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Physics

Higher and Standard level

Specimen papers 1A, 1B and 2

For first examinations in 2025

CONTENTS

Diploma Programme
Programme du diplôme
Programa del Diploma

Physics
Higher level
Paper 1A

Specimen paper

2 hours [Paper 1A and Paper 1B]

Instructions to candidates

- Do not open this examination paper until instructed to do so.
- Answer all questions.
- For each question, choose the answer you consider to be the best and indicate your choice on the answer sheet provided.
- A calculator is required for this paper.
- A clean copy of the **physics data booklet** is required for this paper.
- The maximum mark for paper 1A is **[40 marks]**.
- The maximum mark for paper 1A and paper 1B is **[60 marks]**.

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1. A car has an initial speed of $16\,m\,s^{-1}$. It decelerates at $4.0\,m\,s^{-2}$ until it stops.

What is the distance travelled by the car?

A. 4 m

B. 16 m

C. 32 m

D. 64 m

2. A block of mass 2.0 kg accelerates from a speed of $15\,m\,s^{-1}$ to a speed of $20\,m\,s^{-1}$ without changing its direction.

What impulse acts on the block?

A. 2.5 N s

B. 5.0 N s

C. 10 N s

D. 17.5 N s

3. A net force of 8.0 N accelerates a 4.0 kg body from rest to a speed of $5.0\,m\,s^{-1}$.

What is the work done by the force?

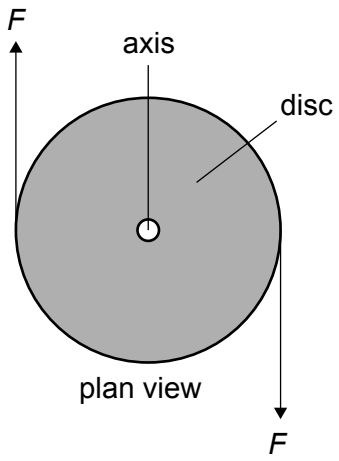
A. 50 J

B. 40 J

C. 32 J

D. 20 J

4. A disc of mass M and radius R is on a horizontal frictionless table. Two equal and opposite forces, each of magnitude F, act on the disc. The moment of inertia of the disc about its axis is $\frac{1}{2}MR^2$.



What is the angular acceleration of the disc?

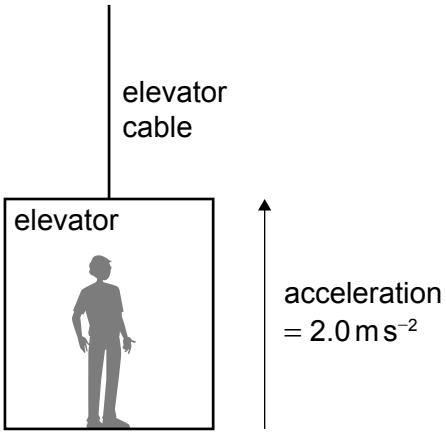
A. 0

B. $\frac{F}{MR}$

C. $\frac{2F}{MR}$

D. $\frac{4F}{MR}$

5. A person stands in an elevator (lift). The total mass of the person and the elevator is 800 kg. The elevator accelerates upward at $2.0\,\text{m}\,\text{s}^{-2}$.



What is the tension in the cable?

A. 1.6 kN

B. 6.4 kN

C. 8.0 kN

D. 9.6 kN

6. An object is released from rest in a vacuum at a height H above the Earth's surface.

As the object falls it passes a point at a height of $0.75H$ above the surface.

What is $\dfrac{\text{kinetic energy of the object at a height of } 0.75H}{\text{gravitational potential energy of the object at a height of } H}$?

A. $\dfrac{1}{16}$

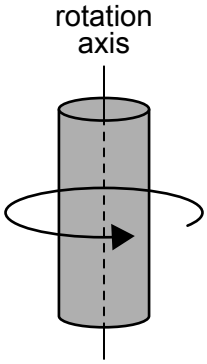
B. $\dfrac{1}{4}$

C. $\dfrac{9}{16}$

D. $\dfrac{3}{4}$

7. A cylinder of mass *M* and radius *R* rotates at constant angular speed ω about an axis through its centre. The rotational kinetic energy of the cylinder is *K*.

The moment of inertia of the cylinder is $\frac{1}{2}MR^2$.



A second cylinder has mass 2*M*, radius 2*R* and rotates with angular speed 2ω.

What is the rotational kinetic energy of the second cylinder?

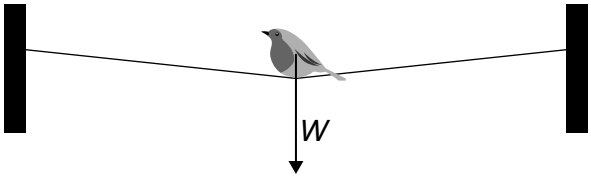
A. 8*K*

B. 16*K*

C. 32*K*

D. 64*K*

8. A bird of weight W sits on a thin rope at its midpoint. The rope is almost horizontal and has negligible mass.



The tension in the rope is

A. less than $\frac{W}{2}$

B. equal to $\frac{W}{2}$

C. between $\frac{W}{2}$ and W

D. greater than W

9. A spacecraft, moving with speed v relative to Earth, passes Earth on its way to a planet. As the spacecraft passes Earth, clocks on Earth and in the spacecraft show zero.

The planet is a distance D from Earth, according to an observer on Earth.

What are the readings on the Earth clock and on the spacecraft clock when the spacecraft arrives at the planet?

	Earth clock reading	**Spacecraft clock reading**
A.	$\frac{D}{v}$	$\frac{D}{v}\sqrt{1-\frac{v^2}{c^2}}$
B.	$\frac{D}{v}$	$\frac{D}{v\sqrt{1-\frac{v^2}{c^2}}}$
C.	$\frac{D}{v\sqrt{1-\frac{v^2}{c^2}}}$	$\frac{D}{v}$
D.	$\frac{D}{v}\sqrt{1-\frac{v^2}{c^2}}$	$\frac{D}{v}$

10. The internal energy of a real gas is

A. zero.

B. equal to the intermolecular potential energy of the particles.

C. equal to the total kinetic energy of the particles.

D. equal to the sum of the intermolecular potential energy and the total kinetic energy of the particles.

11. A gas undergoes one cycle of a cyclic process.

The net change in internal energy of the gas is

A. zero.

B. positive.

C. negative.

D. determined by the initial temperature of the gas.

12. A working refrigerator with the door open is placed in a sealed room.

The entropy of the room

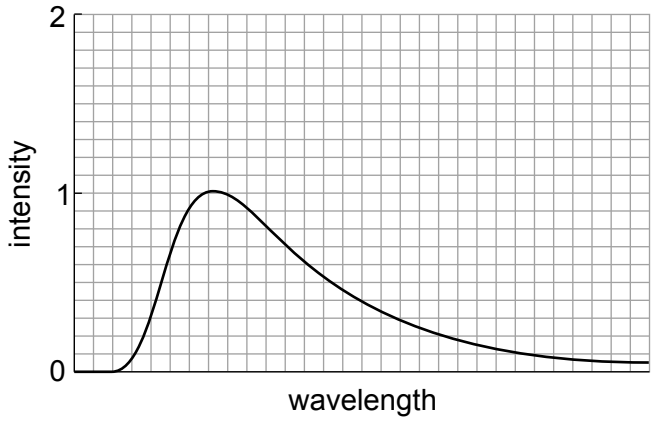
A. is zero.

B. decreases.

C. remains unchanged.

D. increases.

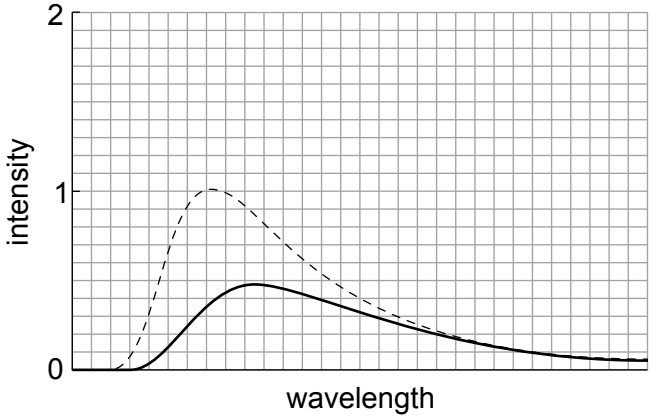
13. The black-body radiation curve of an object at 600 K is shown. The intensity units are arbitrary.



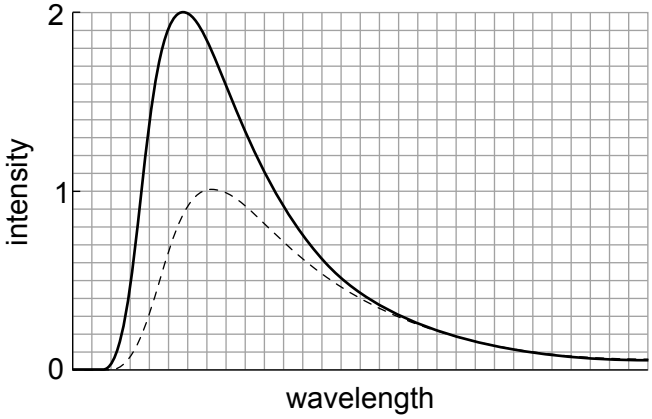
What is the radiation curve of the same object at 450 K?

The original curve is shown with a dashed line.

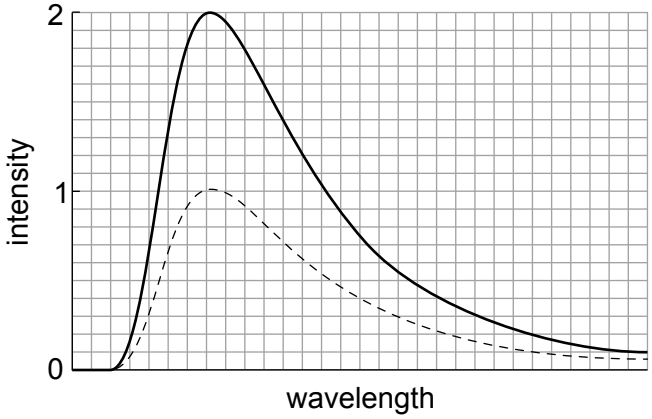
A.



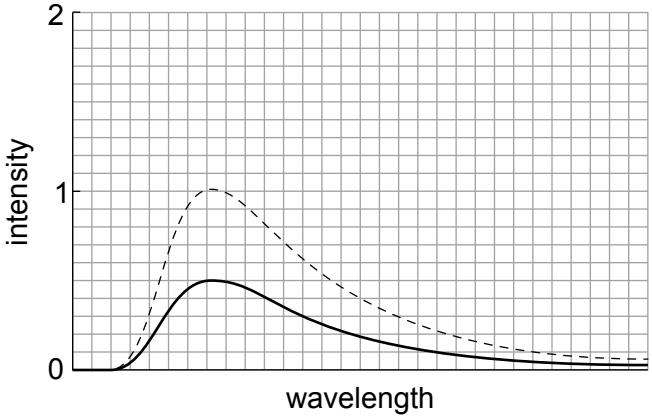
B.



C.



D.



14. Star X has a luminosity L and an apparent brightness b. Star X is at a distance d from Earth.

Star Y has the same apparent brightness as X but is four times more luminous.

What is the distance of Star Y from Earth?

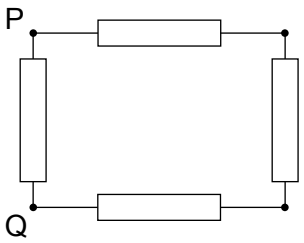
A. $4d$

B. $2d$

C. $\frac{d}{2}$

D. $\frac{d}{4}$

15. Four identical resistors, each of resistance R, are connected as shown.



What is the effective resistance between P and Q?

A. $\frac{3R}{4}$

B. R

C. $\frac{4R}{3}$

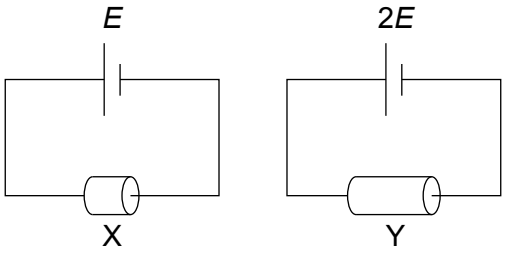
D. $4R$

16. Conductor X is connected to a cell of emf E. A power of 16 W is dissipated in X.

Conductor Y is made from the same material with the same diameter as X but is twice as long. A cell of emf $2E$ is connected to Y.

Both cells have negligible internal resistance.

What power is dissipated in Y?



A. 8.0 W

B. 16 W

C. 32 W

D. 64 W

17. Two containers, X and Y, are filled with an ideal gas at the same pressure.

The volume of X is four times the volume of Y. The temperature of X is 327 °C and the temperature of Y is 27 °C.

What is $\frac{\text{amount of substance in X}}{\text{amount of substance in Y}}$?

A. $\frac{1}{8}$

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

C. 2

D. 8

18. An electromagnetic wave has a wavelength that is about the size of the diameter of an atom.

What region of the electromagnetic spectrum does the wave belong to?

A. Infrared

B. Visible light

C. Ultraviolet

D. X-ray

19. A particle undergoes simple harmonic motion of period T. At time $t = 0$ the particle is at its equilibrium position.

What is t when the particle is at its greatest distance from the equilibrium position?

A. $\frac{T}{8}$

B. $\frac{T}{2}$

C. $\frac{3T}{4}$

D. T

20. Diagram 1 shows the variation with position of the displacement of a standing wave formed on a string.

Diagram 2 shows the variation with position of the displacement of a travelling wave moving to the right along a string.

Diagram 1

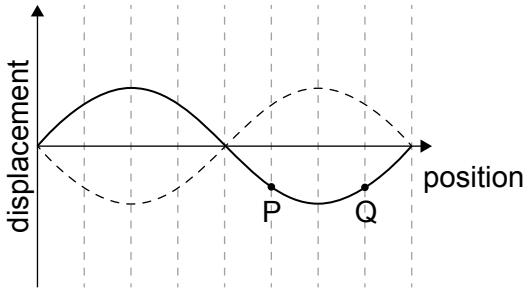
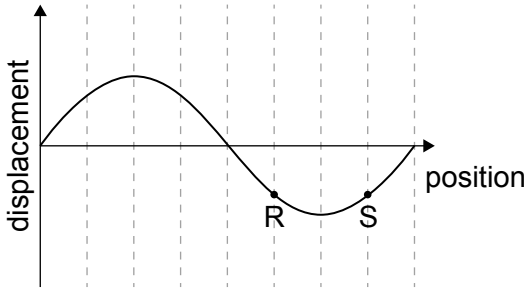


Diagram 2



Points P, Q, R and S are points on the string.

What is the phase difference between P and Q and the phase difference between R and S?

	Phase difference between P and Q	**Phase difference between R and S**
A.	0	0
B.	$\frac{\pi}{2}$	0
C.	0	$\frac{\pi}{2}$
D.	$\frac{\pi}{2}$	$\frac{\pi}{2}$

21. A mass of 0.25 kg hangs from a spring of spring constant 4.0 N m^{-1}.

What is the natural frequency of oscillation for this system?

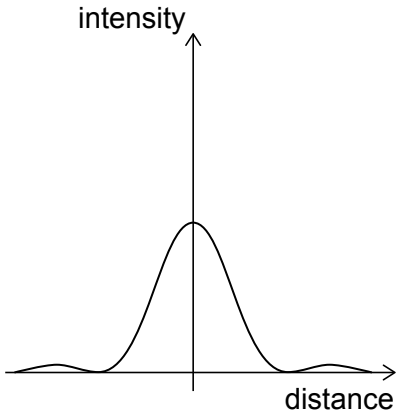
A. 0.50 Hz

B. 0.64 Hz

C. 1.6 Hz

D. 2.0 Hz

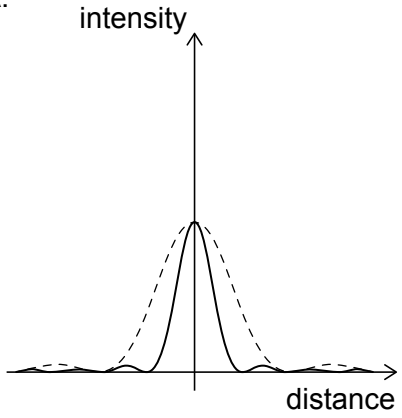
22. Light from a monochromatic source is incident on a single slit and the resulting diffraction pattern is viewed on a screen. The graph shows the variation of intensity with distance on the screen.



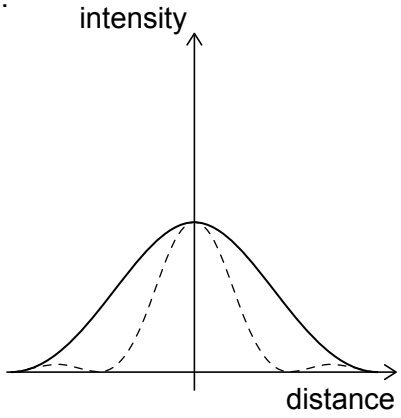
The intensity of the source remains the same. The width of the slit is increased.

Which graph correctly shows the variation of intensity after the change? The original curve is shown with a dashed line.

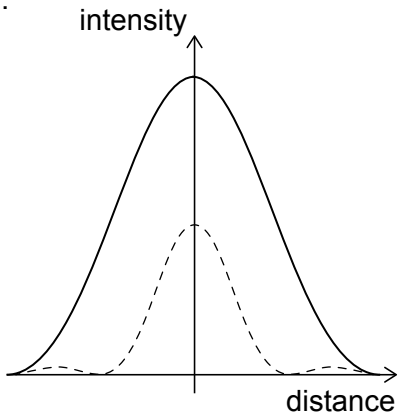
A.



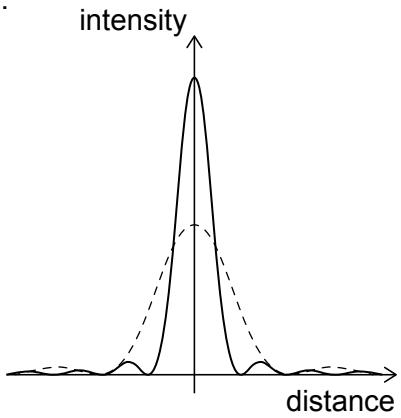
B.



C.



D.



23. Monochromatic light is incident on a diffraction grating. The diffraction pattern from the diffraction grating is then formed on a screen.

Only the central maximum and the first-order maxima can be observed on the screen.

What change will allow the second-order maxima to be observed on the screen?

A. Decrease the distance between the diffraction grating and the source of light

B. Increase the distance between the diffraction grating and the screen

C. Increase the wavelength of the monochromatic light

D. Reduce the number of lines per unit length of the diffraction grating

24. A solid metallic sphere is positively charged and isolated from all other charges.

The electric potential due to the sphere

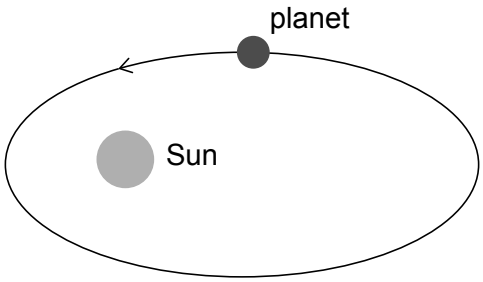
A. is constant inside the sphere.

