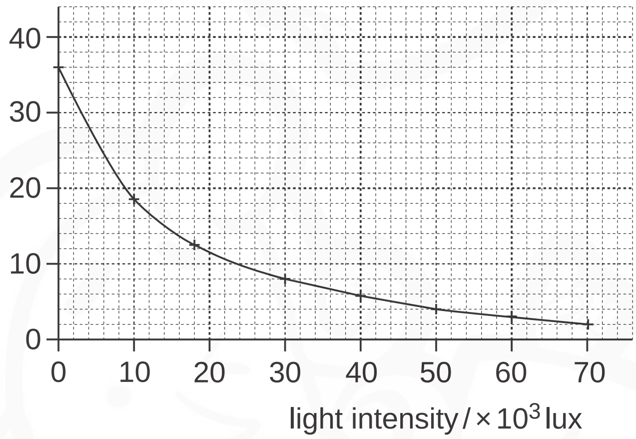
Your answer ☐ **[1]**

23 An LDR is used in a potential divider circuit.



The graph shows the LDR resistance against light intensity.

LDR resistance R_{LDR} / kΩ



When the light intensity on the LDR is 30 × 10^3 lux, the reading on the voltmeter is 2.0 V.
What is the resistance R of the resistor?

A 4.0 kΩ

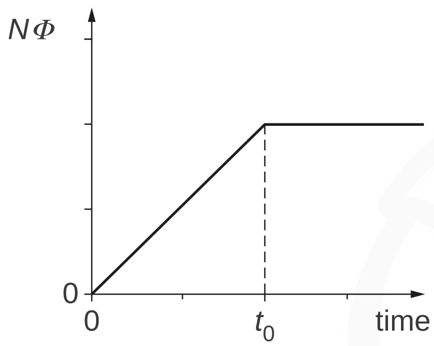
B 8.0 kΩ

C 12 kΩ

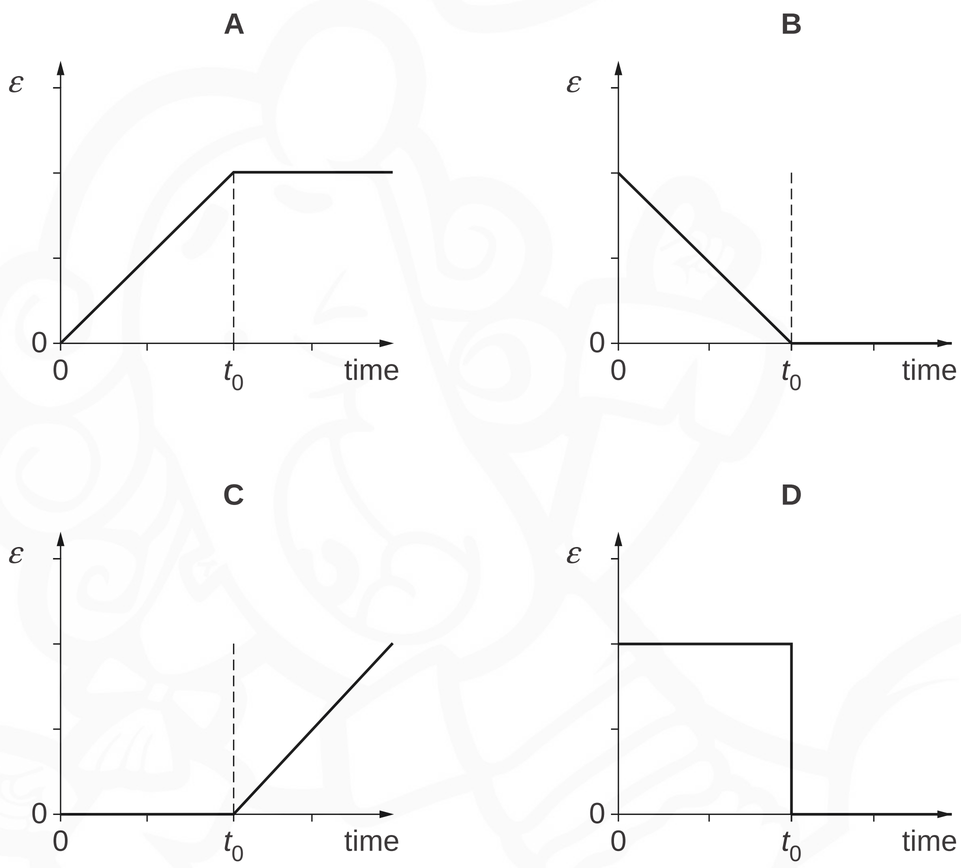
D 16 kΩ

Your answer ☐ **[1]**

24 The graph shows how the flux linkage $N\Phi$ through a coil changes with time when the coil is moved into a magnetic field.



Which of the following graphs shows the magnitude of the induced e.m.f. ε in the coil over the same time period?



Your answer

[1]

The following information is for use in questions **25** and **26**.

A beam of α-particles collides with a lead sheet and is absorbed.
Each α-particle in the beam has a mass of 7×10^{-27} kg and a speed of 1×10^{7} m s^{-1}.
3×10^{3} α-particles per second collide with an area of 1×10^{-4} m^{2} of lead.

