

© International Baccalaureate Organization 2024

All rights reserved. No part of this product may be reproduced in any form or by any electronic or mechanical means, including information storage and retrieval systems, without the prior written permission from the IB. Additionally, the license tied with this product prohibits use of any selected files or extracts from this product. Use by third parties, including but not limited to publishers, private teachers, tutoring or study services, preparatory schools, vendors operating curriculum mapping services or teacher resource digital platforms and app developers, whether fee-covered or not, is prohibited and is a criminal offense.

More information on how to request written permission in the form of a license can be obtained from <https://ibo.org/become-an-ib-school/ib-publishing/licensing/applying-for-a-license/>.

© Organisation du Baccalauréat International 2024

Tous droits réservés. Aucune partie de ce produit ne peut être reproduite sous quelque forme ni par quelque moyen que ce soit, électronique ou mécanique, y compris des systèmes de stockage et de récupération d'informations, sans l'autorisation écrite préalable de l'IB. De plus, la licence associée à ce produit interdit toute utilisation de tout fichier ou extrait sélectionné dans ce produit. L'utilisation par des tiers, y compris, sans toutefois s'y limiter, des éditeurs, des professeurs particuliers, des services de tutorat ou d'aide aux études, des établissements de préparation à l'enseignement supérieur, des fournisseurs de services de planification des programmes d'études, des gestionnaires de plateformes pédagogiques en ligne, et des développeurs d'applications, moyennant paiement ou non, est interdite et constitue une infraction pénale.

Pour plus d'informations sur la procédure à suivre pour obtenir une autorisation écrite sous la forme d'une licence, rendez-vous à l'adresse <https://ibo.org/become-an-ib-school/ib-publishing/licensing/applying-for-a-license/>.

© Organización del Bachillerato Internacional, 2024

Todos los derechos reservados. No se podrá reproducir ninguna parte de este producto de ninguna forma ni por ningún medio electrónico o mecánico, incluidos los sistemas de almacenamiento y recuperación de información, sin la previa autorización por escrito del IB. Además, la licencia vinculada a este producto prohíbe el uso de todo archivo o fragmento seleccionado de este producto. El uso por parte de terceros —lo que incluye, a título enunciativo, editoriales, profesores particulares, servicios de apoyo académico o ayuda para el estudio, colegios preparatorios, desarrolladores de aplicaciones y entidades que presten servicios de planificación curricular u ofrezcan recursos para docentes mediante plataformas digitales—, ya sea incluido en tasas o no, está prohibido y constituye un delito.

En este enlace encontrará más información sobre cómo solicitar una autorización por escrito en forma de licencia: <https://ibo.org/become-an-ib-school/ib-publishing/licensing/applying-for-a-license/>.