B. is constant outside the sphere.

C. is smallest at the surface of the sphere.

D. increases with distance from the sphere.

25. A planet orbits the Sun in an elliptical orbit moving in the direction shown.



At the position shown, which quantity is decreasing for the planet?

A. Acceleration

B. Angular momentum

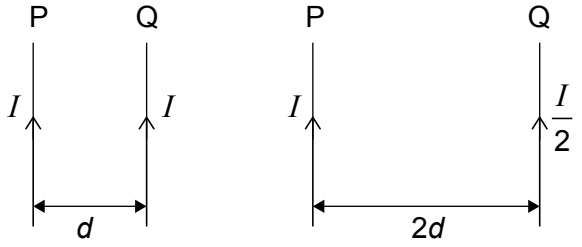
C. Kinetic energy

D. Gravitational potential energy

26. Two long parallel wires P and Q are a distance *d* apart. They each carry a current.

A magnetic force per unit length *F* acts on P due to Q.

The distance between the wires is increased to 2*d* and the current in Q is decreased to $\frac{I}{2}$.



What is the magnetic force per unit length that acts on P due to Q after the changes?

A. $\frac{F}{8}$

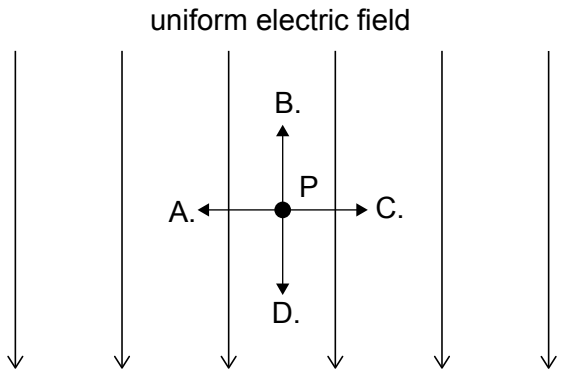
B. $\frac{F}{4}$

C. $\frac{F}{2}$

D. F

27. P is a point in a uniform electric field.

What is the direction in which the electric potential increases at P?



28. Planets X and Y orbit the same star.

The average distance between planet X and the star is five times greater than the average distance between planet Y and the star.

What is $\frac{\text{orbital period of planet X}}{\text{orbital period of planet Y}}$?

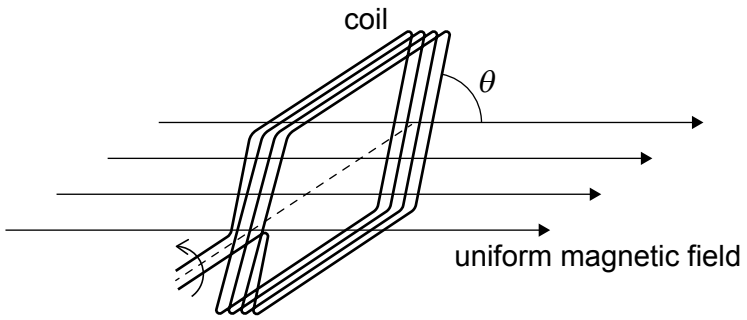
A. $\sqrt[3]{5}$

B. $\sqrt{5}$

C. $\sqrt[3]{5^2}$

D. $\sqrt{5^3}$

29. A rectangular conducting coil rotates at a constant angular velocity in a uniform magnetic field. The rotation axis of the coil is perpendicular to the field.



At one instant the plane of the coil is at an angle θ to the direction of the field.

The magnitude of the emf induced in the coil is

A. never zero.

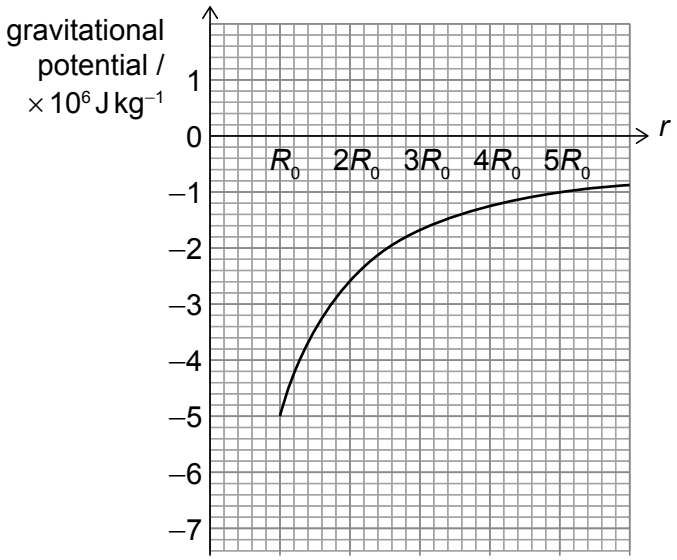
B. at a maximum when $\theta = 0°$ or 180°.

C. at a maximum when $\theta = 45°$ or 225°.

D. at a maximum when $\theta = 90°$ or 270°.

30. A spherical planet has a radius R_0.

The graph shows the variation of the gravitational potential due to the planet with distance r from the centre of the planet.



What is the escape speed from the surface of the planet?

A. $1.6 \times 10^3\,\mathrm{m\,s^{-1}}$

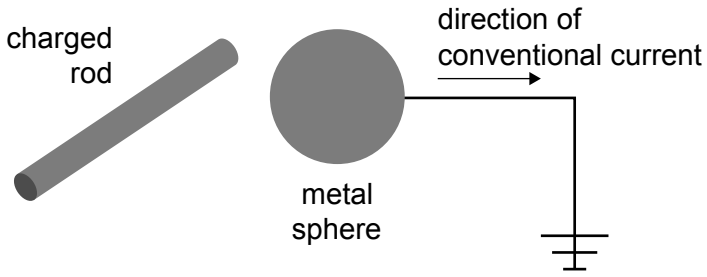
B. $2.2 \times 10^3\,\mathrm{m\,s^{-1}}$

C. $3.2 \times 10^3\,\mathrm{m\,s^{-1}}$

D. $4.5 \times 10^3\,\mathrm{m\,s^{-1}}$

31. A charged rod is brought near an initially neutral metal sphere without touching it.

When the sphere is grounded (earthed), there is an electric current for a short time from the sphere to the ground.

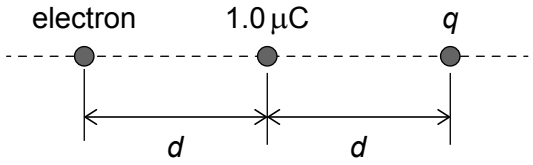


The ground connection is then removed.

What are the charge on the rod and the charge induced on the sphere when the connection is removed?

	Charge on the rod	Charge induced on the sphere
A.	negative	negative
B.	negative	positive
C.	positive	negative
D.	positive	positive

32. A positive point charge of magnitude 1.0 μC and a point charge q are separated by a distance d.



An electron is placed at a distance d from the +1.0 μC charge. The electric force on the electron is zero.

What is q?

A. −4.0 μC

B. −2.0 μC

C. 2.0 μC

D. 4.0 μC

33. What is the sequence for the evolution of a main sequence star of about 2 solar masses?

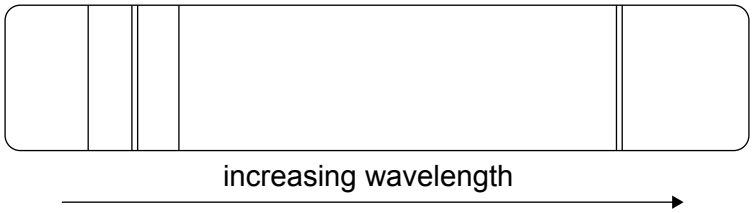
A. Red super giant → supernova → neutron star

B. Red giant → planetary nebula → white dwarf

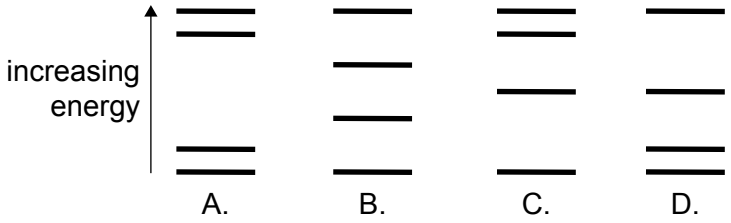
C. Red giant → supernova → white dwarf

D. Red super giant → planetary nebula → neutron star

34. The diagram shows the emission spectrum of an atom.



Which of the following atomic energy level models can produce this spectrum?



35. A photon of wavelength λ scatters off an electron at rest. The scattered photon has wavelength λ'.

What is the fraction of the incident photon energy that gets transferred to the electron?

A. $\frac{\lambda}{\lambda'}$

B. $\frac{\lambda'}{\lambda}$

C. $\frac{\lambda' - \lambda}{\lambda}$

D. $\frac{\lambda' - \lambda}{\lambda'}$

36. Three statements about a nuclear fission reactor are:

I. The heat exchanger transfers energy from the fuel rods to the moderator.

II. The control rods must be good absorbers of neutrons.

III. The moderator must slow neutrons down.

Which statements about the reactor are correct?

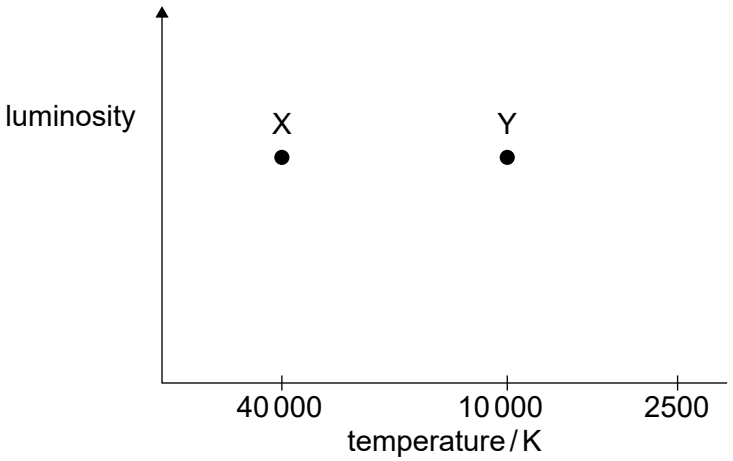
A. I and II only

B. I and III only

C. II and III only

D. I, II and III

37. The Hertzsprung–Russell diagram shows two stars, X and Y.



What is $\frac{\text{radius of X}}{\text{radius of Y}}$?

A. $\frac{1}{16}$

B. $\frac{1}{4}$

C. 4

D. 16

38. The energy of the nth level of hydrogen is given by $-\frac{E_0}{n^2}$. What is the frequency of the photon emitted in the transition from $n = 4$ to $n = 2$?

A. $\frac{1}{16} \times \frac{E_0}{h}$

B. $\frac{3}{16} \times \frac{E_0}{h}$

C. $\frac{1}{4} \times \frac{E_0}{h}$

D. $\frac{3}{4} \times \frac{E_0}{h}$

39. Monochromatic light of frequency f_1 is incident on the surface of a metal. The stopping voltage for this light is V_1. When the frequency of the radiation is changed to f_2, the stopping voltage is V_2.

What is the quantity $\frac{V_2 - V_1}{f_2 - f_1}$ equal to?

A. h

B. $\frac{h}{e}$

C. $\frac{h}{c}$

D. $\frac{hc}{e}$

40. An alpha particle ($^4_2$He) of initial energy 5.5 MeV moves towards the centre of a nucleus of gold-197 ($^{197}_{79}$Au).

What is the distance of closest approach of the alpha particle?

A. 1.0×10^{-13} m

B. 4.1×10^{-14} m

C. 2.1×10^{-14} m

D. 6.6×10^{-33} m

Diploma Programme
Programme du diplôme
Programa del Diploma

Markscheme

Specimen paper

Physics

Higher level

Paper 1A

2 pages

1.	C	16.	C	31.	C	46.	–
2.	C	17.	C	32.	A	47.	–
3.	A	18.	D	33.	B	48.	–
4.	D	19.	C	34.	A	49.	–
5.	D	20.	C	35.	D	50.	–
6.	B	21.	B	36.	C	51.	–
7.	C	22.	D	37.	A	52.	–
8.	D	23.	D	38.	B	53.	–
9.	A	24.	A	39.	B	54.	–
10.	D	25.	D	40.	B	55.	–
11.	A	26.	B	41.	–	56.	–
12.	D	27.	B	42.	–	57.	–
13.	A	28.	D	43.	–	58.	–
14.	B	29.	B	44.	–	59.	–
15.	A	30.	C	45.	–	60.	–

Diploma Programme
Programme du diplôme
Programa del Diploma

Physics
Higher level
Paper 1B

Specimen paper

Candidate session number

2 hours [Paper 1A and Paper 1B]

Instructions to candidates

- Write your session number in the boxes above.
- Do not open this examination paper until instructed to do so.
- Answer all questions.
- Answers must be written within the answer boxes provided.
- A calculator is required for this paper.
- A clean copy of the **physics data booklet** is required for this paper.
- The maximum mark for paper 1B is **[20 marks]**.
- The maximum mark for paper 1A and paper 1B is **[60 marks]**.

0000 – 6502

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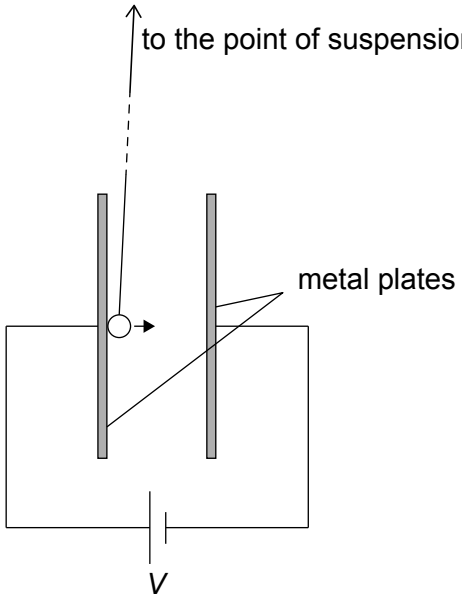
Answer **all** questions. Answers must be written within the answer boxes provided.

1. A group of students investigate the motion of a conducting ball suspended from a long string. The ball is between two vertical metal plates that have an electric potential difference *V* between them. The ball is touched to one plate so that it becomes electrically charged and is repelled from the plate. For a given potential difference, the ball bounces between the plates with a constant period.

diagram not to scale



(a) The students vary *V* and measure the time *T* for the ball to move **once** from one plate to the other. The table shows some of the data.

***V* / kV**	***T* / s ± 0.1 s**
3.00	1.4
5.00	0.8
7.00	0.6

(i) *V* is provided by two identical power supplies connected in series. The potential difference of each of the power supplies is known with an uncertainty of 0.01 kV.

State the uncertainty in the potential difference *V*. [1]

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(This question continues on the following page)

(Question 1 continued)

(ii) T is measured with an electronic stopwatch that measures to the nearest 0.1 s.

Describe how an uncertainty in T of less than 0.1 s can be achieved using this stopwatch. [2]

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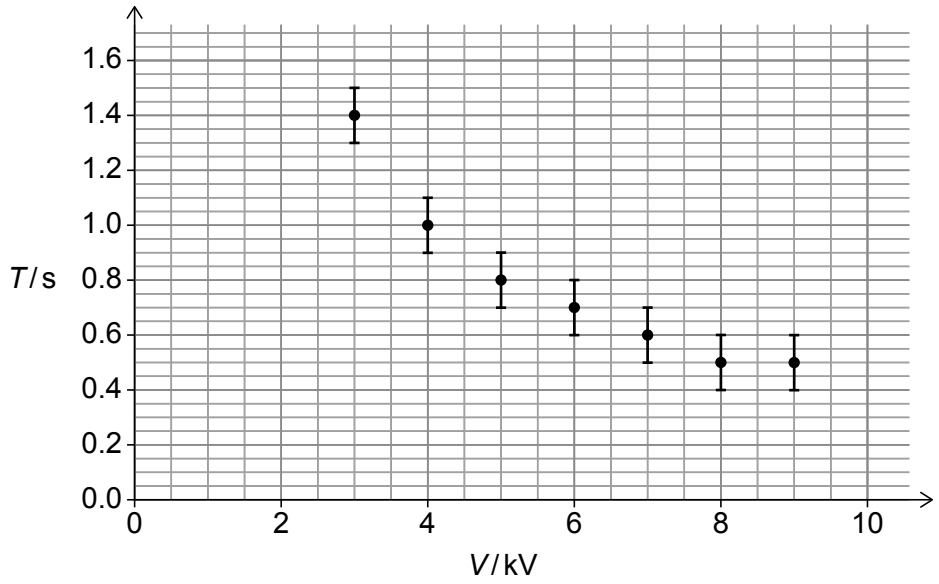
The graph shows the variation of T with V. The uncertainty in V is not plotted.



(iii) Outline why it is unlikely that the relationship between T and V is linear. [1]

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(iv) Calculate the largest fractional uncertainty in T for these data. [2]

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(This question continues on the following page)

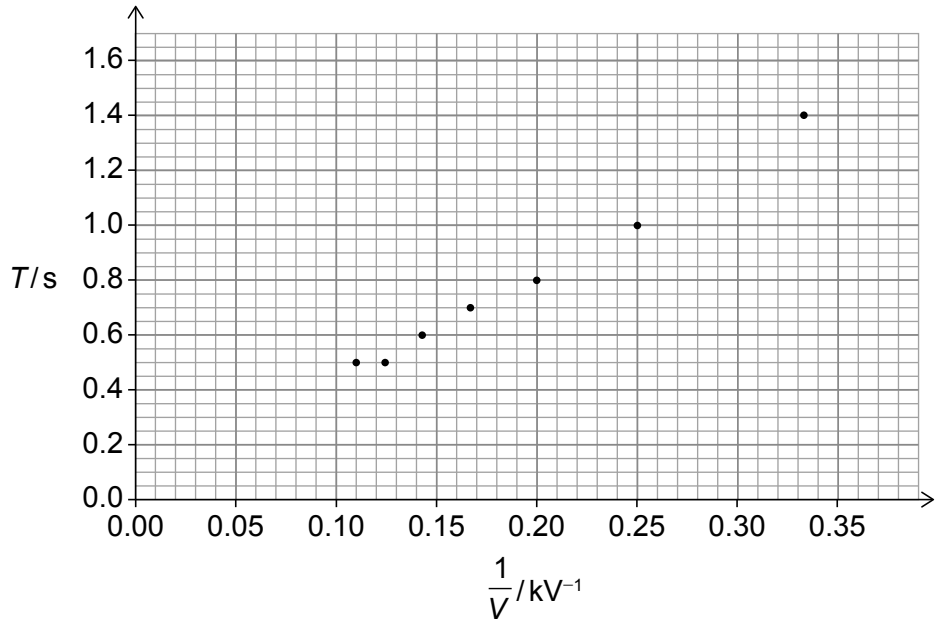
(Question 1 continued)

(b) The students suggest the following theoretical relationship between T and V:

$$T = \frac{A}{V}$$

where A is a constant.