25 What is the best estimate of the average pressure exerted on the lead by the α-particles?

A 2×10^{-20} Pa

B 2×10^{-16} Pa

C 2×10^{-12} Pa

D 2×10^{-8} Pa

Your answer ☐ **[1]**

26 What is the best estimate of the energy of **one** of the α-particles?

A 2.2 MeV

B 3.5 MeV

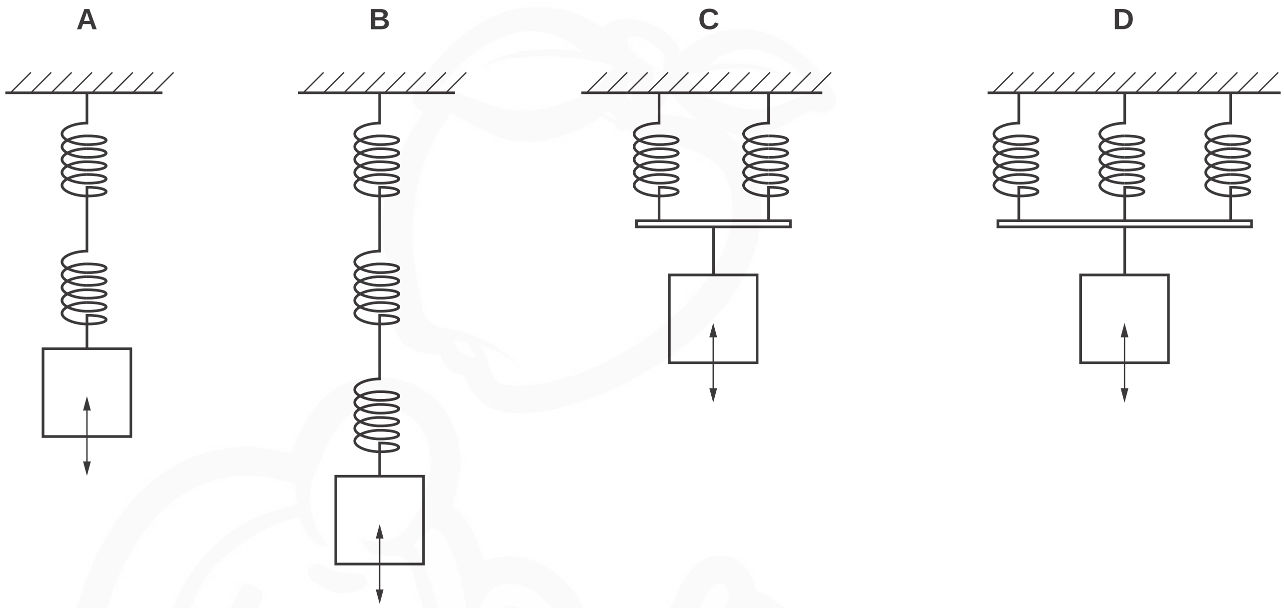
C 4.4 MeV

D 5.6 MeV

Your answer ☐ **[1]**

This diagram is for use in questions **27** and **28**.

It shows a number of identical springs attached to identical masses joined in four different arrangements. Each spring constant is *k* and each mass is *m*.



27 Which of the arrangements will give the simple harmonic oscillator of **lowest** frequency?

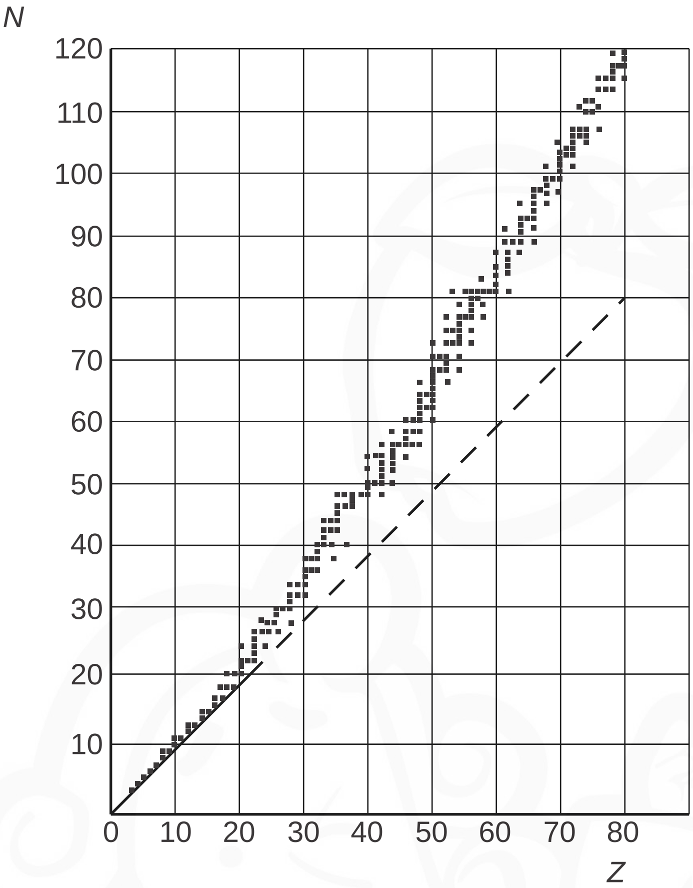
Your answer ☐ **[1]**

28 Which of the arrangements will give a simple harmonic oscillator whose frequency *f* is given by the following equation?

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

Your answer ☐ **[1]**

29 The graph shows neutron number N plotted against proton number Z for stable nuclei.



Which statements about stable nuclei are correct?

1 Nuclei of elements with $Z > 20$ have more protons than neutrons.

2 For the nuclei of lighter elements $N \approx Z$.

3 Greater $\frac{N}{Z}$ ratio is needed to hold larger nuclei together, because only nearest neighbour nucleons take part in the strong nuclear force of attraction to balance electrostatic repulsion.