To verify the relationship, the variation of T with $\frac{1}{V}$ is plotted.



(i) Determine A by drawing the line of best fit. [3]

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(This question continues on the following page)

(Question 1 continued)

(ii) State the units of *A*. [1]

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(iii) The theoretical relationship assumes that the ball is only affected by the electric force.

Suggest why, in order to test the relationship, the length of the string should be much greater than the distance between the plates. [2]

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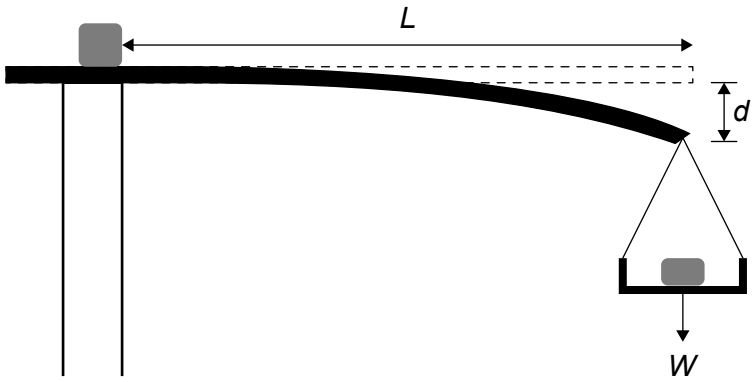
2. A group of students investigate the bending of a plastic ruler that is clamped horizontally at one end. A weight *W* attached to the other end causes the ruler to bend. The weight is contained in a scale pan.

The students fix the length *L* of the ruler and vary *W*. For each value of *W*, the group measures the deflection *d* of the end of the ruler to which the weight is attached.



(a) The group obtains the following repeated readings for *d* for **one** value of *W*.

Reading	1	2	3	4	5	6
***d* / cm**	2.7	2.9	3.6	2.7	2.8	2.9

The group divides into two subgroups, A and B, to analyse the data.

Group A quotes the mean value of *d* as 2.93 cm.

Group B quotes the mean value of *d* as 2.8 cm.

Discuss the values that the groups have quoted. [2]

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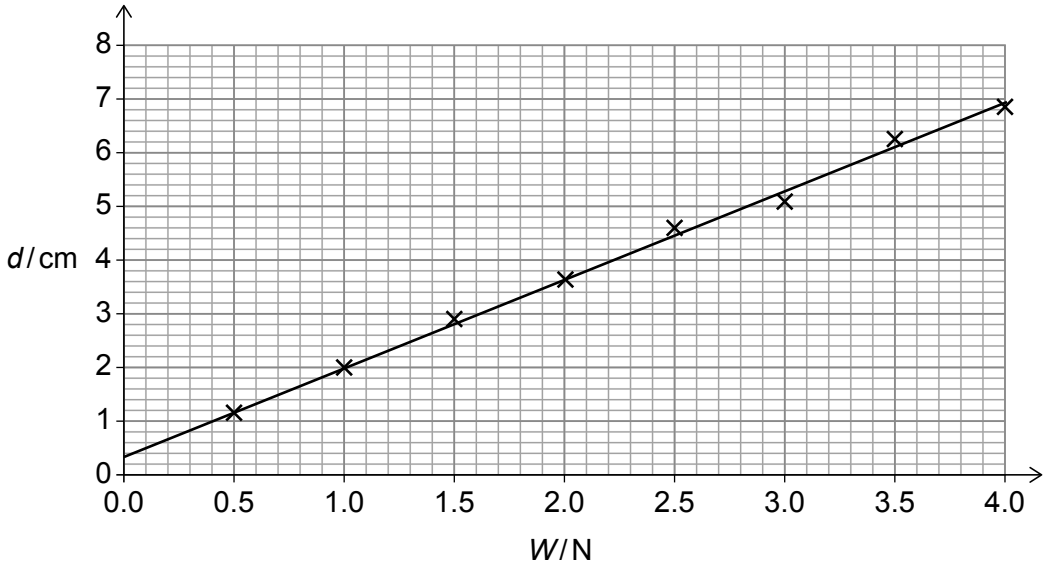
(Question 2 continued)

(b) The variation of d with W is shown.



Outline **one** experimental reason why the graph does not go through the origin. [1]

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(c) Theory predicts that

$$d \propto \frac{W^x L^y}{EI}$$

where E and I are constants. The fundamental units of I are m^4 and those of E are $kg\,m^{-1}\,s^{-2}$.

Calculate x and y. [2]

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(This question continues on the following page)

(Question 2 continued)

(d) The ruler has cross-sectional area $A = a \times b$, where $a = (28 \pm 1)$ mm and $b = (3.00 \pm 0.05)$ mm.

(i) Suggest an appropriate measuring instrument for determining b. [1]

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(ii) Calculate the percentage uncertainty in the value of A. [2]

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Diploma Programme
Programme du diplôme
Programa del Diploma

Markscheme

Specimen paper

Physics

Higher level

Paper 1B

4 pages

Subject Details: Physics HL Paper 1B Markscheme

Mark Allocation

Candidates are required to answer ALL questions. Maximum total = [20 marks].

1. Each row in the "Question" column relates to the smallest subpart of the question.

2. The maximum mark for each question subpart is indicated in the "Total" column.

3. Each marking point in the "Answers" column is shown by means of a tick (✓) at the end of the marking point.

4. A question subpart may have more marking points than the total allows. This will be indicated by "max" written after the mark in the "Total" column. The related rubric, if necessary, will be outlined in the "Notes" column.

5. An alternative wording is indicated in the "Answers" column by a slash (/). Either wording can be accepted.

6. An alternative answer is indicated in the "Answers" column by "***OR***" between the alternatives. Either answer can be accepted.

7. Words in angled brackets **« »** in the "Answers" column are not necessary to gain the mark.

8. Words that are underlined are essential for the mark.

9. The order of marking points does not have to be as in the "Answers" column, unless stated otherwise in the "Notes" column.

10. If the candidate's answer has the same "meaning" or can be clearly interpreted as being of equivalent significance, detail and validity as that in the "Answers" column then award the mark. Where this point is considered to be particularly relevant in a question it is emphasized by ***OWTTE*** (or words to that effect) in the "Notes" column.

11. Remember that many candidates are writing in a second language. Effective communication is more important than grammatical accuracy.

12. Occasionally, a part of a question may require an answer that is required for subsequent marking points. If an error is made in the first marking point then it should be penalized. However, if the incorrect answer is used correctly in subsequent marking points then **follow through** marks should be awarded. When marking, indicate this by adding **ECF** (error carried forward) on the script. "Allow ECF" will be displayed in the "Notes" column.

13. Do **not** penalize candidates for errors in units or significant figures, **unless** it is specifically referred to in the "Notes" column.

14. Allow reasonable substitutions where in common usage, *eg* ^{c} for rad.

Question			Answers	Notes	Total
1.	a	i	0.02 «kV» ✓		1
1.	a	ii	by measuring the time for many bounces ✓ and dividing the result by the number of bounces ✓		2
1.	a	iii	it is not possible to draw a straight line through all the error bars ✓		1
1.	a	iv	$T = 0.5$ s ✓ «$\frac{0.1}{0.5}$ =» 0.2 ✓		2
1.	b	i	a best-fit line drawn through the entire range of the data ✓ large triangle greater than half a line or two data points on the line greater than half a line apart ✓ correct read offs consistent with the line, *eg* $\frac{1.6-0}{0.40-0} = 4.0$ ✓	*Accept answer in the range 3.8–4.2*	3
1.	b	ii	kV s ✓		1
1.	b	iii	the angle between the string and the vertical should be very small «for any position of the ball» ✓ so that the tension in the string is «almost» balanced by the ball's weight ***OR*** restoring force from the string / horizontal component of tension negligibly small «compared with electric force» ✓	*OWTTE*	2

Question			Answers	Notes	Total
2.	**a**		3 sf is inappropriate for *A* ✓ rejects trial 3 as outlier for *B* ✓		**2**
2.	**b**		beam bends under its own weight / weight of pan ***OR*** specified systematic error in *d* ✓		**1**
2.	**c**		units of *W* : kg m s^{-2} ✓ work leading to $x = 1$ and $y = 3$ ✓		**2**
2.	**d**	**i**	instrument (capable of reading to 0.05 mm) with reason related to resolution of instrument ✓	*eg micrometer screw gauge, Vernier caliper, travelling microscope*	**1**
2.	**d**	**ii**	attempt to calculate fractional uncertainty in either *a* or *b* [0.0357, 0.0167] ✓ $0.0357 + 0.0167 = 0.05 = 5\ \%$ ✓		**2**

Diploma Programme
Programme du diplôme
Programa del Diploma

Physics
Higher level
Paper 2

Specimen paper

Candidate session number

2 hours 30 minutes

Instructions to candidates

- Write your session number in the boxes above.
- Do not open this examination paper until instructed to do so.
- Answer all questions.
- Answers must be written within the answer boxes provided.
- A calculator is required for this paper.
- A clean copy of the **physics data booklet** is required for this paper.
- The maximum mark for this examination paper is **[90 marks]**.

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28 pages

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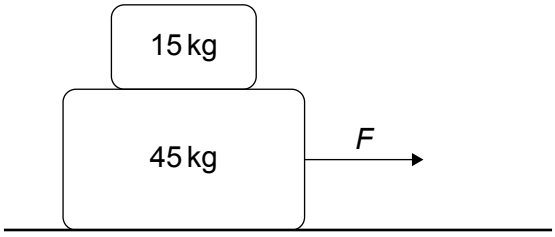
Answer **all** questions. Answers must be written within the answer boxes provided.

1. A block of mass 45 kg is placed on a horizontal table. There is no friction between the block and the table.

An object of mass 15 kg is placed on top of the block.

A force *F* acts on the block so that it accelerates. The acceleration of the object and the acceleration of the block are the same so that they do not move relative to each other.



The coefficient of static friction between the block and the object is 0.60.

(a) State the nature and direction of the force that accelerates the 15 kg object. [1]

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(b) Determine the largest magnitude of *F* for which the block and the object do not move relative to each other. [3]

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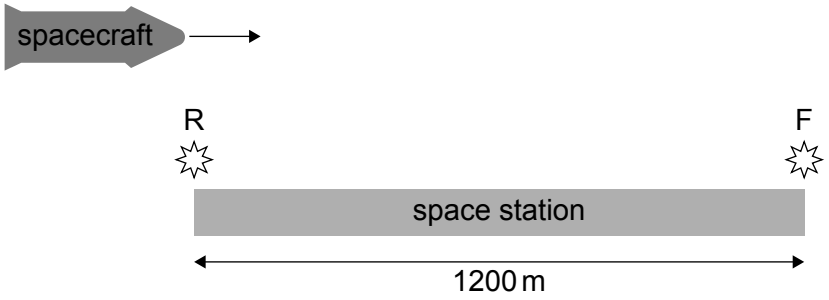
2. A spacecraft is flying past a space station at a relative speed of 0.80*c*. Beacons, R and F, at each end of the space station emit light pulses at the same time according to observers on the space station. The pulses are emitted 1200 m apart as measured by space station observers.



(a) Calculate γ for a speed of 0.80*c*. [1]

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(b) Calculate, for the reference frame of the spacecraft,

(i) the distance between the light pulses. [1]

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(ii) the time between the light pulses. [2]

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(c) Determine which light pulse happened first. [2]

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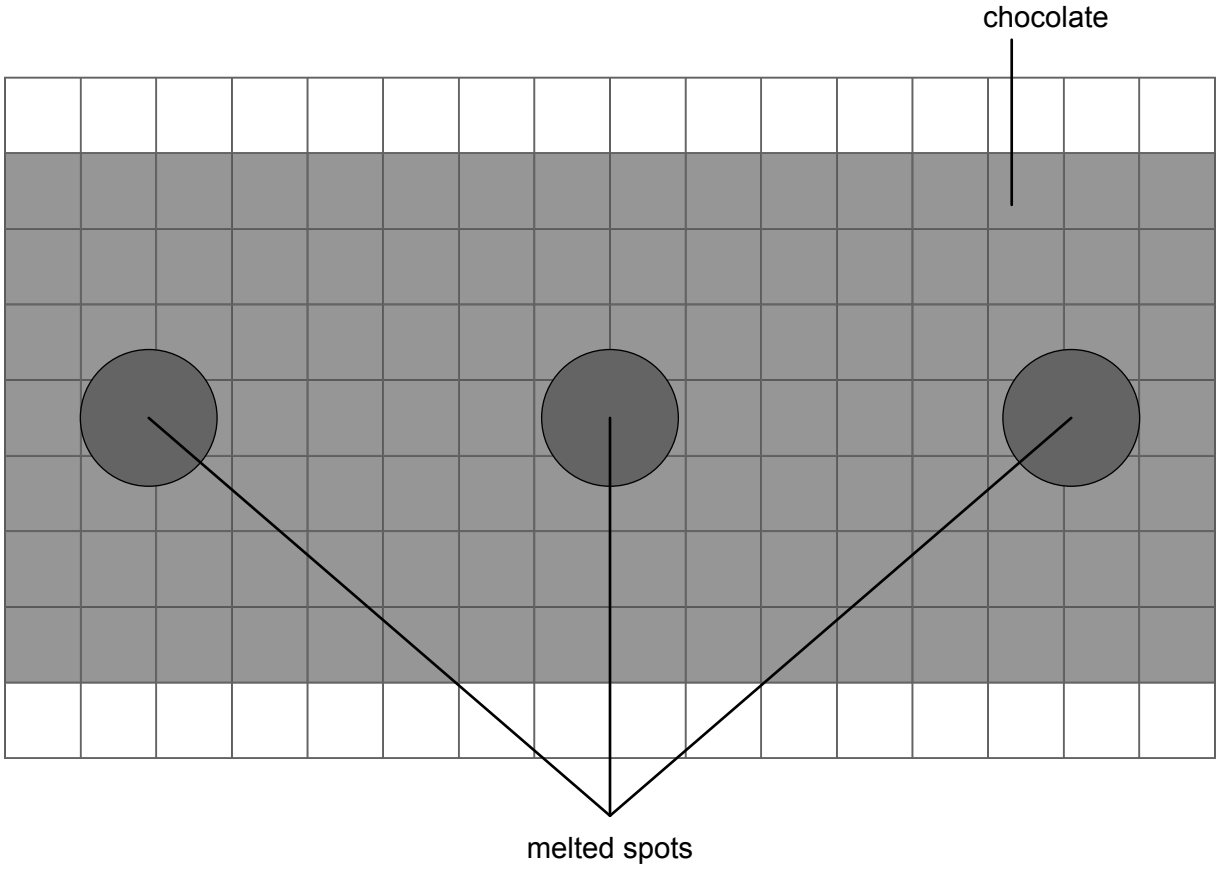
3. In a microwave oven electromagnetic waves are emitted so that a standing wave pattern is established inside the oven.

A flat piece of chocolate is placed inside the oven and the microwaves are switched on. The chocolate is stationary.

Melted spots form on the surface of the chocolate. The diagram shows the pattern of melting on the chocolate. Each square has a length of 1 cm.



(a) Outline how this standing wave pattern of melted spots is formed. [2]

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(This question continues on the following page)

(Question 3 continued)

(b) Determine, taking appropriate measurements from the diagram, the frequency of the electromagnetic waves in the oven. [3]

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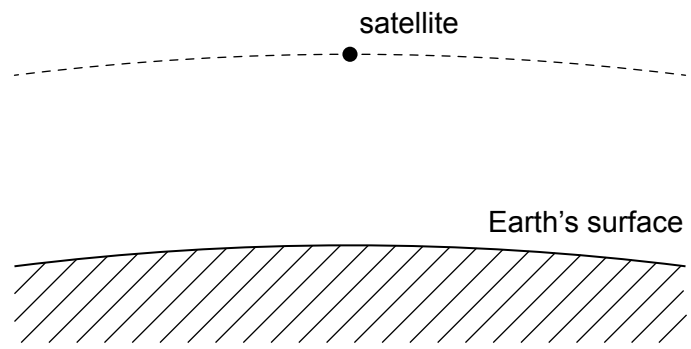
4. A satellite moves around Earth in a circular orbit.



(a) Draw an arrow on the diagram to represent the direction of the acceleration of the satellite. [1]

(b) The following data are given:

Mass of Earth, $M = 5.97 \times 10^{24}\,\text{kg}$

Radius of Earth, $R = 6.37 \times 10^{6}\,\text{m}$

Orbital period of the satellite, $T = 5.62 \times 10^{3}\,\text{s}$

(i) Kepler's Third Law of orbital motion states that $T^2 = kr^3$ where k is a constant and r is the orbital radius of the satellite.

Show that $k = \dfrac{4\pi^2}{GM}$. [1]

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(ii) Determine the height of the satellite above the Earth's surface. [2]

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(This question continues on the following page)

(Question 4 continued)

(c) The atmosphere exerts a small viscous drag force on the satellite.

Outline how the total energy, kinetic energy, and gravitational potential energy change for the satellite during one orbit around Earth. [3]

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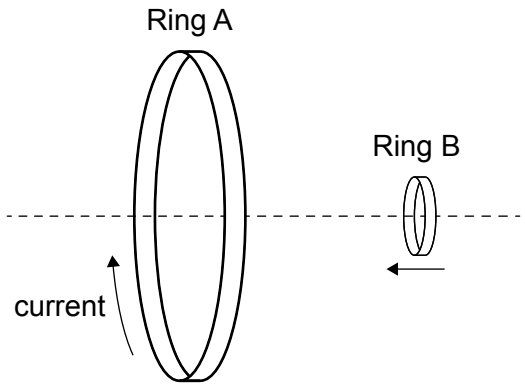
5. Two conducting rings, A and B, have their centres on the same line. The planes of A and B are parallel. There is a constant clockwise current in A. Ring A is stationary and ring B moves towards ring A at a constant speed.



(a) Outline why the magnetic flux in ring B increases. [1]

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(b) State the direction of the induced current in ring B. [1]

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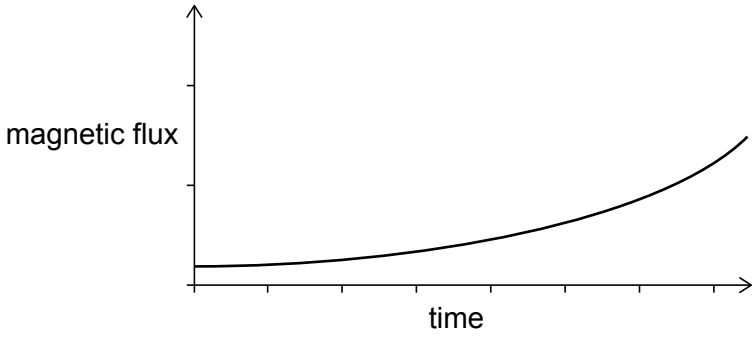
(This question continues on the following page)

(Question 5 continued)

(c) The graph shows how the magnetic flux in ring B varies with time.