A 1, 2 and 3 are correct

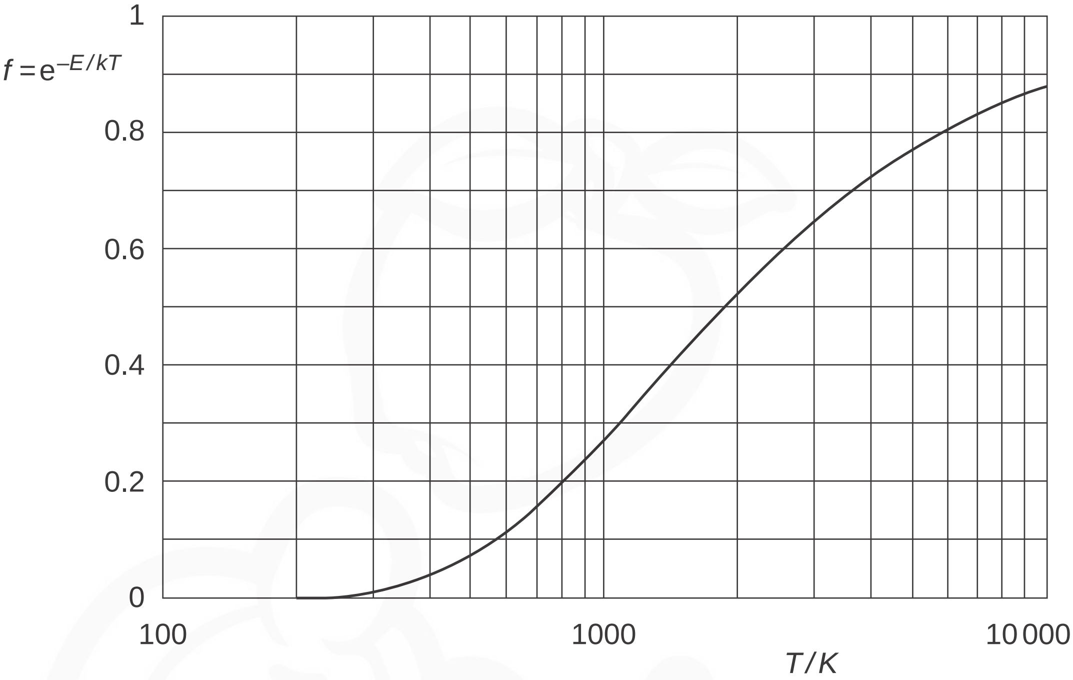
B only 1 and 2 are correct

C only 2 and 3 are correct

D only 1 is correct

Your answer [ ] **[1]**

30 The graph shows how the Boltzmann factor $f = e^{-E/kT}$ varies with absolute temperature T for an excitation process involving activation energy E.



Which is the best estimate of the activation energy?

A 8×10^{-21} J

B 2×10^{-20} J

C 8×10^{-20} J

D 2×10^{-19} J

Your answer

[1]

SECTION B

Answer **all** the questions.

31 A student finds two electrical resistors; one is labelled 50 Ω and the other 0.10 S.

(a) Calculate the total resistance of the two resistors when in series.

total resistance = ... Ω **[1]**

(b) Calculate the total conductance of the two resistors when in parallel.

total conductance = ... S **[1]**

32 A ball is projected horizontally twice with different velocities from 44 m above the base of a vertical cliff as shown in **Fig. 32**.

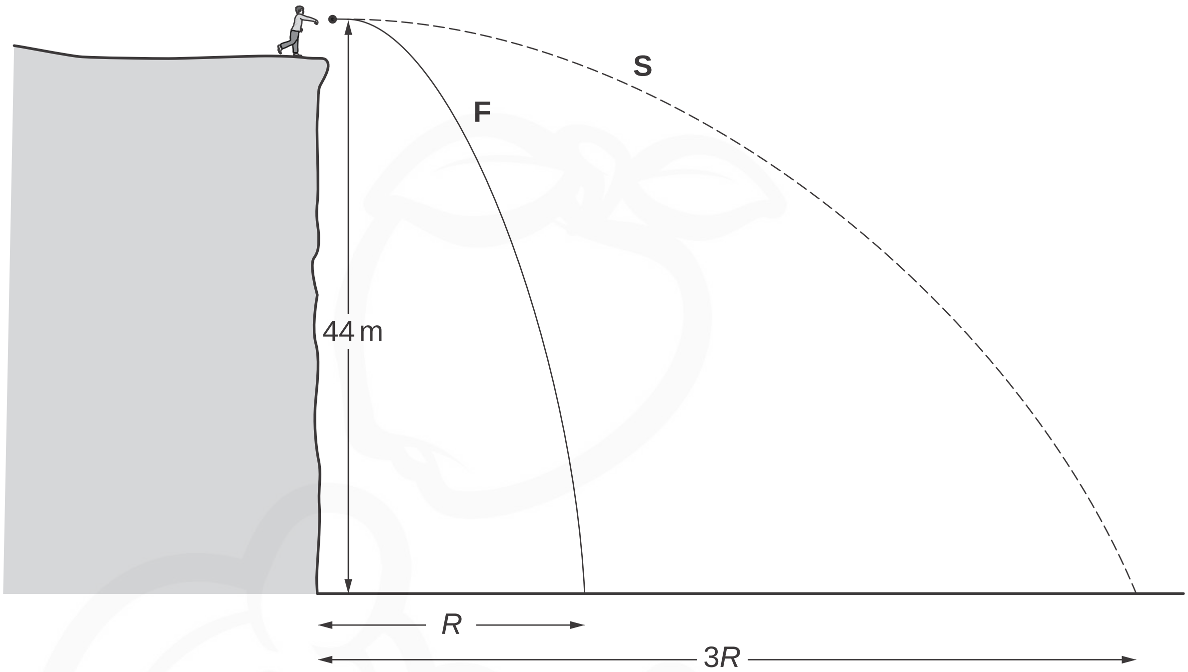


Fig. 32

(a) The first throw path **F** has initial horizontal velocity of $8.0\,\text{m}\,\text{s}^{-1}$.

Calculate the horizontal range R for this path. You may ignore the effects of air resistance.

Gravitational acceleration, $g = 9.8\,\text{m}\,\text{s}^{-2}$.

R = ... m **[3]**

(b) The second path **S** is also from a horizontal projection and achieves a range that is three times larger ($3R$) than the first path **F**.

State the initial horizontal projection velocity for path **S**. Make your reasoning clear.

initial projection velocity = ... $\text{m}\,\text{s}^{-1}$ **[2]**

33 A step-down transformer is shown in **Fig. 33**. Treat it as an ideal transformer.

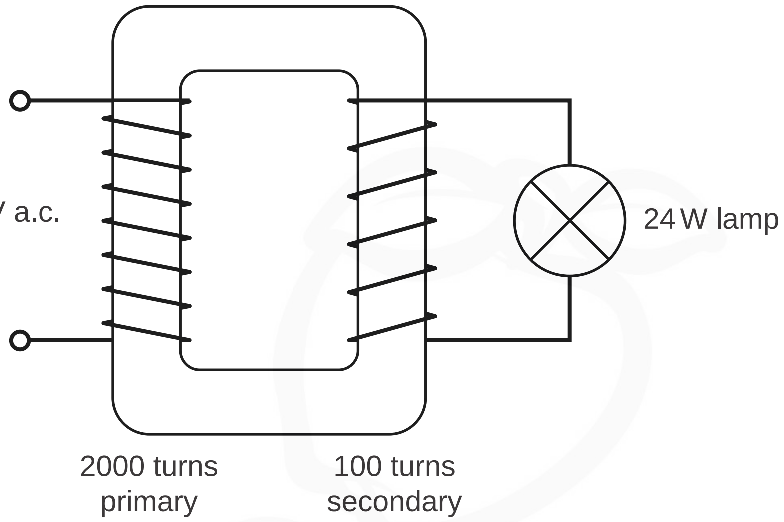


Fig. 33

(a) **(i)** Calculate the voltage across the lamp on the secondary coil.

voltage = ... V **[2]**

(ii) Calculate the current flowing in the primary coil.

current = ... A **[2]**

(b) Real transformers are not ideal because of energy losses.