Discuss the variation with time of the induced current in ring B. [3]

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(d) Outline why work must be done on ring B as it moves towards ring A at a constant speed. [2]

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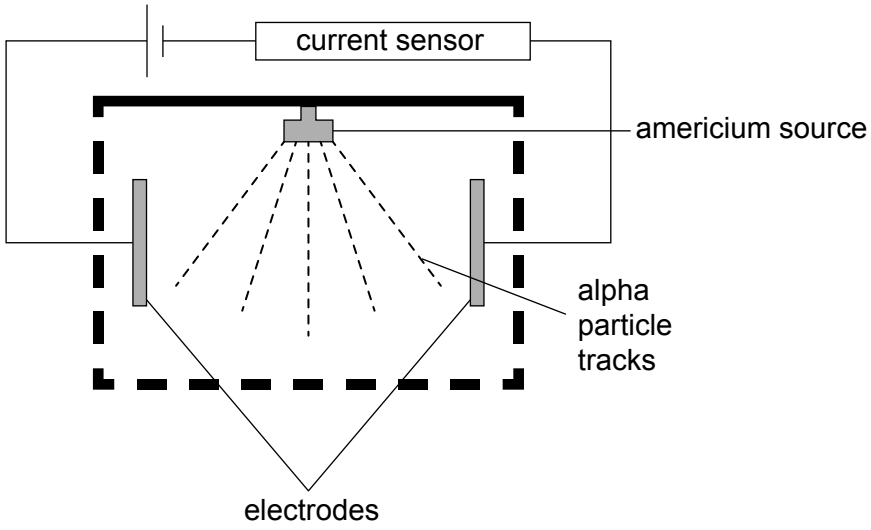
6. A smoke detector uses the radioactive nuclide americium-241.

The americium is contained in a chamber that is open to the air. There are two electrodes in the chamber that are connected to a power supply and a current sensor.



Americium-241 emits alpha particles that ionize the air in the chamber. Each ionization forms one positive ion and one electron; these are called an ion pair. The electrons and the positive ions move towards the electrodes and the sensor detects a current in the air.

When smoke enters the chamber, fewer ion pairs are formed and the current in the sensor decreases, sounding an alarm.

The decay constant of americium-241 is $5.08 \times 10^{-11}\,s^{-1}$.
The chamber is 0.10 m in each dimension.

(a) A nucleus of americium-241 has 146 neutrons. This nuclide decays to neptunium through alpha emission.

Complete the nuclear equation for this decay. [2]

$$\_\!\!^{\_}_{\_}\text{Am} \rightarrow \_\!\!^{\_}_{\_}\text{Np} + \_\!\!^{\_}_{\_}\alpha$$

(This question continues on the following page)

(Question 6 continued)

(b) Outline why the radioactive source is safe for use in a house. [1]

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(c) Deduce whether the radioactive source will need to be replaced during the life of the detector. [3]

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The initial activity of the source is 42 kBq. 33 % of the alpha particles emitted by this source enter the chamber and form an ion pair.
Each alpha particle has an initial kinetic energy of 5.5 MeV.
The energy required to form one ion pair is 15 eV.

(d) Calculate the maximum current in the chamber due to the electrons when there is no smoke in the chamber. [3]

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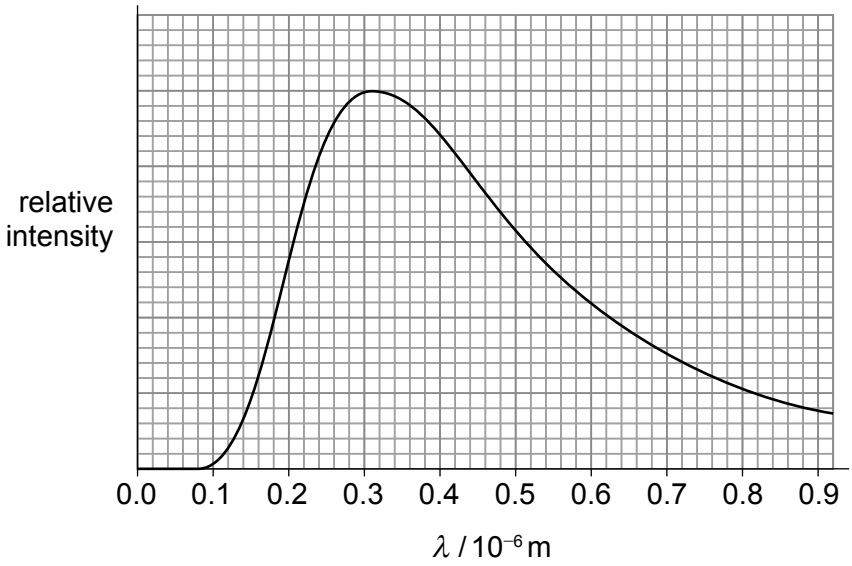
7. The star δ Vel A is a main sequence star that has a black-body spectrum as shown.



(a) Show that the surface temperature of δ Vel A is about 9000 K. [1]

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(b) The apparent brightness of δ Vel A is $2.2 \times 10^{-9}\,\text{W m}^{-2}$ and it is 6.2×10^{14} km from Earth.

Estimate the radius of δ Vel A. [3]

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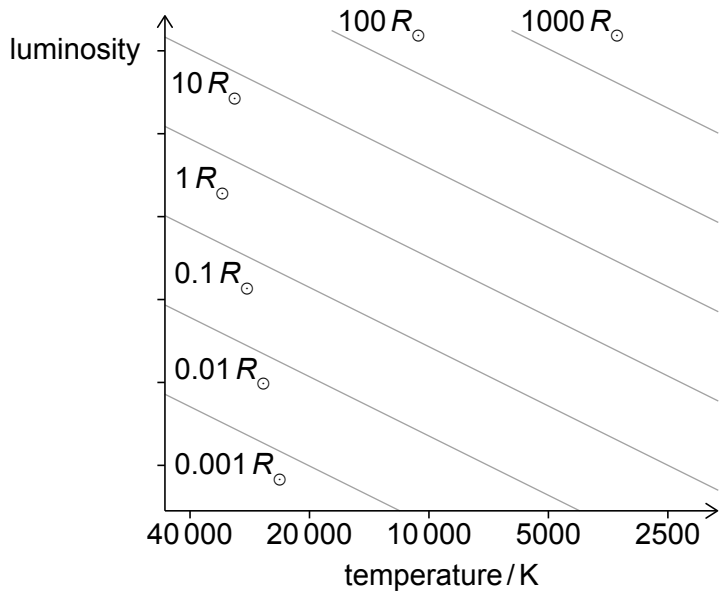
(This question continues on the following page)

(Question 7 continued)

(c) The radius of the Sun, $R_\odot$, is 7.0×10^5 km.

Sketch, on the Hertzsprung-Russell diagram, the position of δ Vel A. [2]



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Answers written on this page
will not be marked.

8. Small pieces of solid paraffin with a total mass of 30 g at a temperature of 42 °C are mixed with 150 g of liquid paraffin at a temperature of 240 °C. The mixture is stirred until an equilibrium temperature is reached.

The following data for paraffin are available:

Specific heat capacity of solid paraffin = $0.7\,kJ\,kg^{-1}\,K^{-1}$
Specific heat capacity of liquid paraffin = $2.13\,kJ\,kg^{-1}\,K^{-1}$
Specific latent heat of fusion of paraffin = $220\,kJ\,kg^{-1}$
Melting point of paraffin = 47 °C

(a) Calculate the theoretical equilibrium temperature of the mixture. [3]

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(b) (i) When the experiment was carried out, the equilibrium temperature of the mixture was found to be different from the theoretical value.

Suggest the reason for this difference. [2]

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(ii) The mixture was held in a large metal container during the mixing.

Explain **one** change to the procedure that will reduce the difference in (b)(i). [1]

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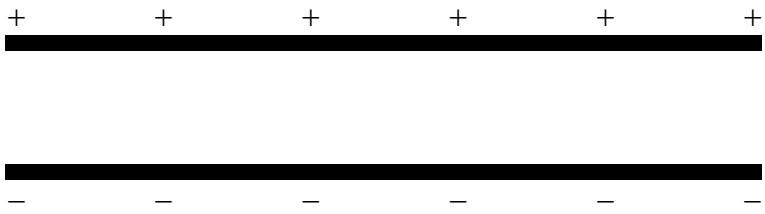
9. The diagram shows two parallel conducting plates that are oppositely charged.



(a) (i) Draw the electric field lines due to the charged plates. [2]

(ii) The potential difference between the plates is 960 V and the distance between them is 8.0 mm. Calculate the electric field strength *E* between the plates. [2]

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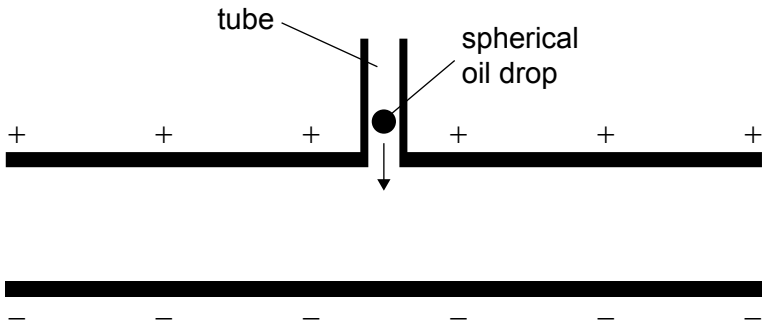
(This question continues on the following page)

(Question 9 continued)

In an experiment, an oil drop is introduced into the space between the plates through a small hole in the upper plate. The oil drop moves through air in a tube before falling between the plates.



(b) Explain why the oil drop becomes charged as it falls through the tube. [1]

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(This question continues on the following page)

(Question 9 continued)

(c) The oil drop is observed to be stationary in the space between the plates. Buoyancy is one of the forces acting on the drop.

The density of oil is 730 times greater than that of air.

(i) Show that the buoyancy force is much smaller than the weight. [3]

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(ii) Draw the forces acting on the oil drop, ignoring the buoyancy force. [2]

oil drop

(This question continues on the following page)

(Question 9 continued)

(iii) Show that the electric charge on the oil drop is given by

$$q = \frac{\rho_o g V}{E}$$

where ρ_o is the density of oil and V is the volume of the oil drop. [2]

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(iv) State the sign of the charge on the oil drop. [1]

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(This question continues on page 21)

Please **do not** write on this page.

Answers written on this page
will not be marked.

(Question 9 continued)

(d) The electric field is turned off. The oil drop falls vertically reaching a constant speed v.

(i) Outline why, for this drop, $\rho_o gV = 6\pi\eta rv$ where η is the viscosity of air and r is the radius of the oil drop. [2]

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(ii) Show that the charge on the oil drop is about 4.8×10^{-19} C.

The following data for the oil drop are available:

$r = 1.36\,\mu m$
$\eta = 1.60 \times 10^{-5}\,Pa\,s$
$v = 0.140\,mm\,s^{-1}$ [3]

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(iii) The oil drop splits into two parts of equal mass. Both are charged. Deduce the net charge on each part. [2]

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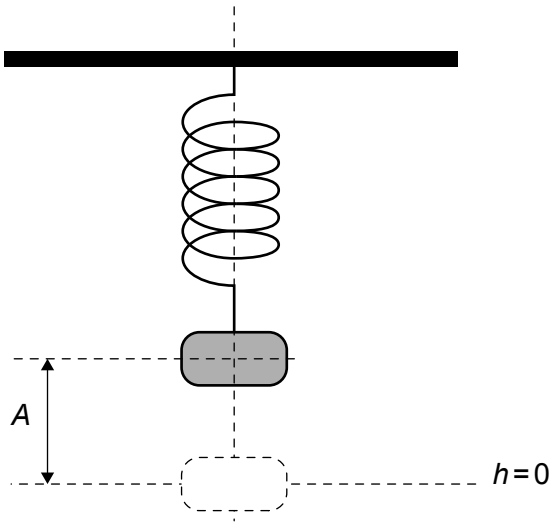
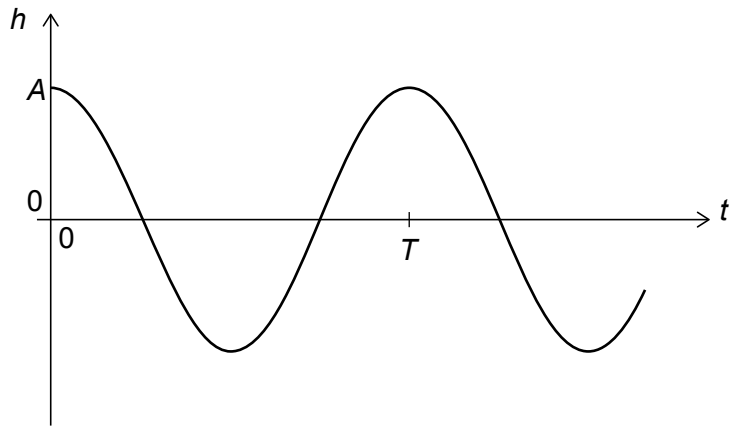
10. An object hangs in equilibrium from a spring of elastic constant k. The object is displaced through a vertical height $h = A$ and released at time $t = 0$ so that it oscillates with a simple harmonic motion of period T.



The graph shows the variation of h with t.



(a) State the equation of motion for this oscillation. [1]

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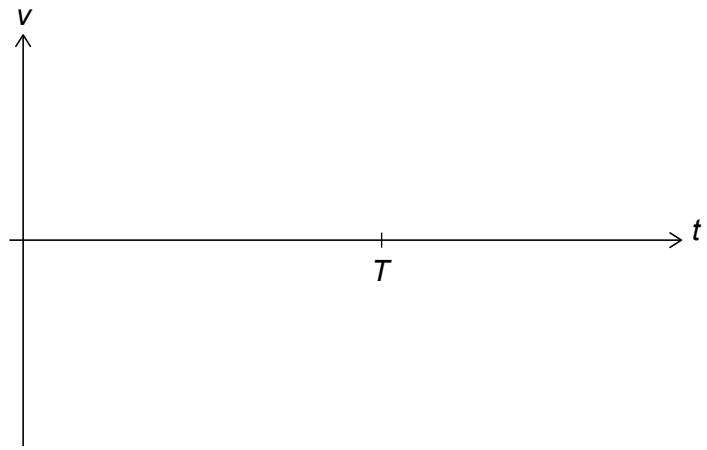
(This question continues on the following page)

(Question 10 continued)

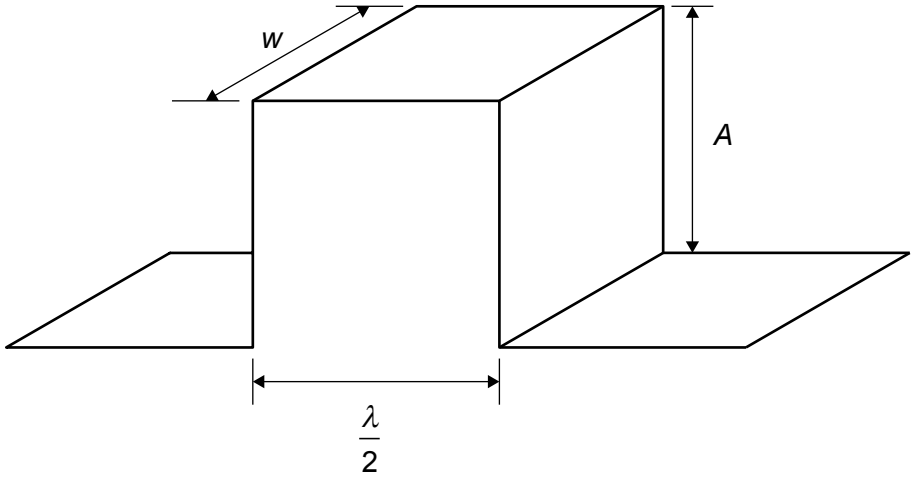
(b) Sketch, on the axes, the variation with t of the velocity v of the object. Label the peak value on the v-axis with an appropriate expression in terms of A and T. [2]



(This question continues on the following page)

(Question 10 continued)

Sea waves are produced by wind and carry energy that can be transferred into electrical energy. A sea wave can be modelled as a square wave of wavelength λ, amplitude A, and width w.



(c) (i) Show that the gravitational potential energy of the sea wave shown in the diagram can be modelled as

$$E_p = \frac{1}{4}\rho g w \lambda A^2$$

where ρ is the density of sea water. [3]

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(This question continues on the following page)

(Question 10 continued)

(ii) The wave is moving at a speed v. The maximum power available from the sea wave is P.

Explain why the maximum power per unit length of the wavefront $\frac{P}{w}$ available from the sea wave is $\frac{1}{2}\rho g v A^2$. [2]

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(This question continues on the following page)

(Question 10 continued)

Thermal energy is also used in the production of electrical energy. The thermal energy is usually transferred from the chemical energy of a fuel or from the nuclear energy of a fissionable element.

(d) (i) A fuel is used to transfer thermal energy to water to produce steam at a pressure of 20 MPa and a temperature of 550 °C. The steam turns the blades of a turbine generator system and finally condenses at atmospheric pressure and a temperature of 30 °C.

Explain, with reference to the second law of thermodynamics, why a steam turbine operating between these temperatures must be less than about 60 % efficient. [2]

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In nuclear reactors, the water is vaporized in the transfer of nuclear energy from the fission of Uranium-235 ($^{235}_{92}U$). The fission is induced by the collision of a neutron with the nucleus.

The table gives some common nuclear fragments that are present in a fuel rod following the fission of $^{235}_{92}U$. The symbol of the element is followed by its proton number and some of the nucleon numbers that are observed in the fragments.

Element symbol	Proton number	Observed nucleon numbers						
Br	35	81						
Kr	36	86	87	88	89			
Rb	37	85	87					
Sr	38	88	89	90				
Y	39	89	90	91				
Zr	40	90	91	92	93	94	95	96

(This question continues on the following page)

(Question 10 continued)

(ii) In a fission, two nuclei are produced together with several neutrons. One of the products is a $^{147}_{56}Ba$ nucleus.

State the nuclear reaction for the fission that has this product. [2]

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On average, the fission of an atom of Uranium-235 releases 200 MeV. The energy density of coal is approximately 25 MJ kg^{-1}.

(iii) Estimate the ratio

$$\frac{\text{energy density of } ^{235}U}{\text{energy density of coal}}$$ [3]

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(iv) The energy in a star arises from nuclear fusion. Attempts are being investigated to use fusion on Earth to provide electrical energy on a large scale.

Identify **one** advantage and **one** difficulty for this to become a reality on Earth. [2]

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(This question continues on the following page)

(Question 10 continued)

(e) Four methods for energy production are mentioned in this question. These methods are sea waves, coal, nuclear fission and nuclear fusion.

Discuss these methods.