State **one** reason for energy losses in transformers.

....

.... **[1]**

34 Subatomic particles called π^- mesons are produced with a kinetic energy of 73 MeV.
The rest mass for π^- mesons is 140 MeV.

(a) **(i)** Show that the relativistic time dilation factor γ for these particles is less than 2.

γ = ... **[2]**

(ii) Show that they are travelling at about 0.75 c.

[2]

(b) The mean lifetime of π^- mesons at low speeds is 2.6×10^{-8} s.

Calculate the mean distance the fast mesons will travel before decaying.

mean distance = ... m **[2]**

35 **Fig. 35** (not to scale) shows a double slit illuminated by laser light.
The positions of the central maximum and the first minimum for the waves incident on a distant screen are shown. The phasors representing these waves are given in the first and fourth rows of the table below. Positions **A** and **B** divide the distance between the central maximum and the first minimum into equal thirds.

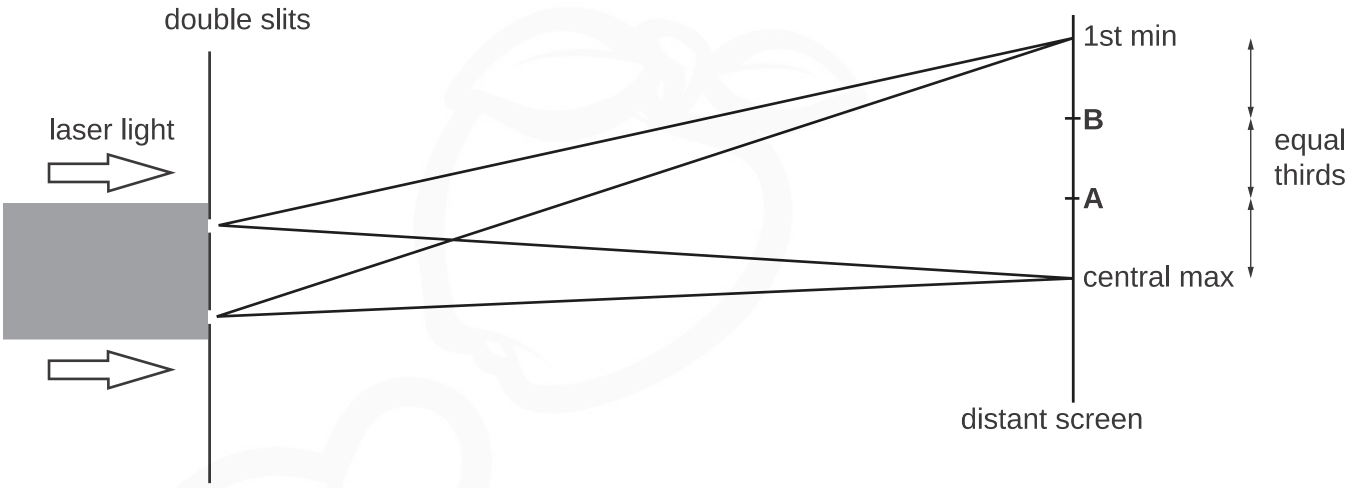
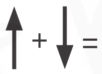
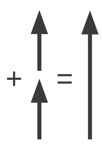


Fig. 35 (not to scale)

Position	**Phasors**	**Resultant phasor**	**Relative intensity**
1st min		0	0
B		1	1
A			
central max		2	4

Complete the table above for positions **A** and **B**, showing the phasors, their addition and the value of the relative intensity at the distant screen. **[3]**

SECTION C

Answer **all** the questions.

36 This question considers the digital image processing of medical images. **Fig. 36.1** compares the response to radiation of photographic film **F** and a digital X-ray detector **D**.

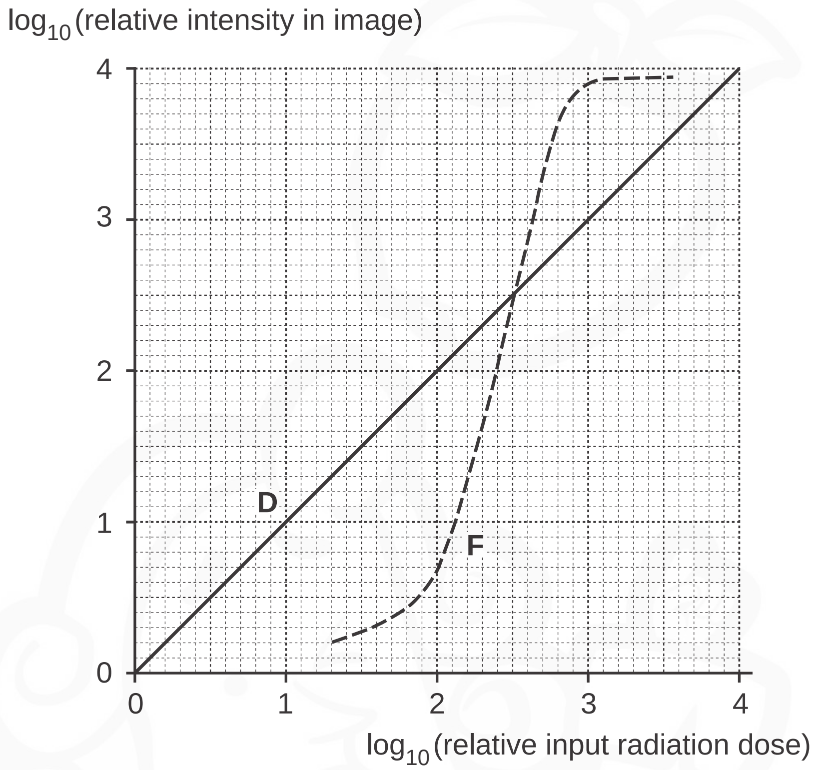


Fig. 36.1

(a) **(i)** State why a log – log scale has been used to represent the data.