In your answer you should refer to

- efficiency of the methods
- their environmental impacts
- availability of the resources. [3]

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Diploma Programme
Programme du diplôme
Programa del Diploma

Markscheme

Specimen paper

Physics

Higher level

Paper 2

16 pages

International Baccalaureate®
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Subject Details: Physics HL Paper 2 Markscheme

Mark Allocation

Candidates are required to answer ALL questions. Maximum total = [90 marks].

1. Each row in the "Question" column relates to the smallest subpart of the question.

2. The maximum mark for each question subpart is indicated in the "Total" column.

3. Each marking point in the "Answers" column is shown by means of a tick (✓) at the end of the marking point.

4. A question subpart may have more marking points than the total allows. This will be indicated by "max" written after the mark in the "Total" column. The related rubric, if necessary, will be outlined in the "Notes" column.

5. An alternative wording is indicated in the "Answers" column by a slash (/). Either wording can be accepted.

6. An alternative answer is indicated in the "Answers" column by "***OR***" between the alternatives. Either answer can be accepted.

7. Words in angled brackets **« »** in the "Answers" column are not necessary to gain the mark.

8. Words that are underlined are essential for the mark.

9. The order of marking points does not have to be as in the "Answers" column, unless stated otherwise in the "Notes" column.

10. If the candidate's answer has the same "meaning" or can be clearly interpreted as being of equivalent significance, detail and validity as that in the "Answers" column then award the mark. Where this point is considered to be particularly relevant in a question it is emphasized by ***OWTTE*** (or words to that effect) in the "Notes" column.

11. Remember that many candidates are writing in a second language. Effective communication is more important than grammatical accuracy.

12. Occasionally, a part of a question may require an answer that is required for subsequent marking points. If an error is made in the first marking point then it should be penalized. However, if the incorrect answer is used correctly in subsequent marking points then **follow through** marks should be awarded. When marking, indicate this by adding **ECF** (error carried forward) on the script. "Allow ECF" will be displayed in the "Notes" column.

13. Do **not** penalize candidates for errors in units or significant figures, **unless** it is specifically referred to in the "Notes" column.

14. Allow reasonable substitutions where in common usage, *eg* ^{c} for rad.

Question			Answers	Notes	Total
1.	a		static friction force «between blocks» **AND** directed to the right✓		1
1.	b		$F = 60a$ ✓ $F_f = 0.6 \times 15 \times 9.8$ «$= 88.2$N» ✓ $88.2 = 15 \times \frac{F}{60} \Rightarrow F = 350$«N» ✓	*Allow use of* $a = 0.6g$ *leading to 353 N.*	3

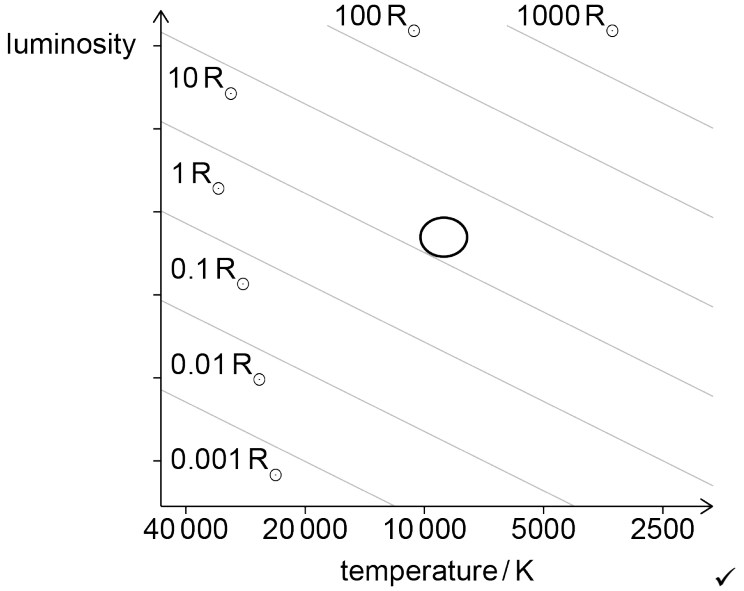
Question			Answers	Notes	Total
2.	**a**		$\gamma = \frac{1}{\sqrt{1-0.80^2}} = \frac{5}{3} = 1.67$ ✓		**1**
2.	**b**	**i**	«$\Delta x' = \gamma(\Delta x - v\Delta t) =$» $\frac{5}{3} \times 1200 = 2000$ «m» ✓	*Allow ecf from 1a.* *Allow use of* $L = \frac{L_0}{\gamma}$.	**1**
2.	**b**	**ii**	«$\Delta t' = \gamma(\Delta t - \frac{v}{c^2}\Delta x) =$» $\frac{5}{3}(0 - \frac{0.80}{3 \times 10^8} \times 1200)$ ✓ $\Delta t' =$ «–»5.3 «μs» ✓	*Allow use of* $\Delta t = \gamma \Delta t_0$.	**2**
2.	**c**		Because $\Delta t' < 0$ ✓ F occurred first ✓	*2nd MP only awarded if correct interpretation of 1st MP.*	**2**

Question			Answers	Notes	Total
3.	**a**		standing waves form «in the oven» by superposition / constructive interference✓ energy transfer is greatest at the antinodes «of the standing wave pattern»✓		**2**
3.	**b**		$\lambda = 12.2$«cm» ✓ f«$= \frac{c}{\lambda}$» $= \frac{3.0 \times 10^{8}}{1.22 \times 10^{-1}}$ ✓ $f = 2.46\,\text{GHz}$ ✓ correct answer only including power of ten	*Allow* $\lambda \pm 2$ *mm.* *Condone power of ten error in MP2 only.*	**3**

Question			Answers	Notes	Total
4.	a		arrow normal to the orbit towards the Earth ✓		1
4.	b	i	use of $v_{\text{orbital}} = \frac{2\pi r}{T}$ AND either $v_{\text{orbital}} = \sqrt{\frac{GM}{r}}$ or $\frac{mv_{\text{orbital}}^2}{r} = \frac{GMm}{r^2}$ correctly manipulated✓ «to yield $T^2 = \left(\frac{4\pi^2}{GM}\right) r^3$ »	*Allow use of* ω.	1
4.	b	ii	$r = \sqrt[3]{\frac{GMT^2}{4\pi^2}} = \sqrt[3]{\frac{6.67\times10^{-11}\times5.97\times10^{24}\times(5620)^2}{4\pi^2}}$ ✓ $= 6.83\times10^6$ «m» height $= «6.83\times10^6 - 6.37\times10^6 =» \ 4.6\times10^5$ «m» ✓		2
4.	c		Total energy is reduced ✓ hence decrease in orbital radius leads to increase in kinetic energy ✓ decrease in potential energy must be larger than increase in kinetic energy for total energy to decrease✓	*Allow ECF from b ii.*	3

Question			Answers	Notes	Total
5.	**a**		ring B cuts an increasing number of magnetic field lines **OR** magnetic field from current in A increases at the position of B ✓		**1**
5.	**b**		counterclockwise ✓		**1**
5.	**c**		the rate of change of «magnetic» flux in B increases **OR** The gradient of the graph is increasing with time ✓ Faraday's law states that the induced emf in B will «therefore» increase ✓ so induced current will increase because resistance of ring is constant ✓		**3**
5.	**d**		the current induced in B gives rise to a magnetic field opposing that of A **OR** there will be a magnetic force opposing the motion ✓ work must be done to move B in the opposite direction to this force✓		**2**

Question			Answers	Notes	Total
6.	a		$^{241}_{95}\text{Am}$ ✓ $^{237}_{93}\text{Np} + {}^{4}_{2}\alpha$ ✓		2
6.	b		Alpha particles only travel a few cm in air / penetration of alpha particles is poor (and will not escape the chamber) ✓	*OWTTE*	1
6.	c		$\text{Half-life} = \frac{\ln 2}{5.08 \times 10^{-11}} \approx 10^{10}\ \text{s}$ ✓ Idea that this is much longer than lifetime of other components ✓ Reasoned comparison by conversion to reasonable unit eg ≈ 430 year ✓		3
6.	d		Each alpha gives rise to $\frac{5.5 \times 10^{6}}{15} = 3.67 \times 10^{5}$ ion pairs ✓ So $\frac{3.67 \times 10^{5} \times 42000}{3} = 5.13 \times 10^{9}$ ion pairs per second ✓ $\text{current} = 1.6 \times 10^{-19} \times 5.13 \times 10^{9} = 0.82 \times 10^{-9}$ «A» ✓		3

Question			Answers	Notes	Total
7.	a		correct substitution into $\lambda_{max} = \frac{2.9 \times 10^{-3}}{T}$ OR 9350 K ✓		1
7.	b		Attempted use of $L = 4\pi bd^2$ ✓ use of $r = \sqrt{\frac{L}{4\pi\sigma T^4}}$ ✓ $r = 1.4\,\text{Gm}$ ✓	*Accept a range of values between 1.3 to 1.5 Gm*	3
7.	c		Shows $r \approx 2R_\odot$ ✓ Correct position on diagram  ✓	*[use of 9000 K gives $2.2R_\odot$]*	2

Question			Answers	Notes	Total
8.	a		$(0.030\times0.7\times10^3\times5)+(0.030\times220\times10^3)+(0.030\times2.13\times10^3)(T-47)$ $=(0.150\times2.13\times10^3)(240-T)$ One heat capacity term correctly substituted ✓ latent heat correctly substituted $(0.030\times220\times10^3)$ ✓ $T=190$«°C» ✓		**3**
8.	b	i	Experimental temperature will be lower ✓ Heat loss to the environment ✓		**2**
8.	b	ii	Insulate the container **OR** Carry out experiment quicker **OR** Use larger volumes of substances ✓		**MAX 1**

Question			Answers	Notes	Total
9.	a	i	equally spaced arrows «by eye» all pointing down ✓ edge effects also shown with arrows ✓		2
9.	a	ii	$E = \frac{V}{d} = \frac{960}{8.0 \times 10^{-3}}$ ✓ $E = 1.2 \times 10^{5}$ «NC^{-1}» ✓		2
9.	b		friction transfers electron(s) to or from drop ***AND*** through collisions/ interaction with air molecules in the tube OR through collisions/interaction with wall of tube ✓		1
9.	c	i	weight of oil drop is $\rho_o gV$ ✓ $\frac{F_b}{W} = \frac{\rho_a gV}{\rho_o gV} = \frac{\rho_a}{\rho_o}$ ✓ «$\frac{F_b}{W} = \frac{1}{730}$ =»1.4×10^{-3} ***OR*** Ratio of F_b to W is much less than 1 ✓		3

9.	**c**	**ii**	Weight vertically down ***AND*** electric force vertically up ✓ Of equal length «by eye» ✓		**2**
9.	**c**	**iii**	Mass of drop is $\rho_0 V$ ✓ $qE = (\rho_0 V)g$ ✓ «hence answer»	*MP1 must be shown implicitly for credit.*	**2**
9.	**c**	**iv**	Negative ✓		**1**
9.	**d**	**i**	Net force is zero ✓ Acceleration of the oil drop is zero ✓ ***OR*** For terminal velocity drag must equal weight ✓ weight $= \rho_0 gV$ **and** drag $= 6\pi\eta rv$ ✓		**2**

9.	**d**	**ii**	$q = \frac{6\pi\eta r v}{E}$ ✓ $q = \frac{6\pi \times 1.60 \times 10^{-5} \times 1.36 \times 10^{-6} \times 1.40 \times 10^{-4}}{1.2 \times 10^{5}}$ ✓ $q = 4.79 \times 10^{-19}$ «C» ✓	*Answer must be shown to 3+ sf.*	**3**
9.	**d**	**iii**	charge is quantized ✓ so, the charges must be 1e and 2e ✓		**2**

Question			Answers	Notes	Total
10.	**a**		$h = A\cos(\frac{2\pi}{T}t)$ ***OR*** $h = A\sin(\frac{2\pi}{T}t + \frac{\pi}{2})$ ✓	*Do not accept use of* ω *or* x *or other symbols unless explained.*	**1**
10.	**b**		negative sin curve of period T ✓ labelled $\frac{2\pi A}{T}$ for the peak value ✓	*Accept* ωA *for the second mark.*	**2**
10.	**c**	**i**	Identifies mass of one crest $m = \rho V = \rho\frac{\lambda}{2}Aw$ ✓ Recognizes position of centre of mass of one crest at $\frac{A}{2}$ ✓ Correctly combined expressions for mass and height <<to obtain the answer>> ✓		**3**
10.	**c**	**ii**	gravitational potential energy per unit length of wavefront is transferred at a rate of $\frac{\rho g w \lambda A^2}{4wT} = \frac{\rho g v A^2}{4}$ ✓ kinetic energy is transferred at the same rate as gravitational potential energy so the total power is $\frac{2\rho g v A^2}{4}$ ✓		**2**

10.	**d**	**i**	Efficiency $= 1 - \frac{303}{823} = 0.63$ ✓ second law sets an upper limit on the maximum efficient transfer from thermal to mechanical energy ✓	*MP1 to 2sf or better for credit.*	**2**
10.	**d**	**ii**	e.g. ${}^{235}_{92}\text{U} + {}^{1}_{0}\text{n} \rightarrow {}^{87}_{36}\text{Kr} + {}^{147}_{56}\text{Ba} + 2{}^{1}_{0}\text{n}$ Kr identified✓ nuclear equation completely correct ✓	*Accept any example with 2 or 3 neutrons on the right hand side where mass numbers add up to 236.*	**2**
10.	**d**	**iii**	***ALTERNATIVE 1*** $200 \times 10^{6} \times 1.6 \times 10^{-19} \times 6.02 \times 10^{-23} = 1.9 \times 10^{13}\,\text{J}$ ✓ $\frac{1.9 \times 10^{13} \times 1000}{235} = 81\text{TJ}$ ✓ $\text{ratio} = \frac{81 \times 10^{12}}{25 \times 10^{6}} = 3.2 \times 10^{6}$ ✓ ***ALTERNATIVE 2*** $E = 200\text{MeV} \times e = 3.2 \times 10^{-11}\text{J}$ ✓ $\frac{E}{m} = \frac{3.2 \times 10^{-11}}{235 \times 1.67 \times 10^{-27}} = 8.2 \times 10^{13}\,\text{Jkg}^{-1}$ ✓	*Allow ecf from second m.p.*	**3**

			$\frac{8.2\times10^{13}}{25\times10^{6}}=3.3\times10^{6}$ ✓		
10.	**d**	**iv**	any suitable one e.g.: no radioactive fragments, readily available fusionable elements ✓ extreme initial temperatures to overcome electrical repulsion, containments at this temperature ✓		**2**
10.	**e**		3 Marks (✓✓✓): Compares correctly all three methods mentioned in question referring twice to some data described during the question with appropriate concepts referring to efficiency, environmental impact or availability of the resource. 2 marks (✓✓): Compares at least two of the three methods mentioned in the question correctly, referring at least once to some data from the question in terms of two appropriate concepts drawn from efficiency, environmental impact or availability of the resource. 1 mark (✓)**:** Refers correctly to one method making reference to at least one correct concept related to efficiency, environmental impact or availability of the resource. 0 marks: Generic concepts with no correct points specific to this question.		**3**

Diploma Programme
Programme du diplôme
Programa del Diploma

Physics
Standard level
Paper 1A

Specimen paper

1 hour 30 minutes [Paper 1A and Paper 1B]

Instructions to candidates

- Do not open this examination paper until instructed to do so.
- Answer all questions.
- For each question, choose the answer you consider to be the best and indicate your choice on the answer sheet provided.
- A calculator is required for this paper.
- A clean copy of the **physics data booklet** is required for this paper.
- The maximum mark for paper 1A is **[25 marks]**.
- The maximum mark for paper 1A and paper 1B is **[45 marks]**.

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1. A car has an initial speed of $16\,m\,s^{-1}$. It decelerates at $4.0\,m\,s^{-2}$ until it stops.

What is the distance travelled by the car?

A. 4 m

B. 16 m

C. 32 m

D. 64 m

2. A block of mass 2.0 kg accelerates from a speed of $15\,m\,s^{-1}$ to a speed of $20\,m\,s^{-1}$ without changing its direction.

What impulse acts on the block?

A. 2.5 N s

B. 5.0 N s

C. 10 N s

D. 17.5 N s

3. A net force of 8.0 N accelerates a 4.0 kg body from rest to a speed of $5.0\,m\,s^{-1}$.

What is the work done by the force?

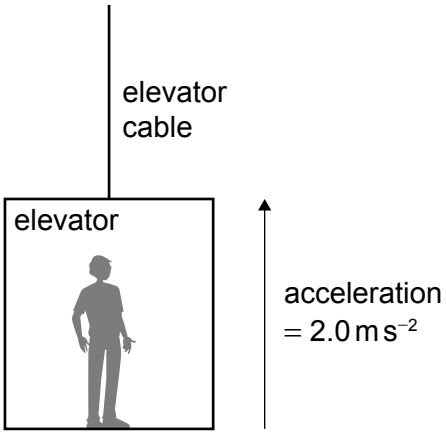
A. 50 J

B. 40 J

C. 32 J

D. 20 J

4. A person stands in an elevator (lift). The total mass of the person and the elevator is 800 kg. The elevator accelerates upward at $2.0\,m\,s^{-2}$.



What is the tension in the cable?

A. 1.6 kN

B. 6.4 kN

C. 8.0 kN

D. 9.6 kN

5. An object is released from rest in a vacuum at a height H above the Earth's surface.

As the object falls it passes a point at a height of $0.75H$ above the surface.

What is $\dfrac{\text{kinetic energy of the object at a height of } 0.75H}{\text{gravitational potential energy of the object at a height of } H}$?

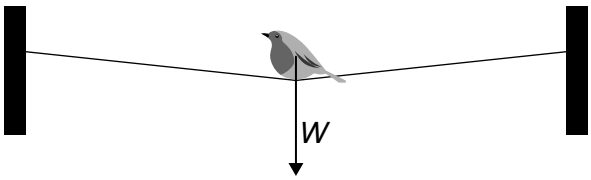
A. $\dfrac{1}{16}$

B. $\dfrac{1}{4}$

C. $\dfrac{9}{16}$

D. $\dfrac{3}{4}$

6. A bird of weight W sits on a thin rope at its midpoint. The rope is almost horizontal and has negligible mass.



The tension in the rope is

A. less than $\frac{W}{2}$

B. equal to $\frac{W}{2}$

C. between $\frac{W}{2}$ and W

D. greater than W

7. The internal energy of a real gas is

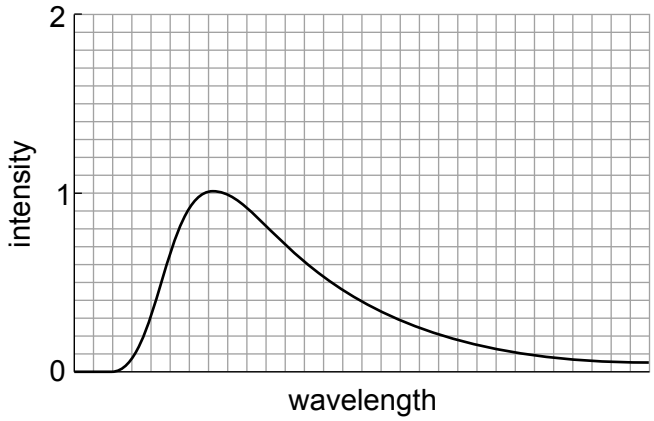
A. zero.