....

.... **[1]**

(ii) State an advantage that the response of the detector **D** has over that of the film **F**.

....

.... **[1]**

(iii) For detector **D** the relative intensity is the pixel value.

Show that 14 bits per pixel are enough to cover the range of intensities plotted.

[2]

(b) **Fig. 36.2** and **Fig. 36.3** show an X-ray digital detector image before and after image processing.

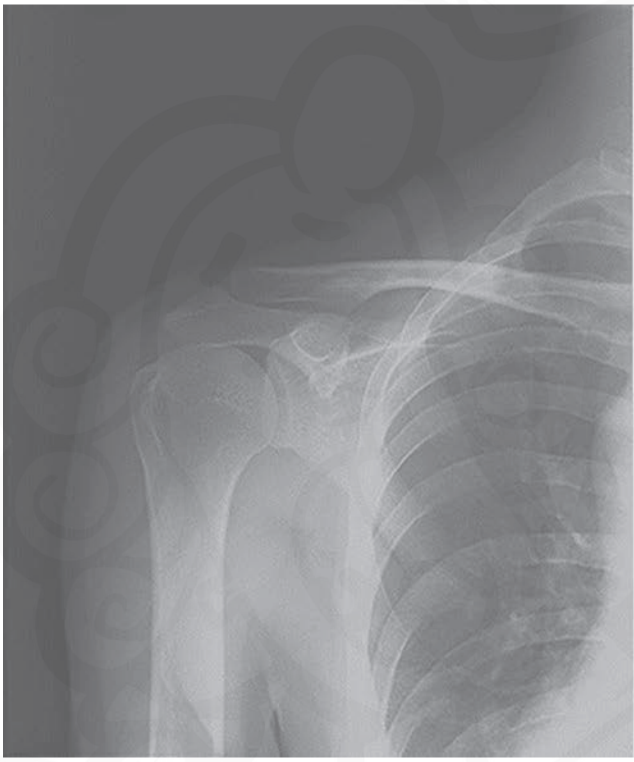


Fig. 36.2

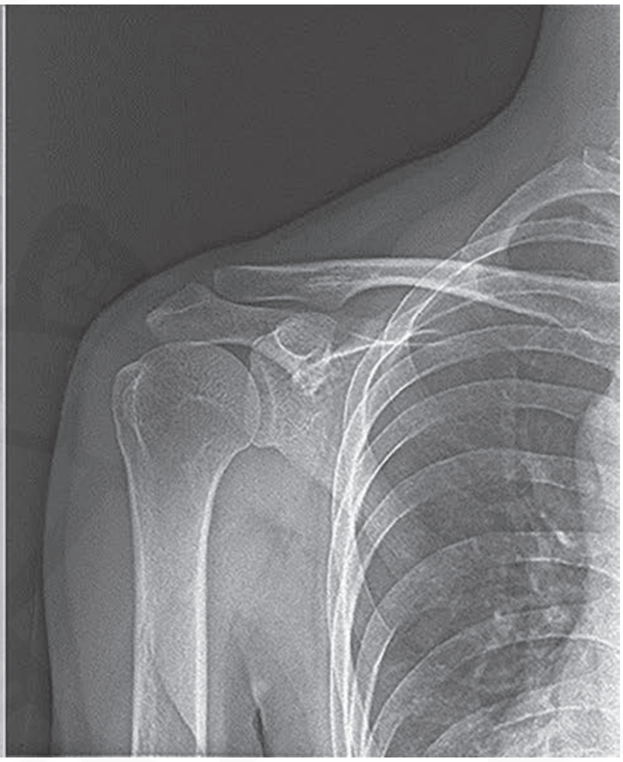


Fig. 36.3

(i) The image format is 2048 × 1680 pixels with 4096 greyscale levels.

Calculate the amount of memory in bits needed to store an uncompressed image.

memory required = ... bits **[2]**

(ii) During image processing the radiologist interpreting the image can stretch the contrast of the bone structures (whiter parts of image) more than the darker regions.

Suggest a benefit to the radiologist of having different contrast adjustment applied to different pixel value ranges.

....

....

....

.... **[1]**

(iii) Identify **one** process (other than contrast improvement) that has been applied to the image in **Fig. 36.2** to produce the enhanced image in **Fig. 36.3**. Suggest the benefit to the radiologist interpreting the image.

....

....

....

....

.... **[1]**

37 This question is about the fusion of the nuclei of the hydrogen isotopes ^{2}H and ^{3}H to produce helium ^{4}He. **Fig. 37.1** shows the average binding energy per nucleon against the nucleon number.

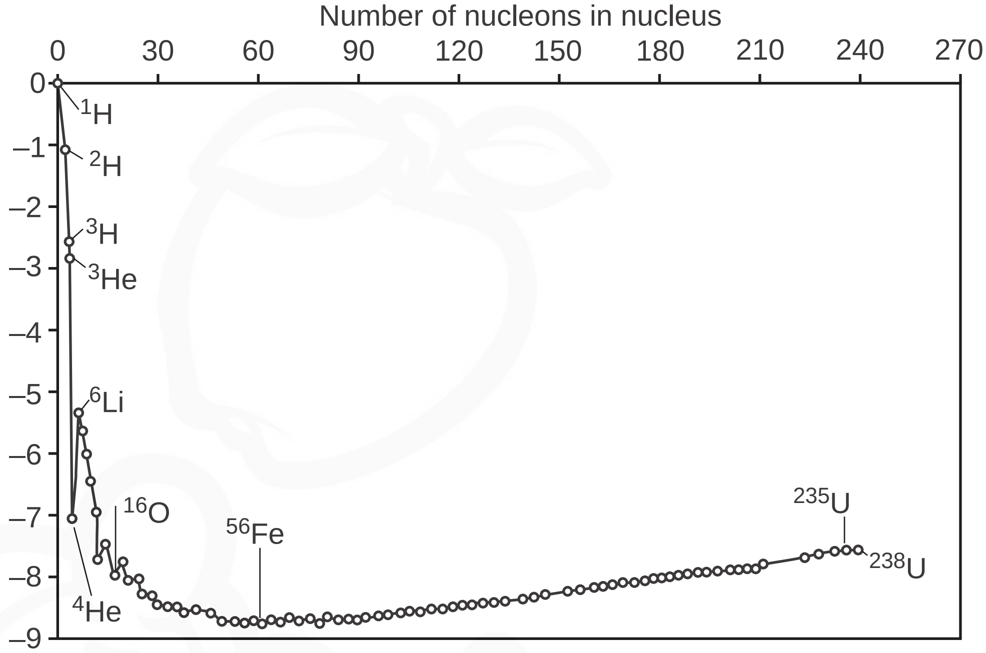


Fig. 37.1

(a) **(i)** Complete the equation for this fusion reaction:

$$^{2}_{1}H + ^{3}_{1}H \rightarrow ^{4}_{....}He + ^{....}_{....}n + \text{ released binding energy.}$$ **[1]**

(ii) Use data from **Fig. 37.1** to show that the binding energy released in this reaction is more than 15 MeV.
You should calculate the binding energy of the reactants (hydrogen nuclei) and products.

1 reactants binding energy = ...

2 products binding energy = ...

[2]

(iii) Use ideas about momentum to explain why the neutron carries away about $\frac{4}{5}$ of this energy.

....

....

....

.... **[2]**

(b) **(i)** To estimate the temperature at which ^{2}H and ^{3}H nuclei will fuse, a student writes down the formula:

$$\frac{e^2}{4\pi\varepsilon_0 R} \approx kT$$

Explain what the two sides of the approximation tell us:

1 $\frac{e^2}{4\pi\varepsilon_0 R}$

2 kT

[2]

(ii) Use the equation in **(b)(i)** to estimate this temperature when $R \approx 2 \times 10^{-14}$ m.

temperature = ... K **[1]**

(c) An experimental fusion reactor uses many powerful lasers focused onto a small spherical bead of solid ^{2}H and ^{3}H. The volume of the bead is 4.2 mm^{3}.
The aim is to produce a plasma implosion where fusion will begin when the temperature and density are high enough.

(i) The density of the bead of solid ^{2}H and ^{3}H (1:1 ratio by atoms) is 230 kg m^{-3}.

Estimate the energy needed to produce plasma at 400 MK from this bead of material.

energy = ... J **[3]**

(ii) Compare this to the possible fusion energy released by the bead.

Use your answer to **(a)(ii)**. You can assume 100% conversion to ^{4}He.

[2]

(iii) Suggest **one** practical difficulty in obtaining energy by this method.

....

....

.... **[1]**

38 This question is about the orbits of two comets **A** and **B** around the Sun.
Fig. 38.1 shows that comet **A** is in a circular orbit and comet **B** is in an elliptical orbit.
Comet **B** is shown in two positions: **B1** approaching the Sun and **B2** receding from the Sun.
Vectors have been added to represent the velocities and the gravitational forces acting on the comets in the positions shown.

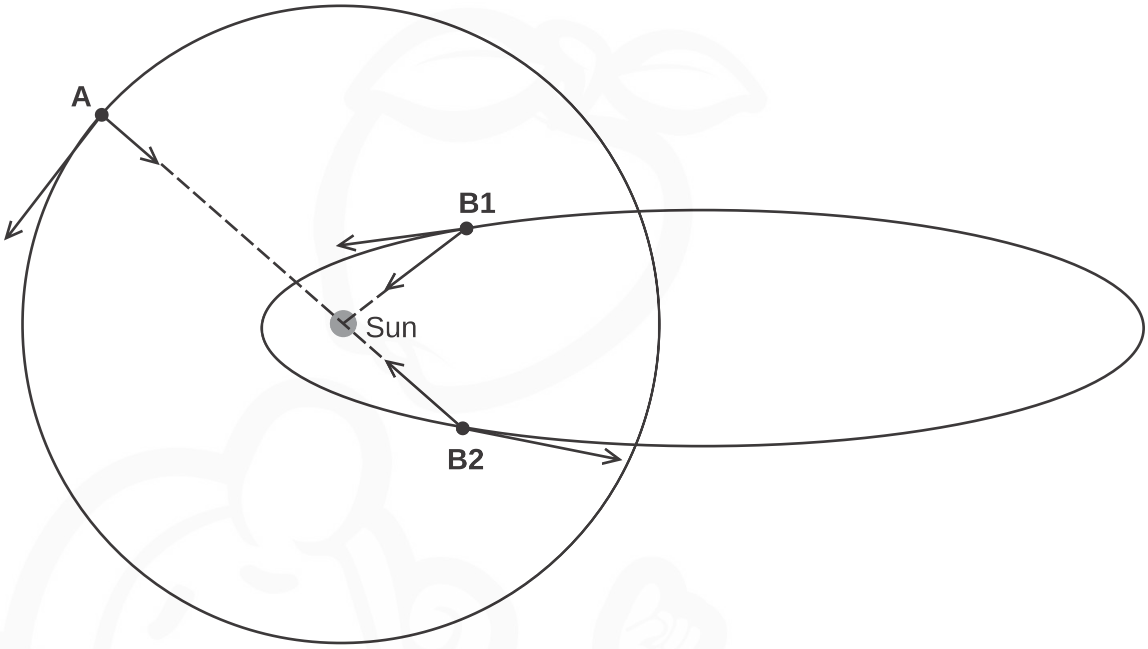


Fig. 38.1

(a)* Compare and explain the orbits of the comets.

In your answer explain how the circular orbit can have a constant speed, and why the elliptical orbit cannot. Consider the role played by the force of gravity, and gravitational potential energy, in changing the velocity of the comets around their orbits.
You may find it useful to use labels on **Fig. 38.1** as part of your answer. **[6]**

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Additional answer space if required.

Question 38 continues on page 34

(b) It is believed that there is a black hole at the centre of our galaxy which is 26000 light-years away. The orbits of several individual stars around the black hole have been determined. **Fig. 38.2** shows the orbits of two stars, around the black hole, in the plane perpendicular to the line of sight from Earth. **S1** is in a nearly circular orbit and **S2** is in an elliptical orbit. The position of the black hole is at the centre of the angle scale.