B. equal to the intermolecular potential energy of the particles.

C. equal to the total kinetic energy of the particles.

D. equal to the sum of the intermolecular potential energy and the total kinetic energy of the particles.

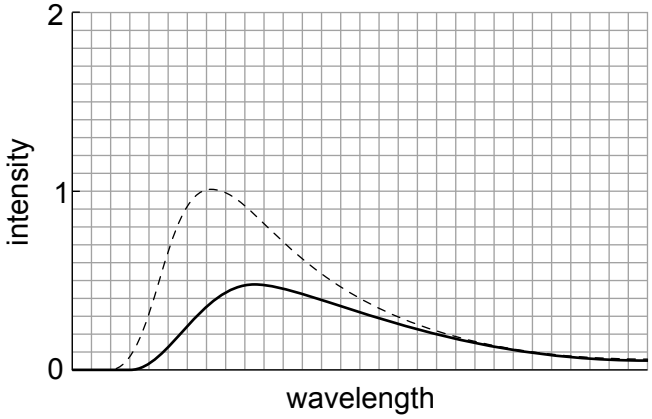
8. The black-body radiation curve of an object at 600 K is shown. The intensity units are arbitrary.



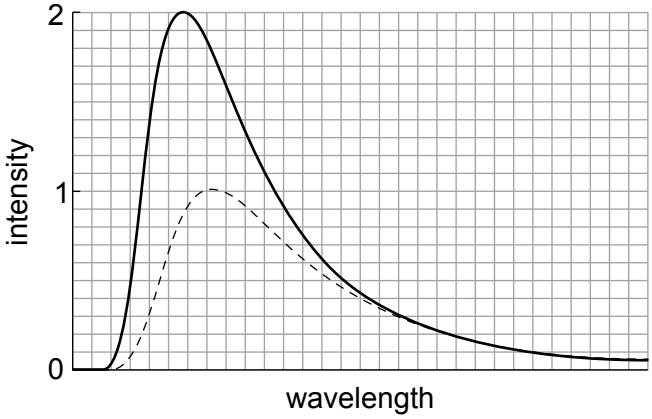
What is the radiation curve of the same object at 450 K?

The original curve is shown with a dashed line.

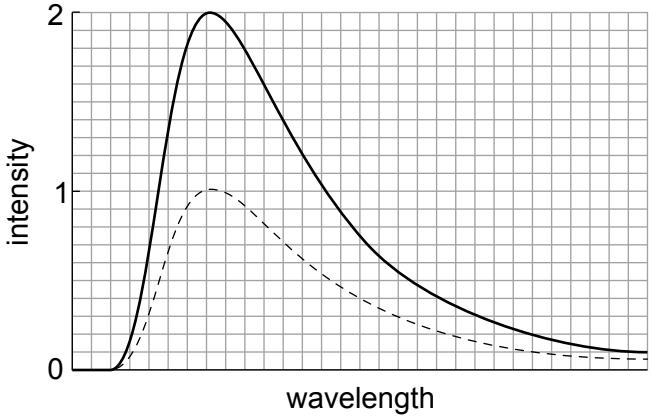
A.



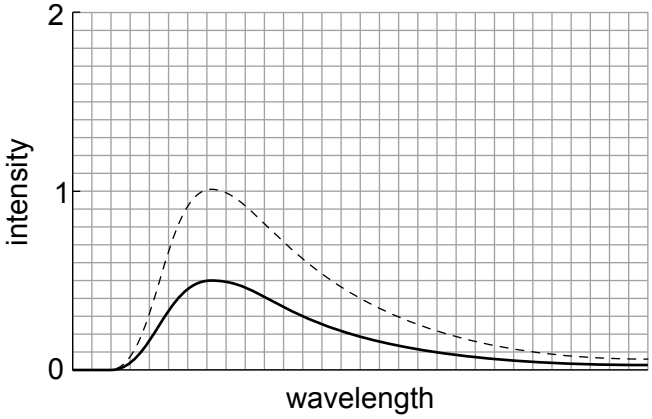
B.



C.



D.



9. Star X has a luminosity L and an apparent brightness b. Star X is at a distance d from Earth.

Star Y has the same apparent brightness as X but is four times more luminous.

What is the distance of Star Y from Earth?

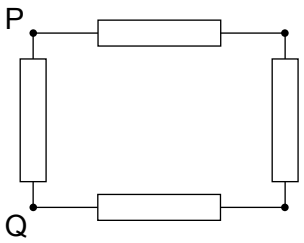
A. $4d$

B. $2d$

C. $\frac{d}{2}$

D. $\frac{d}{4}$

10. Four identical resistors, each of resistance R, are connected as shown.



What is the effective resistance between P and Q?

A. $\frac{3R}{4}$

B. R

C. $\frac{4R}{3}$

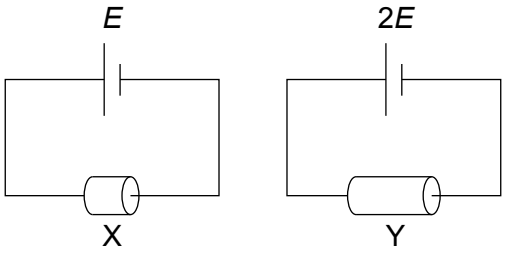
D. $4R$

11. Conductor X is connected to a cell of emf E. A power of 16 W is dissipated in X.

Conductor Y is made from the same material with the same diameter as X but is twice as long. A cell of emf $2E$ is connected to Y.

Both cells have negligible internal resistance.

What power is dissipated in Y?



A. 8.0 W

B. 16 W

C. 32 W

D. 64 W

12. Two containers, X and Y, are filled with an ideal gas at the same pressure.

The volume of X is four times the volume of Y. The temperature of X is 327 °C and the temperature of Y is 27 °C.

What is $\frac{\text{amount of substance in X}}{\text{amount of substance in Y}}$?

A. $\frac{1}{8}$

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

C. 2

D. 8

13. An electromagnetic wave has a wavelength that is about the size of the diameter of an atom.

What region of the electromagnetic spectrum does the wave belong to?

A. Infrared

B. Visible light

C. Ultraviolet

D. X-ray

14. A particle undergoes simple harmonic motion of period T. At time $t = 0$ the particle is at its equilibrium position.

What is t when the particle is at its greatest distance from the equilibrium position?

A. $\frac{T}{8}$

B. $\frac{T}{2}$

C. $\frac{3T}{4}$

D. T

15. Diagram 1 shows the variation with position of the displacement of a standing wave formed on a string.

Diagram 2 shows the variation with position of the displacement of a travelling wave moving to the right along a string.

Diagram 1

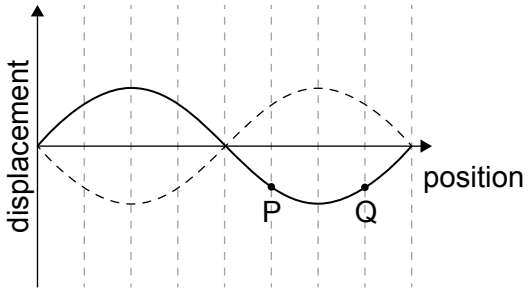
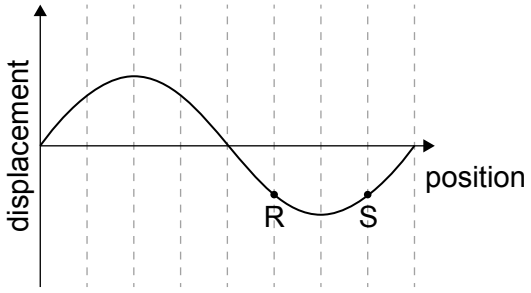


Diagram 2



Points P, Q, R and S are points on the string.

What is the phase difference between P and Q and the phase difference between R and S?

	Phase difference between P and Q	**Phase difference between R and S**
A.	0	0
B.	$\frac{\pi}{2}$	0
C.	0	$\frac{\pi}{2}$
D.	$\frac{\pi}{2}$	$\frac{\pi}{2}$

16. A mass of 0.25 kg hangs from a spring of spring constant 4.0 N m^{-1}.

What is the natural frequency of oscillation for this system?

A. 0.50 Hz

B. 0.64 Hz

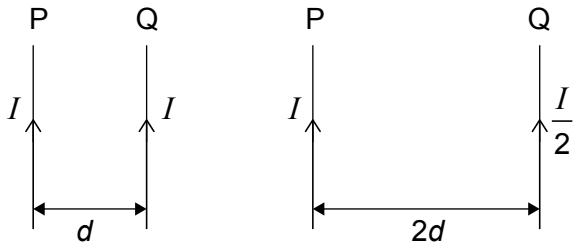
C. 1.6 Hz

D. 2.0 Hz

17. Two long parallel wires P and Q are a distance *d* apart. They each carry a current.

A magnetic force per unit length *F* acts on P due to Q.

The distance between the wires is increased to 2*d* and the current in Q is decreased to $\frac{I}{2}$.



What is the magnetic force per unit length that acts on P due to Q after the changes?

A. $\frac{F}{8}$

B. $\frac{F}{4}$

C. $\frac{F}{2}$

D. F

18. Planets X and Y orbit the same star.

The average distance between planet X and the star is five times greater than the average distance between planet Y and the star.

What is $\frac{\text{orbital period of planet X}}{\text{orbital period of planet Y}}$?

A. $\sqrt[3]{5}$

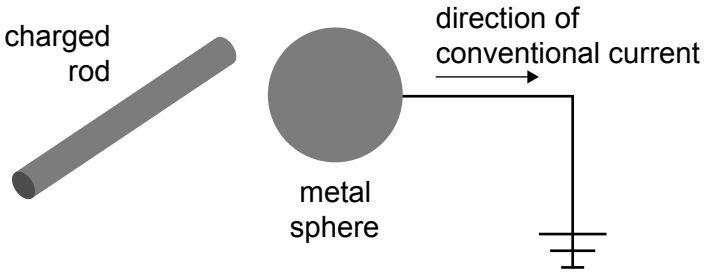
B. $\sqrt{5}$

C. $\sqrt[3]{5^2}$

D. $\sqrt{5^3}$

19. A charged rod is brought near an initially neutral metal sphere without touching it.

When the sphere is grounded (earthed), there is an electric current for a short time from the sphere to the ground.

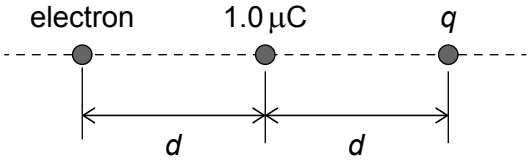


The ground connection is then removed.

What are the charge on the rod and the charge induced on the sphere when the connection is removed?

	Charge on the rod	Charge induced on the sphere
A.	negative	negative
B.	negative	positive
C.	positive	negative
D.	positive	positive

20. A positive point charge of magnitude 1.0 μC and a point charge *q* are separated by a distance *d*.



An electron is placed at a distance *d* from the +1.0 μC charge. The electric force on the electron is zero.

What is *q*?

A. –4.0 μC

B. –2.0 μC

C. 2.0 μC

D. 4.0 μC

21. What is the sequence for the evolution of a main sequence star of about 2 solar masses?

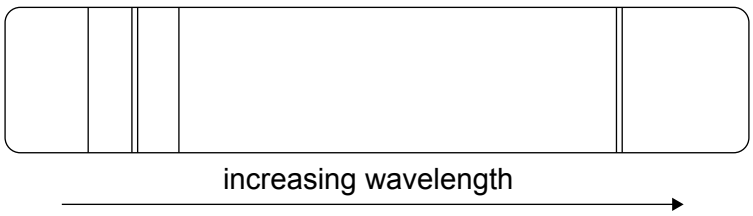
A. Red super giant → supernova → neutron star

B. Red giant → planetary nebula → white dwarf

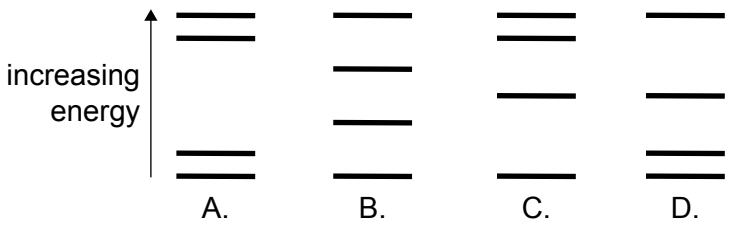
C. Red giant → supernova → white dwarf

D. Red super giant → planetary nebula → neutron star

22. The diagram shows the emission spectrum of an atom.



Which of the following atomic energy level models can produce this spectrum?



23. Two radioactive samples X and Y have the same half-life. Initially the ratio $\frac{\text{activity of X}}{\text{activity of Y}}$ is 4.

What is this ratio after 2 half-lives?

A. $\frac{1}{2}$

B. 1

C. 2

D. 4

24. Three statements about a nuclear fission reactor are:

I. The heat exchanger transfers energy from the fuel rods to the moderator.

II. The control rods must be good absorbers of neutrons.

III. The moderator must slow neutrons down.

Which statements about the reactor are correct?

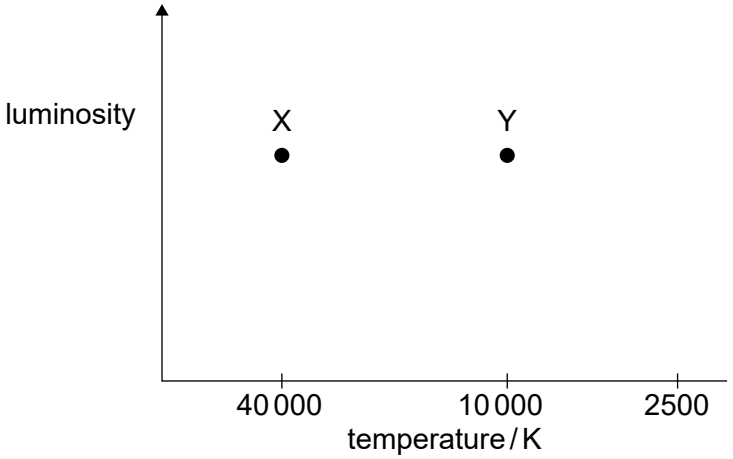
A. I and II only

B. I and III only

C. II and III only

D. I, II and III

25. The Hertzsprung–Russell diagram shows two stars, X and Y.



What is $\frac{\text{radius of X}}{\text{radius of Y}}$?

A. $\frac{1}{16}$

B. $\frac{1}{4}$

C. 4

D. 16

Diploma Programme
Programme du diplôme
Programa del Diploma

Markscheme

Specimen paper

Physics

Standard level

Paper 1A

2 pages

1.	C	16.	B	31.	–	46.	–
2.	C	17.	B	32.	–	47.	–
3.	A	18.	D	33.	–	48.	–
4.	D	19.	C	34.	–	49.	–
5.	B	20.	A	35.	–	50.	–
6.	D	21.	B	36.	–	51.	–
7.	D	22.	A	37.	–	52.	–
8.	A	23.	D	38.	–	53.	–
9.	B	24.	C	39.	–	54.	–
10.	A	25.	A	40.	–	55.	–
11.	C	26.	–	41.	–	56.	–
12.	C	27.	–	42.	–	57.	–
13.	D	28.	–	43.	–	58.	–
14.	C	29.	–	44.	–	59.	–
15.	C	30.	–	45.	–	60.	–

Diploma Programme
Programme du diplôme
Programa del Diploma

Physics
Standard level
Paper 1B

Specimen paper

Candidate session number

1 hour 30 minutes [Paper 1A and Paper 1B]

Instructions to candidates

- Write your session number in the boxes above.
- Do not open this examination paper until instructed to do so.
- Answer all questions.
- Answers must be written within the answer boxes provided.
- A calculator is required for this paper.
- A clean copy of the **physics data booklet** is required for this paper.
- The maximum mark for paper 1B is **[20 marks]**.
- The maximum mark for paper 1A and paper 1B is **[45 marks]**.

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8 pages

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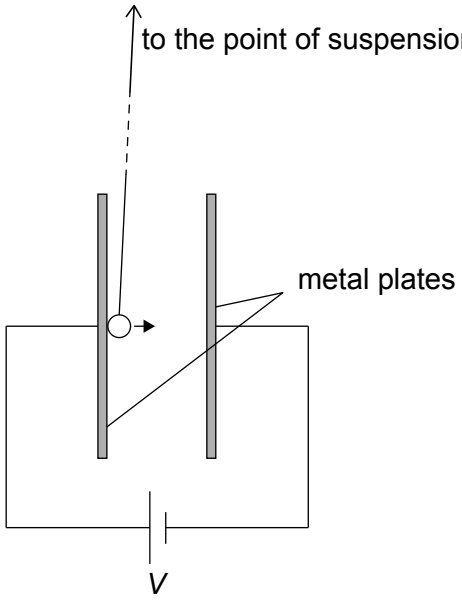
Answer **all** questions. Answers must be written within the answer boxes provided.

1. A group of students investigate the motion of a conducting ball suspended from a long string. The ball is between two vertical metal plates that have an electric potential difference *V* between them. The ball is touched to one plate so that it becomes electrically charged and is repelled from the plate. For a given potential difference, the ball bounces between the plates with a constant period.

diagram not to scale



(a) The students vary *V* and measure the time *T* for the ball to move **once** from one plate to the other. The table shows some of the data.

***V* / kV**	***T* / s ± 0.1 s**
3.00	1.4
5.00	0.8
7.00	0.6

(i) *V* is provided by two identical power supplies connected in series. The potential difference of each of the power supplies is known with an uncertainty of 0.01 kV.

State the uncertainty in the potential difference *V*. [1]

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(This question continues on the following page)

(Question 1 continued)

(ii) T is measured with an electronic stopwatch that measures to the nearest 0.1 s.

Describe how an uncertainty in T of less than 0.1 s can be achieved using this stopwatch. [2]

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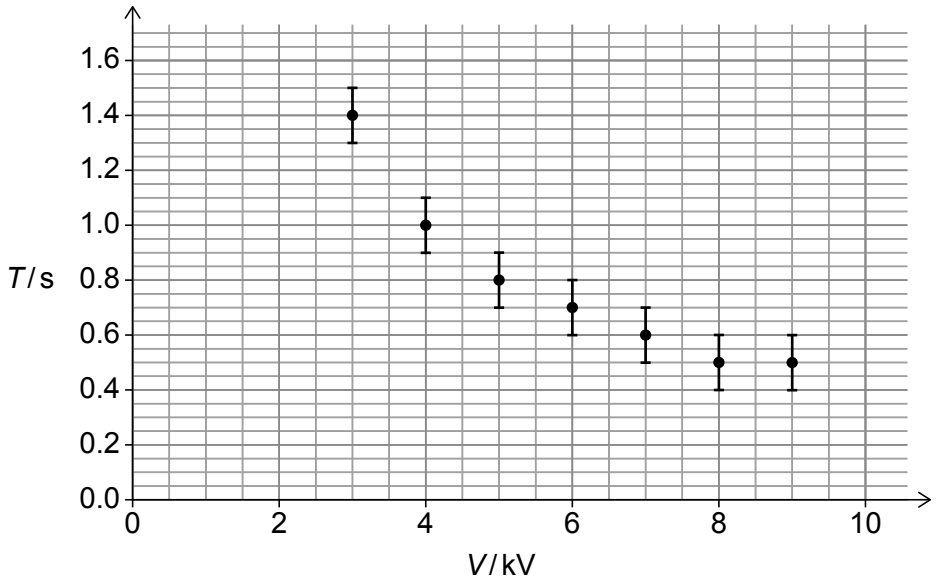
The graph shows the variation of T with V. The uncertainty in V is not plotted.