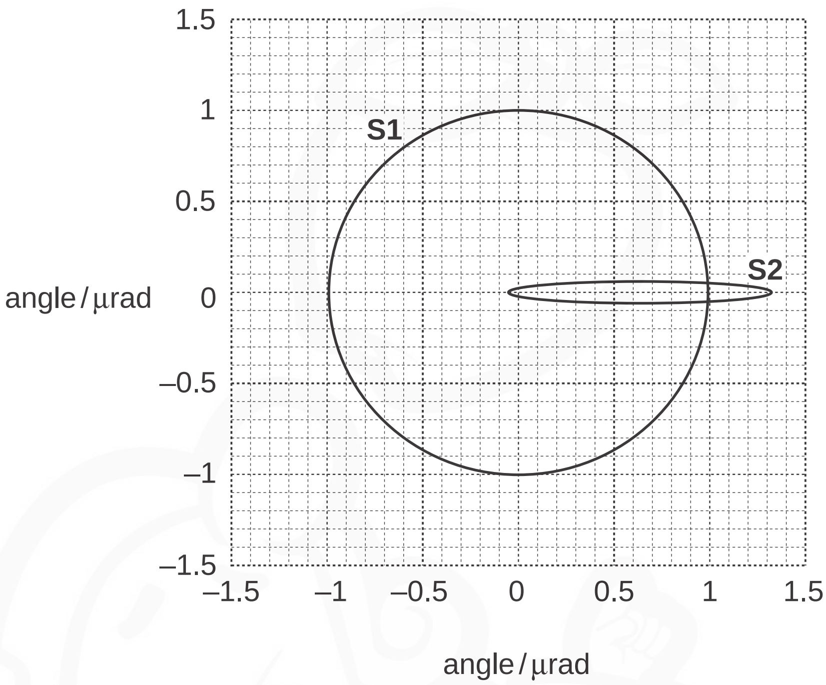

Fig. 38.2

(i) Show that the radius of the **S1** orbit is more than 2×10^{14} m.

1 light year ≈ 9.5×10^{15} m.

[2]

(ii) The orbital period of **S1** is 33 years.

Show that the mass of the black hole is about 4 million times the mass of the Sun.

Mass of the Sun ≈ 2.0×10^{30} kg.

[3]

(iii) Star **S2** is in an elliptical orbit around the black hole.
The closest approach of **S2** to the central mass is 6.5×10^{12} m.

The Schwarzschild radius R_S of a massive body is the radius inside which its escape velocity would be greater than light speed and is given by:

$$R_S = \frac{2GM}{c^2}$$

Show that the Schwarzschild radius of the object at the galactic centre is less than the closest approach of star **S2**.

[1]

39 **Fig. 39.1** shows the charging of a 50 mF capacitor by a 10 V supply.

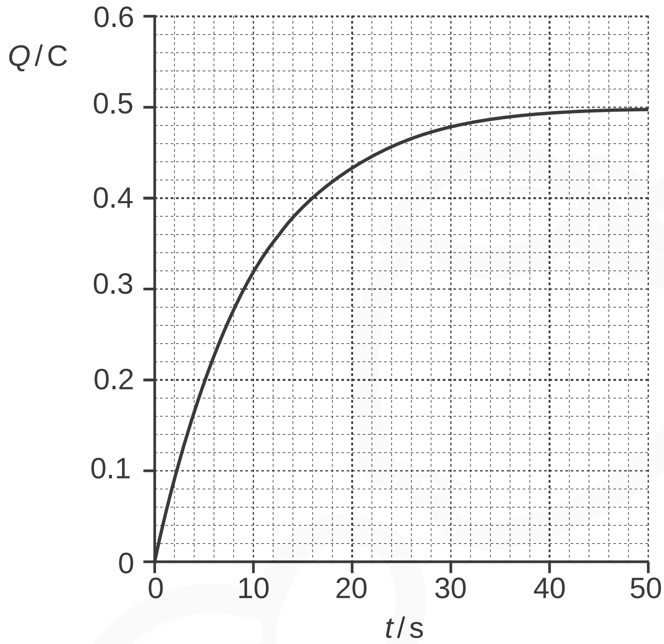

Fig. 39.1

(a) **(i)** Use the graph to find the initial current when the capacitor starts to charge. Make your method clear.

initial current = ... A **[2]**

(ii) Calculate the size of the electrical resistance in the charging circuit.

resistance = ... Ω **[2]**

(b) Explain why the charging current decreases as the capacitor charges.

....

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.... **[1]**

(c) **(i)** A student makes an iterative model for the charging of the capacitor in **(a)**, using time intervals Δt = 2.0 s. The start conditions and the situation at times t = 2.0 s and 4.0 s have been correctly completed in the table below.

Time lapsed / s t	**Charge Q on capacitor / C** $Q = (Q + \Delta Q)$	**P.d. across capacitor / V** $V_C = \frac{Q}{C}$	**Current flowing / A** $I = \frac{V_R}{R} = \frac{(10 - V_C)}{200}$	**Charge ΔQ arriving in time interval Δt = 2 s / C** $\Delta Q \approx I\,\Delta t$
0	0	0	10/200 = 0.050	0.05 × 2 = 0.1
2.0	0.10	0.1/0.05 = 2.0	8/200 = 0.040	0.04 × 2 = 0.08
4.0	0.18	0.18/0.05 = 3.6	6.4/200 = 0.032	0.032 × 2 = 0.064
6.0	....	....	....	....

Complete the numerical values at time t = 6.0 s in the cells in the table. **[2]**

(ii) Compare the model values for the charge Q on the capacitor at time t = 4.0 s with the experimental values from **Fig. 39.1**.
Explain any differences and state how the model could be improved to be closer to the experimental values.

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.... **[2]**

40 **Fig. 40.1** shows the voltage–current characteristic for an illuminated solar cell.