(iii) Outline why it is unlikely that the relationship between T and V is linear. [1]

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(iv) Calculate the largest fractional uncertainty in T for these data. [2]

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(This question continues on the following page)

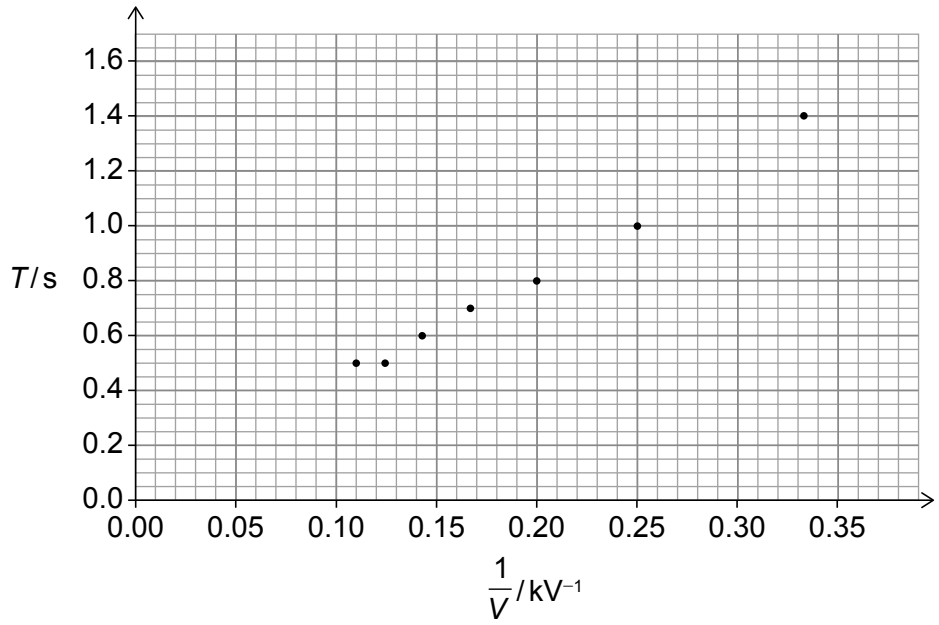
(Question 1 continued)

(b) The students suggest the following theoretical relationship between T and V:

$$T = \frac{A}{V}$$

where A is a constant.

To verify the relationship, the variation of T with $\frac{1}{V}$ is plotted.



(i) Determine A by drawing the line of best fit. [3]

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(This question continues on the following page)

(Question 1 continued)

(ii) State the units of *A*. [1]

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(iii) The theoretical relationship assumes that the ball is only affected by the electric force.

Suggest why, in order to test the relationship, the length of the string should be much greater than the distance between the plates. [2]

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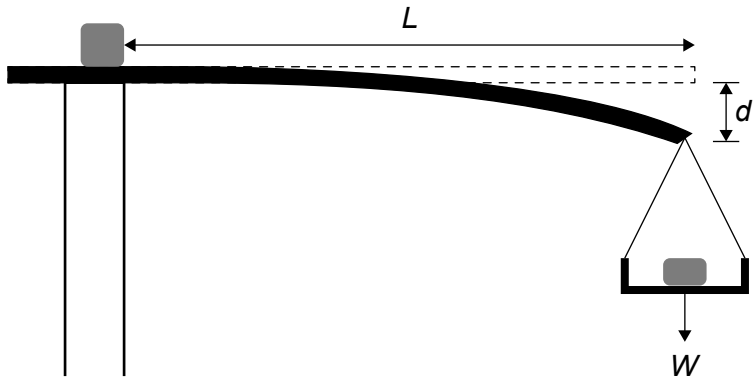
2. A group of students investigate the bending of a plastic ruler that is clamped horizontally at one end. A weight *W* attached to the other end causes the ruler to bend. The weight is contained in a scale pan.

The students fix the length *L* of the ruler and vary *W*. For each value of *W*, the group measures the deflection *d* of the end of the ruler to which the weight is attached.



(a) The group obtains the following repeated readings for *d* for **one** value of *W*.

Reading	1	2	3	4	5	6
***d* / cm**	2.7	2.9	3.6	2.7	2.8	2.9

The group divides into two subgroups, A and B, to analyse the data.

Group A quotes the mean value of *d* as 2.93 cm.

Group B quotes the mean value of *d* as 2.8 cm.

Discuss the values that the groups have quoted. [2]

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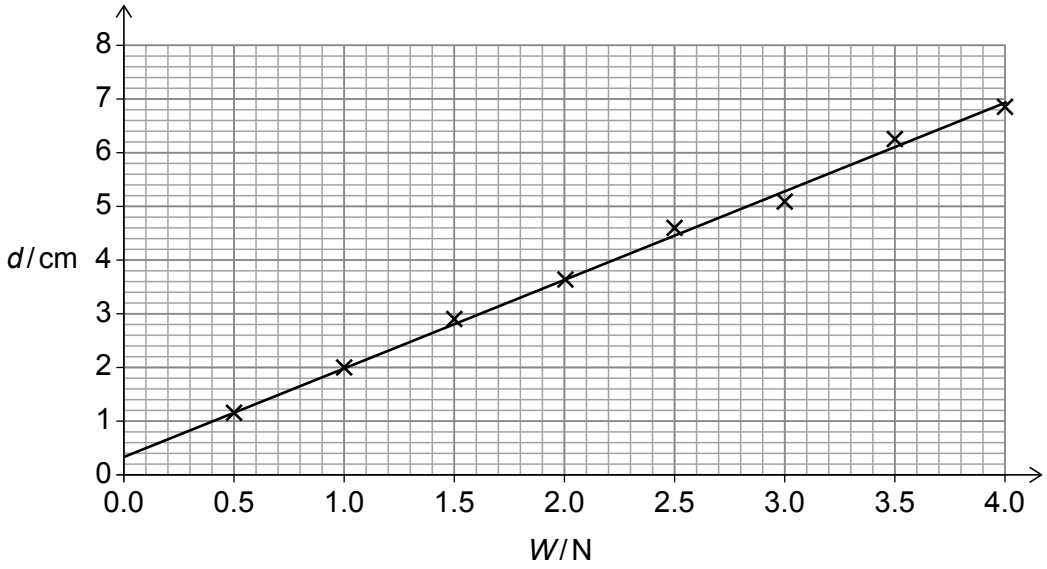
(Question 2 continued)

(b) The variation of d with W is shown.



Outline **one** experimental reason why the graph does not go through the origin. [1]

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(c) Theory predicts that

$$d \propto \frac{W^x L^y}{EI}$$

where E and I are constants. The fundamental units of I are m^4 and those of E are $kg\,m^{-1}\,s^{-2}$.

Calculate x and y. [2]

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(This question continues on the following page)

(Question 2 continued)

(d) The ruler has cross-sectional area $A = a \times b$, where $a = (28 \pm 1)$ mm and $b = (3.00 \pm 0.05)$ mm.

(i) Suggest an appropriate measuring instrument for determining b. [1]

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(ii) Calculate the percentage uncertainty in the value of A. [2]

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Markscheme

Specimen paper

Physics

Standard level

Paper 1B

4 pages

Subject Details: Physics SL Paper 1B Markscheme

Mark Allocation

Candidates are required to answer ALL questions. Maximum total = [20 marks].

1. Each row in the "Question" column relates to the smallest subpart of the question.

2. The maximum mark for each question subpart is indicated in the "Total" column.

3. Each marking point in the "Answers" column is shown by means of a tick (✓) at the end of the marking point.

4. A question subpart may have more marking points than the total allows. This will be indicated by "max" written after the mark in the "Total" column. The related rubric, if necessary, will be outlined in the "Notes" column.

5. An alternative wording is indicated in the "Answers" column by a slash (/). Either wording can be accepted.

6. An alternative answer is indicated in the "Answers" column by "***OR***" between the alternatives. Either answer can be accepted.

7. Words in angled brackets **« »** in the "Answers" column are not necessary to gain the mark.

8. Words that are underlined are essential for the mark.

9. The order of marking points does not have to be as in the "Answers" column, unless stated otherwise in the "Notes" column.

10. If the candidate's answer has the same "meaning" or can be clearly interpreted as being of equivalent significance, detail and validity as that in the "Answers" column then award the mark. Where this point is considered to be particularly relevant in a question it is emphasized by ***OWTTE*** (or words to that effect) in the "Notes" column.

11. Remember that many candidates are writing in a second language. Effective communication is more important than grammatical accuracy.

12. Occasionally, a part of a question may require an answer that is required for subsequent marking points. If an error is made in the first marking point then it should be penalized. However, if the incorrect answer is used correctly in subsequent marking points then **follow through** marks should be awarded. When marking, indicate this by adding **ECF** (error carried forward) on the script. "Allow ECF" will be displayed in the "Notes" column.

13. Do **not** penalize candidates for errors in units or significant figures, **unless** it is specifically referred to in the "Notes" column.

14. Allow reasonable substitutions where in common usage, *eg* ^{c} for rad.

Question			Answers	Notes	Total
1.	a	i	0.02 «kV» ✓		1
1.	a	ii	by measuring the time for many bounces ✓ and dividing the result by the number of bounces ✓		2
1.	b	i	it is not possible to draw a straight line through all the error bars ✓		1
1.	b	ii	$T = 0.5$ s ✓ «$\frac{0.1}{0.5}$ =» 0.2 ✓		2
1.	c	i	a best-fit line drawn through the entire range of the data ✓ large triangle greater than half a line or two data points on the line greater than half a line apart ✓ correct read offs consistent with the line, *eg* $\frac{1.6-0}{0.40-0} = 4.0$ ✓	*Accept answer in the range 3.8–4.2*	3
1.	c	ii	kV s ✓		1
1.	c	iii	the angle between the string and the vertical should be very small «for any position of the ball» ✓ so that the tension in the string is «almost» balanced by the ball's weight ***OR*** restoring force from the string / horizontal component of tension negligibly small «compared with electric force» ✓	*OWTTE*	2

Question			Answers	Notes	Total
2.	**a**		3 sf is inappropriate for *A* ✓ rejects trial 3 as outlier for *B* ✓		**2**
2.	**b**		beam bends under its own weight / weight of pan ***OR*** specified systematic error in *d* ✓		**1**
2.	**c**		units of *W* : kg m s^{-2} ✓ work leading to $x = 1$ and $y = 3$ ✓		**2**
2.	**d**	**i**	instrument (capable of reading to 0.05 mm) with reason related to resolution of instrument ✓	*eg micrometer screw gauge, Vernier caliper, travelling microscope*	**1**
2.	**d**	**ii**	attempt to calculate fractional uncertainty in either *a* or *b* [0.0357, 0.0167] ✓ $0.0357 + 0.0167 = 0.05 = 5\ \%$ ✓		**2**

Diploma Programme
Programme du diplôme
Programa del Diploma

Physics
Standard level
Paper 2

Specimen paper

1 hour 30 minutes

Candidate session number

Instructions to candidates

- Write your session number in the boxes above.
- Do not open this examination paper until instructed to do so.
- Answer all questions.
- Answers must be written within the answer boxes provided.
- A calculator is required for this paper.
- A clean copy of the **physics data booklet** is required for this paper.
- The maximum mark for this examination paper is **[50 marks]**.

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Please **do not** write on this page.

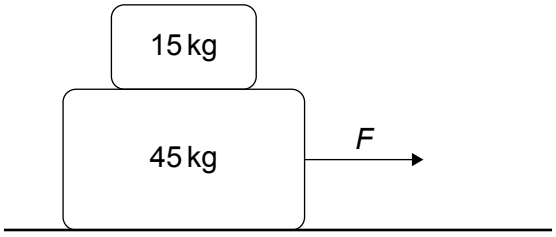
Answers written on this page
will not be marked.

Answer **all** questions. Answers must be written within the answer boxes provided.

1. A block of mass 45 kg is placed on a horizontal table. There is no friction between the block and the table.

An object of mass 15 kg is placed on top of the block.

A force *F* acts on the block so that it accelerates. The acceleration of the object and the acceleration of the block are the same so that they do not move relative to each other.



The coefficient of static friction between the block and the object is 0.60.

(a) State the nature and direction of the force that accelerates the 15 kg object. [1]

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(b) Determine the largest magnitude of *F* for which the block and the object do not move relative to each other. [3]

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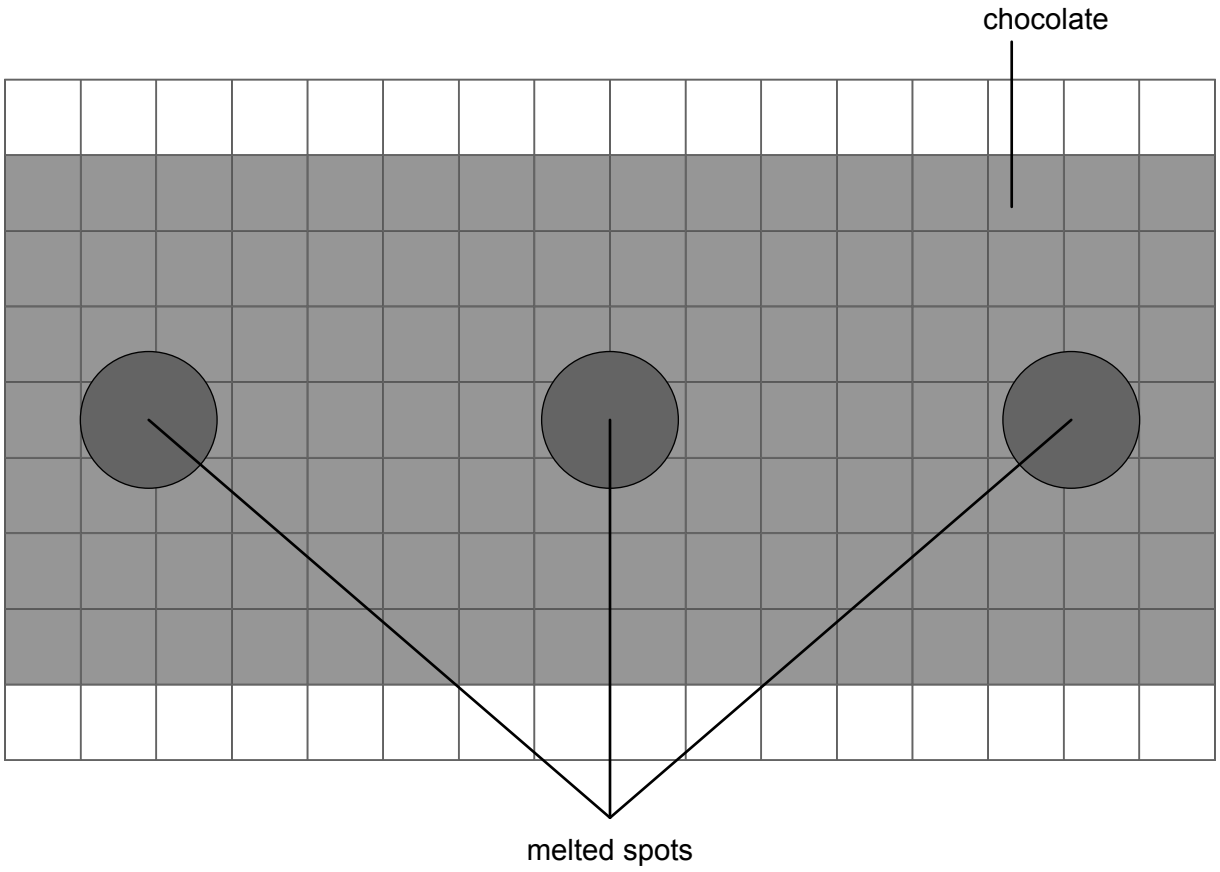
2. In a microwave oven electromagnetic waves are emitted so that a standing wave pattern is established inside the oven.

A flat piece of chocolate is placed inside the oven and the microwaves are switched on. The chocolate is stationary.

Melted spots form on the surface of the chocolate. The diagram shows the pattern of melting on the chocolate. Each square has a length of 1 cm.



(a) Outline how this standing wave pattern of melted spots is formed. [2]

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(This question continues on the following page)

(Question 2 continued)

(b) Determine, taking appropriate measurements from the diagram, the frequency of the electromagnetic waves in the oven. [3]

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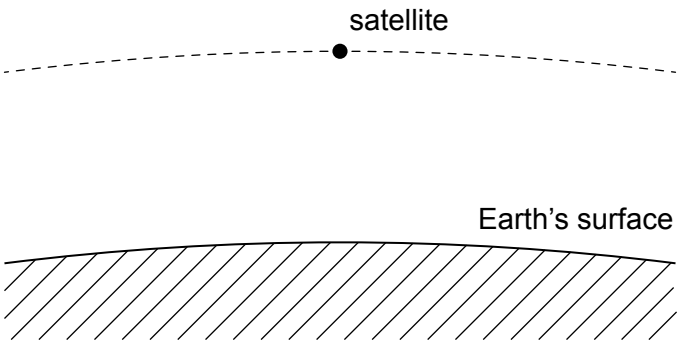
Please **do not** write on this page.

Answers written on this page
will not be marked.

3. A satellite moves around Earth in a circular orbit.



(a) Draw an arrow on the diagram to represent the direction of the acceleration of the satellite. [1]

(b) The following data are given:

Mass of Earth, $M = 5.97 \times 10^{24}$ kg
Radius of Earth, $R = 6.37 \times 10^{6}$ m
Orbital period of the satellite, $T = 5.62 \times 10^{3}$ s

(i) Kepler's Third Law of orbital motion states that $T^2 = kr^3$ where k is a constant and r is the orbital radius of the satellite.

Show that $k = \dfrac{4\pi^2}{GM}$. [1]

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(ii) Determine the height of the satellite above the Earth's surface. [2]

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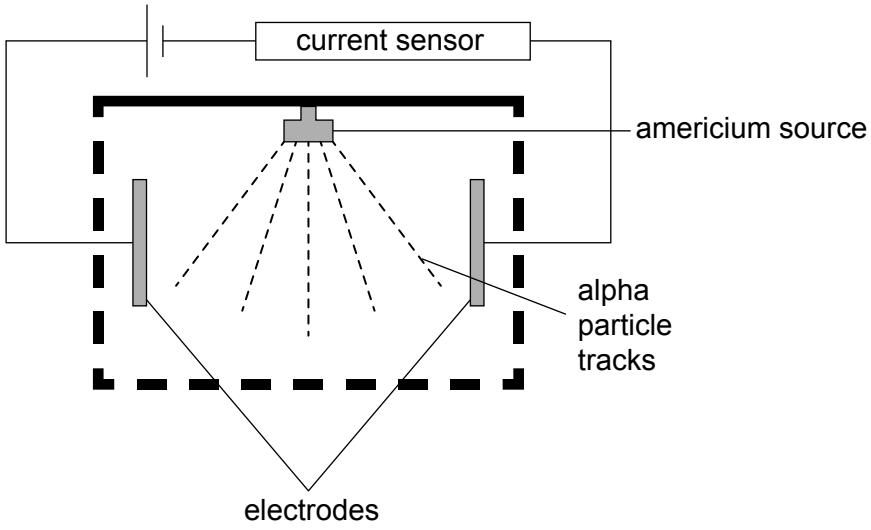
4. A smoke detector uses the radioactive nuclide americium-241.

The americium is contained in a chamber that is open to the air. There are two electrodes in the chamber that are connected to a power supply and a current sensor.



Americium-241 emits alpha particles that ionize the air in the chamber. Each ionization forms one positive ion and one electron; these are called an ion pair. The electrons and the positive ions move towards the electrodes and the sensor detects a current in the air.

When smoke enters the chamber, fewer ion pairs are formed and the current in the sensor decreases, sounding an alarm.

The chamber is 0.10 m in each dimension.

(a) A nucleus of americium-241 has 146 neutrons. This nuclide decays to neptunium through alpha emission.

Complete the nuclear equation for this decay. [2]

$$\_\_\text{Am} \rightarrow \_\_\text{Np} + \_\_\alpha$$

(This question continues on the following page)

(Question 4 continued)

(b) Outline why the radioactive source is safe for use in a house. [1]

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The initial activity of the source is 42 kBq. 33 % of the alpha particles emitted by this source enter the chamber and form an ion pair.
Each alpha particle has an initial kinetic energy of 5.5 MeV.
The energy required to form one ion pair is 15 eV.

(c) Calculate the maximum current in the chamber due to the electrons when there is no smoke in the chamber. [3]

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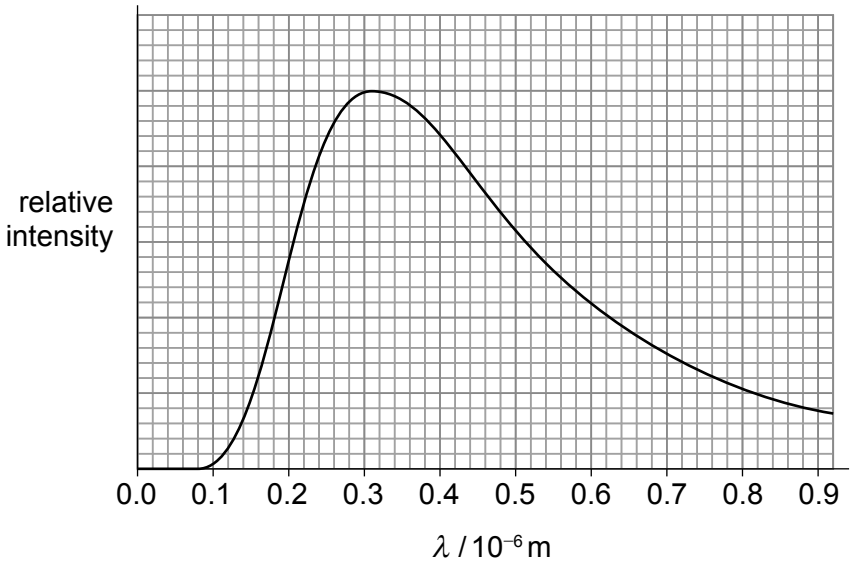
5. The star δ Vel A is a main sequence star that has a black-body spectrum as shown.



(a) Show that the surface temperature of δ Vel A is about 9000 K. [1]

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(b) The apparent brightness of δ Vel A is $2.2 \times 10^{-9}\,\text{W m}^{-2}$ and it is 6.2×10^{14} km from Earth.

Estimate the radius of δ Vel A. [3]

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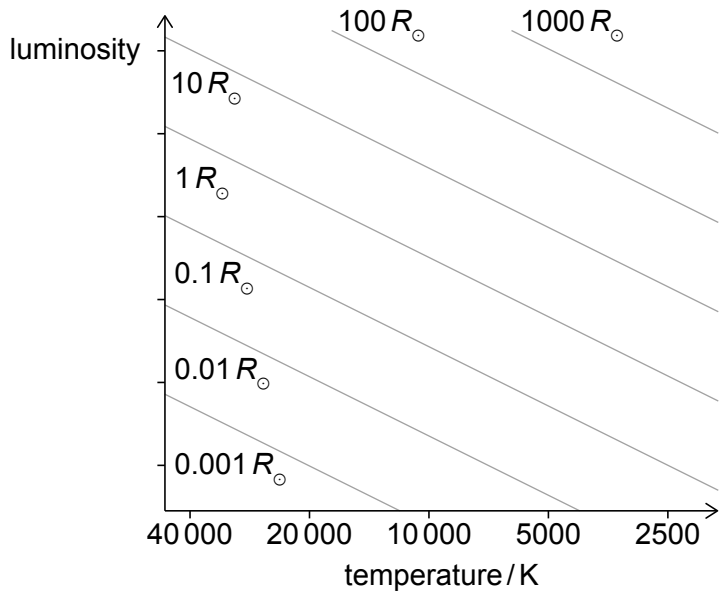
(This question continues on the following page)

(Question 5 continued)

(c) The radius of the Sun, $R_\odot$, is 7.0×10^5 km.

Sketch, on the Hertzsprung-Russell diagram, the position of δ Vel A. [2]



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Answers written on this page
will not be marked.

6. Small pieces of solid paraffin with a total mass of 30 g at a temperature of 42 °C are mixed with 150 g of liquid paraffin at a temperature of 240 °C. The mixture is stirred until an equilibrium temperature is reached.

The following data for paraffin are available:

Specific heat capacity of solid paraffin = $0.7\,kJ\,kg^{-1}\,K^{-1}$
Specific heat capacity of liquid paraffin = $2.13\,kJ\,kg^{-1}\,K^{-1}$
Specific latent heat of fusion of paraffin = $220\,kJ\,kg^{-1}$
Melting point of paraffin = 47 °C

(a) Calculate the theoretical equilibrium temperature of the mixture. [3]

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(b) When the experiment was carried out, the equilibrium temperature of the mixture was found to be different from the theoretical value.

Suggest the reason for this difference. [2]

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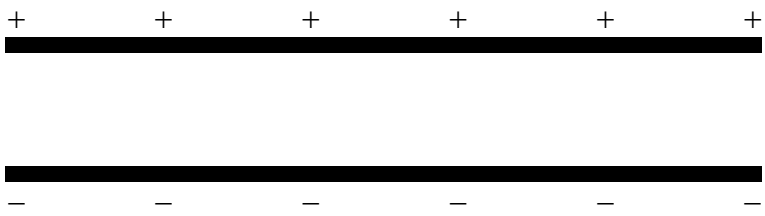
7. The diagram shows two parallel conducting plates that are oppositely charged.



(a) (i) Draw the electric field lines due to the charged plates. [2]

(ii) The potential difference between the plates is 960 V and the distance between them is 8.0 mm. Calculate the electric field strength *E* between the plates. [2]

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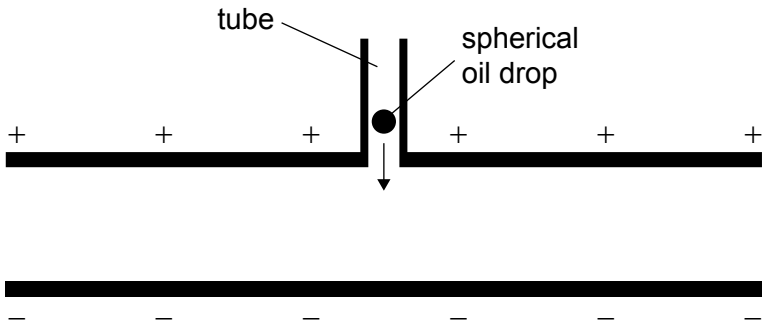
(This question continues on the following page)

(Question 7 continued)

In an experiment, an oil drop is introduced into the space between the plates through a small hole in the upper plate. The oil drop moves through air in a tube before falling between the plates.



(b) Explain why the oil drop becomes charged as it falls through the tube. [1]

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(This question continues on the following page)

(Question 7 continued)

(c) The oil drop is observed to be stationary in the space between the plates. Buoyancy is one of the forces acting on the drop.

The density of oil is 730 times greater than that of air.

(i) Show that the buoyancy force is much smaller than the weight. [3]

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(ii) Draw the forces acting on the oil drop, ignoring the buoyancy force. [2]

oil drop

(This question continues on the following page)

(Question 7 continued)

(iii) Show that the electric charge on the oil drop is given by

$$q = \frac{\rho_o g V}{E}$$

where ρ_o is the density of oil and V is the volume of the oil drop. [2]

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(iv) State the sign of the charge on the oil drop. [1]

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will not be marked.

(Question 7 continued)

(d) The electric field is turned off. The oil drop falls vertically reaching a constant speed v.

(i) Outline why, for this drop, $\rho_o gV = 6\pi\eta rv$ where η is the viscosity of air and r is the radius of the oil drop. [2]

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(ii) Show that the charge on the oil drop is about 4.8×10^{-19} C.

The following data for the oil drop are available:

$r = 1.36\,\mu m$
$\eta = 1.60 \times 10^{-5}\,Pa\,s$
$v = 0.140\,mm\,s^{-1}$ [3]

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(iii) The oil drop splits into two parts of equal mass. Both are charged. Deduce the net charge on each part. [2]

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Diploma Programme
Programme du diplôme
Programa del Diploma

Markscheme

Specimen paper

Physics

Standard level

Paper 2

11 pages

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Subject Details: Physics SL Paper 2 Markscheme

Candidates are required to answer **all** questions. Maximum total = **55 marks**.

1. Each row in the "Question" column relates to the smallest subpart of the question.

2. The maximum mark for each question subpart is indicated in the "Total" column.

3. Each marking point in the "Answers" column is shown by means of a tick (✓) at the end of the marking point.

4. A question subpart may have more marking points than the total allows. This will be indicated by "**max**" written after the mark in the "Total" column. The related rubric, if necessary, will be outlined in the "Notes" column.

5. An alternative wording is indicated in the "Answers" column by a slash (*/*). Either wording can be accepted.

6. An alternative answer is indicated in the "Answers" column by "***OR***". Either answer can be accepted.

7. An alternative markscheme is indicated in the "Answers" column under heading ***ALTERNATIVE 1*** *etc*. Either alternative can be accepted.

8. Words inside chevrons **« »** in the "Answers" column are not necessary to gain the mark.

9. Words that are <u>underlined</u> are essential for the mark.

10. The order of marking points does not have to be as in the "Answers" column, unless stated otherwise in the "Notes" column.

11. If the candidate's answer has the same "meaning" or can be clearly interpreted as being of equivalent significance, detail and validity as that in the "Answers" column then award the mark. Where this point is considered to be particularly relevant in a question it is emphasized by ***OWTTE*** (or words to that effect) in the "Notes" column.

12. Remember that many candidates are writing in a second language. Effective communication is more important than grammatical accuracy.

13. Occasionally, a part of a question may require an answer that is required for subsequent marking points. If an error is made in the first marking point then it should be penalized. However, if the incorrect answer is used correctly in subsequent marking points then **follow through** marks should be awarded. When marking, indicate this by adding **ECF** (error carried forward) on the script. "ECF acceptable" will be displayed in the "Notes" column.

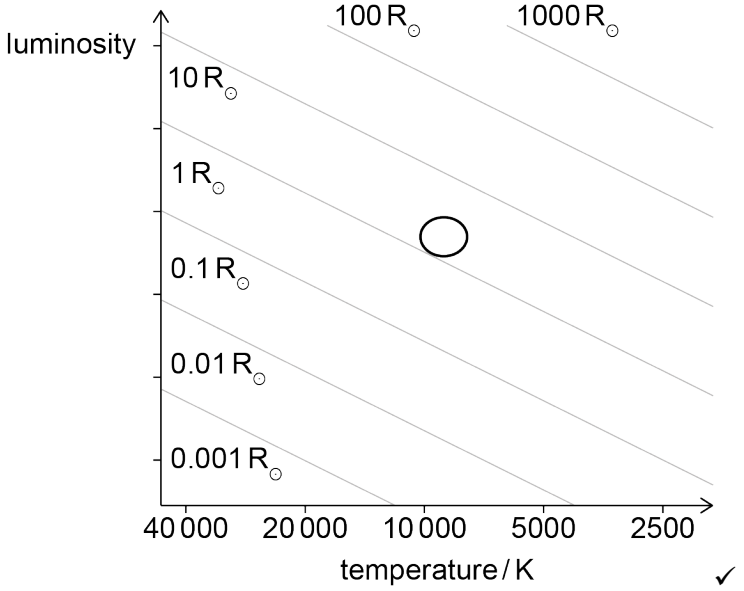
14. Do **not** penalize candidates for errors in units or significant figures, **unless** it is specifically referred to in the "Notes" column.

Question			Answers	Notes	Total
1.	a		static friction force «between blocks» **AND** directed to the right✓		1
1.	b		$F = 60a$ ✓ $F_f = 0.6 \times 15 \times 9.8$ «$= 88.2$N» ✓ $88.2 = 15 \times \frac{F}{60} \Rightarrow F = 350$«N» ✓	*Allow use of* $a = 0.6g$ *leading to 353 N.*	3

Question			Answers	Notes	Total
2.	**a**		standing waves form «in the oven» by superposition / constructive interference✓ energy transfer is greatest at the antinodes «of the standing wave pattern»✓		**2**
2.	**b**		$\lambda = 12.2$«cm» ✓ f«$= \frac{c}{\lambda}$» $= \frac{3.0 \times 10^{8}}{1.22 \times 10^{-1}}$ ✓ $f = 2.46\,\text{GHz}$ ✓ correct answer only including power of ten	*Allow* $\lambda \pm 2$ *mm.* *Condone power of ten error in MP2 only.*	**3**

Question			Answers	Notes	Total
3.	**a**		arrow normal to the orbit towards the Earth ✓		**1**
3.	**b**	**i**	use of $v_{\text{orbital}} = \frac{2\pi r}{T}$ AND either $v_{\text{orbital}} = \sqrt{\frac{GM}{r}}$ or $\frac{mv_{\text{orbital}}^2}{r} = \frac{GMm}{r^2}$ correctly manipulated✓ «to yield $T^2 = \left(\frac{4\pi^2}{GM}\right) r^3$ »	*Allow use of* ω.	**1**
3.	**b**	**ii**	$r = \sqrt[3]{\frac{GMT^2}{4\pi^2}} = \sqrt[3]{\frac{6.67 \times 10^{-11} \times 5.97 \times 10^{24} \times (5620)^2}{4\pi^2}}$ ✓ $= 6.83 \times 10^6$ «m» height $=$ «$6.83 \times 10^6 - 6.37 \times 10^6$ =» 4.6×10^5 «m» ✓		**2**

Question			Answers	Notes	Total
4.	**a**		$^{241}_{95}\text{Am}$ ✓ $^{237}_{93}\text{Np} + {}^{4}_{2}\alpha$ ✓		**2**
4.	**b**		Alpha particles only travel a few cm in air / penetration of alpha particles is poor (and will not escape the chamber) ✓	*OWTTE*	**1**
4.	**c**		Each alpha gives rise to $\frac{5.5\times10^{6}}{15}=3.67\times10^{5}$ ion pairs ✓ So $\frac{3.67\times10^{5}\times42000}{3}=5.13\times10^{9}$ ion pairs per second ✓ current $=1.6\times10^{-19}\times5.13\times10^{9}=0.82\times10^{-9}$ «A» ✓		**3**

Question			Answers	Notes	Total
5.	a		correct substitution into $\lambda_{max} = \frac{2.9\times10^{-3}}{T}$ OR 9350 K ✓		1
5.	b		Attempted use of $L = 4\pi bd^2$ ✓ use of $r = \sqrt{\frac{L}{4\pi\sigma T^4}}$ ✓ $r = 1.4\,\text{Gm}$ ✓	*Accept a range of values between 1.3 to 1.5 Gm*	3
5.	c		Shows $r \approx 2R_\odot$ ✓ Correct position on diagram  ✓	*[use of 9000 K gives $2.2R_\odot$]*	2

Question			Answers	Notes	Total
6.	**a**		$(0.030\times0.7\times10^3\times5)+(0.030\times220\times10^3)+(0.030\times2.13\times10^3)(T-47)$ $=(0.150\times2.13\times10^3)(240-T)$ One heat capacity term correctly substituted ✓ latent heat correctly substituted $(0.030\times220\times10^3)$ ✓ $T=190$«°C» ✓		**3**
6.	**b**		Experimental temperature will be lower ✓ Heat loss to the environment ✓		**2**

Question			Answers	Notes	Total
7.	a	i	equally spaced arrows «by eye» all pointing down ✓ edge effects also shown with arrows ✓		2
7.	a	ii	$E = \frac{V}{d} = \frac{960}{8.0 \times 10^{-3}}$ ✓ $E = 1.2 \times 10^{5}$ «NC^{-1}» ✓		2
7.	b		friction transfers electron(s) to or from drop ***AND*** through collisions/ interaction with air molecules in the tube OR through collisions/interaction with wall of tube ✓		1
7.	c	i	weight of oil drop is $\rho_o gV$ ✓ $\frac{F_b}{W} = \frac{\rho_a gV}{\rho_o gV} = \frac{\rho_a}{\rho_o}$ ✓ «$\frac{F_b}{W} = \frac{1}{730}$ =»1.4×10^{-3} ***OR*** Ratio of F_b to W is much less than 1 ✓		3

7.	**c**	**ii**	Weight vertically down ***AND*** electric force vertically up ✓ Of equal length «by eye» ✓		**2**
7.	**c**	**iii**	Mass of drop is $\rho_0 V$ ✓ $qE = (\rho_0 V)g$ ✓ «hence answer»	*MP1 must be shown implicitly for credit.*	**2**
7.	**c**	**iv**	Negative ✓		**1**
7.	**d**	**i**	Net force is zero ✓ Acceleration of the oil drop is zero ✓ ***OR*** For terminal velocity drag must equal weight ✓ weight $= \rho_0 gV$ **and** drag $= 6\pi\eta rv$ ✓		**2**

7.	**d**	**ii**	$q = \frac{6\pi\eta r v}{E}$ ✓ $q = \frac{6\pi \times 1.60 \times 10^{-5} \times 1.36 \times 10^{-6} \times 1.40 \times 10^{-4}}{1.2 \times 10^{5}}$ ✓ $q = 4.79 \times 10^{-19}$ «C» ✓	*Answer must be shown to 3+ sf.*	**3**
7.	**d**	**iii**	charge is quantized ✓ so, the charges must be 1e and 2e ✓		**2**