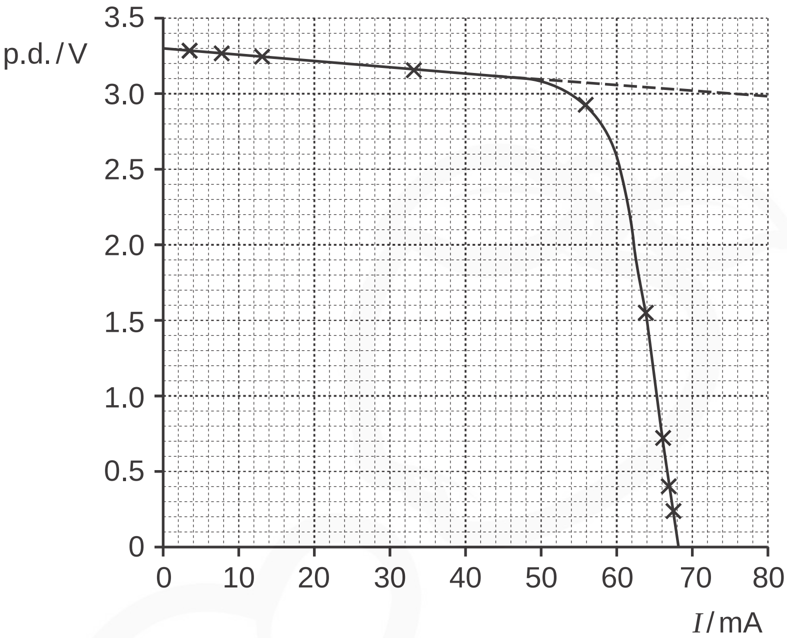

Fig. 40.1

(a) **(i)** Use the initial gradient of the graph to calculate the internal resistance of the cell under this illumination.

internal resistance = ... Ω **[1]**

(ii) Calculate the maximum number of electrons per second that the cell can produce.

electrons per second = ... s^{-1} **[2]**

(iii) Suggest a reason for this maximum rate in the case of the solar cell.

....

.... **[1]**

(b)* Describe the experiment you would use to obtain the data to plot the graph in **Fig. 40.1**. Include a circuit diagram with your method, give estimated values of circuit components, and explain any precautions you would take to ensure reliability. **[6]**

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Additional answer space if required.

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41 This question is about loud annoying oscillations set up in the volume of air in a car when it travels at a specific speed with the sunroof partially open.
The oscillations are driven by a series of eddies that form in the air-flow above the sunroof aperture. Two of the eddies are shown in **Fig. 41.1**.

v = relative wind speed

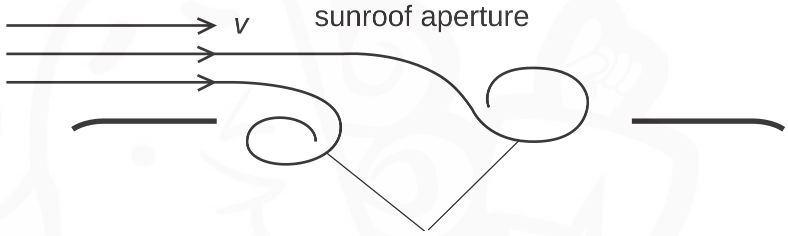

Fig. 41.1

The frequency of eddy production f is given by the equation $f = cv$ where v is the relative speed of the air flow and c is a constant.

(a) **(i)** **Fig. 41.2** shows the $f = cv$ proportionality and **Fig. 41.3** shows how the sound level in the car varies with speed v.

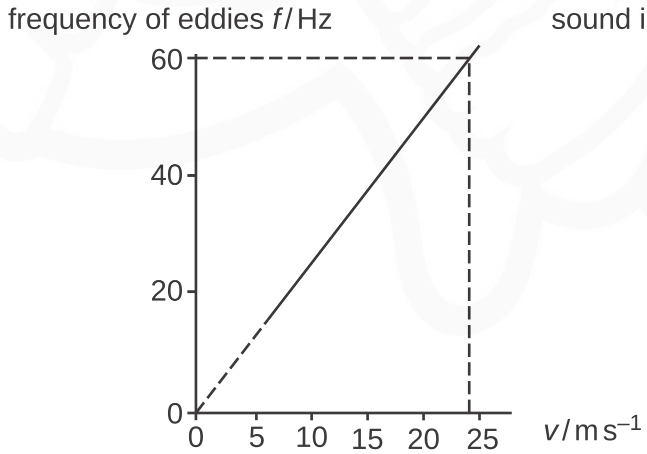

Fig. 41.2

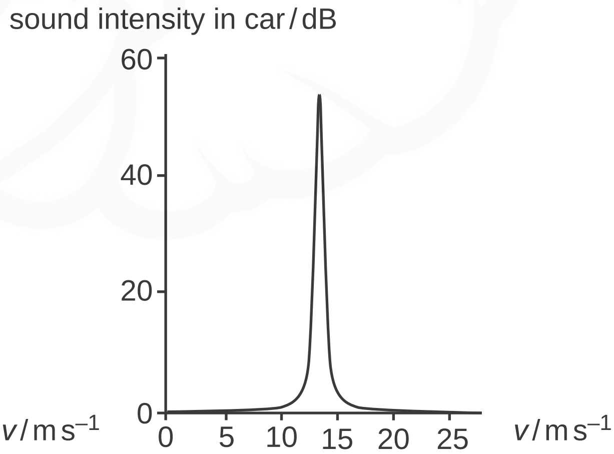

Fig. 41.3

Use **Fig. 41.2** and **Fig. 41.3** to estimate a value for the frequency *f* of the loud oscillation. Make your method clear.

f = ... Hz **[2]**

(ii) State the evidence that shows there is a resonant oscillation happening in this example.

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.... **[2]**

(b) The resonant frequency *f* of an enclosed volume of air *V*, with an aperture area *A*, is given by:

$$f = \frac{u}{2\pi}\sqrt{\frac{A}{VL}}.$$

Calculate the resonant frequency *f* of oscillation of the air in a car with an open sunroof.

Where: $u = 340\,\text{m}\,\text{s}^{-1}$ the speed of sound in air

and for this car:

$L = 0.14\,\text{m}$ the effective length of air mass oscillating in the aperture.
$A = 0.18\,\text{m}^2$
$V = 3.2\,\text{m}^3$

f = ... Hz **[2]**

END OF QUESTION PAPER

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).