Physics
Standard level
Paper 2

26 April 2024

Zone A morning | **Zone B** morning | **Zone C** morning

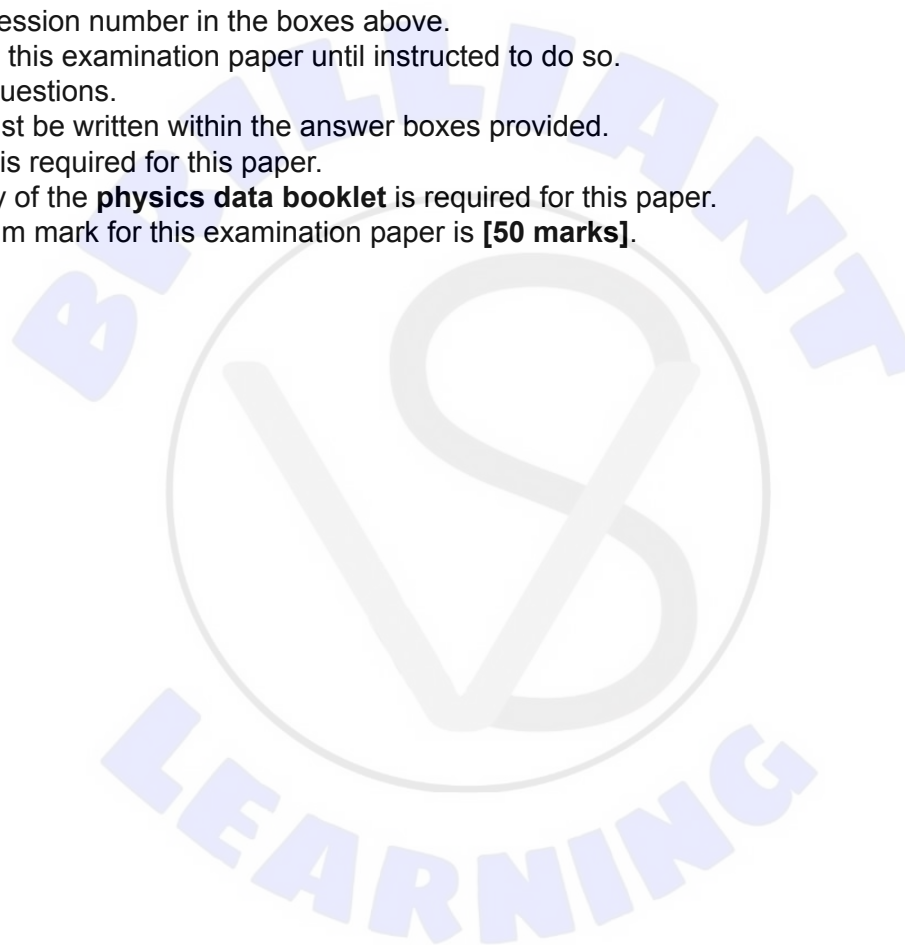
Candidate session number

--	--	--	--	--	--	--	--	--	--

1 hour 15 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 **[50 marks]**.





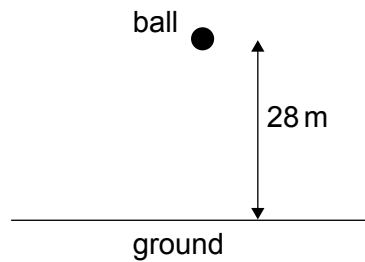
Please **do not** write on this page.

Answers written on this page
will not be marked.



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

1. A ball of mass 2.7 g is released from rest from a height of 28 m above horizontal ground.



- (a) Show that in the absence of air resistance the ball impacts the ground with a speed of about 23 ms^{-1} . [1]

.....

.....

- (b) An air resistance force F acts on the ball. F can be modeled by $F = kv^2$ where v is the speed and k is a constant.

- (i) Determine the unit of k in terms of fundamental units. [2]

.....

.....

- (ii) Describe how the ball reaches terminal speed. [2]

.....

.....

.....

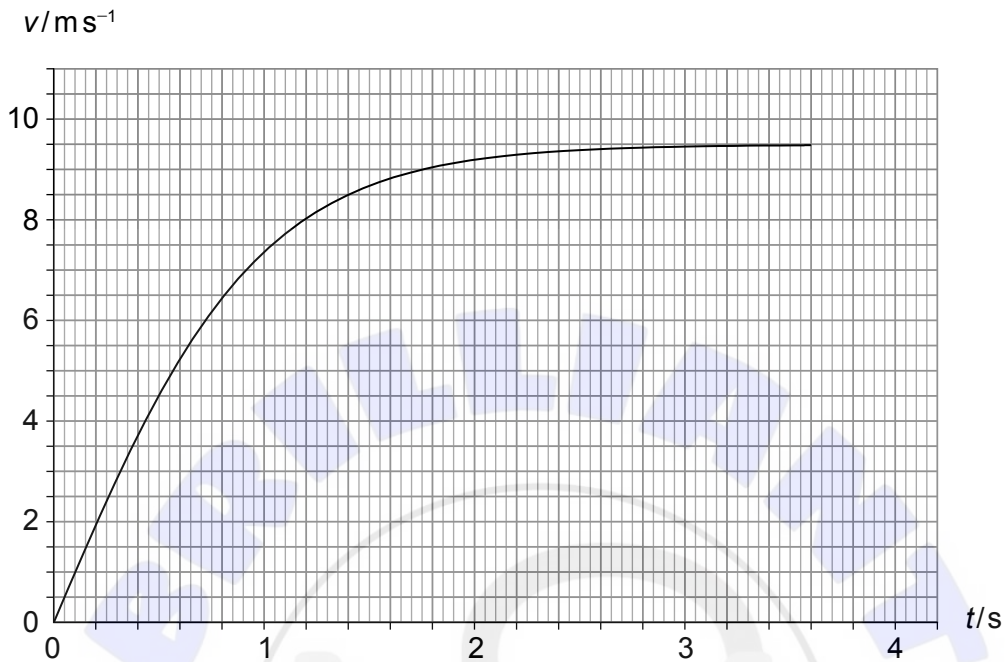
.....

(This question continues on the following page)



(Question 1 continued)

- (c) The graph shows the variation with time t of the speed v of the ball from the instant it is released until it impacts the ground.



- (i) State the value of the area under the curve. [1]

.....

- (ii) Determine k . [2]

.....
.....
.....
.....

(This question continues on the following page)



(Question 1 continued)

- (d) The ball rebounds from the ground with speed 7.8 m s^{-1} . The ball is in contact with the ground for a time T . The average **resultant** force on the ball during this time is 1.1 N .

Determine T .

[2]

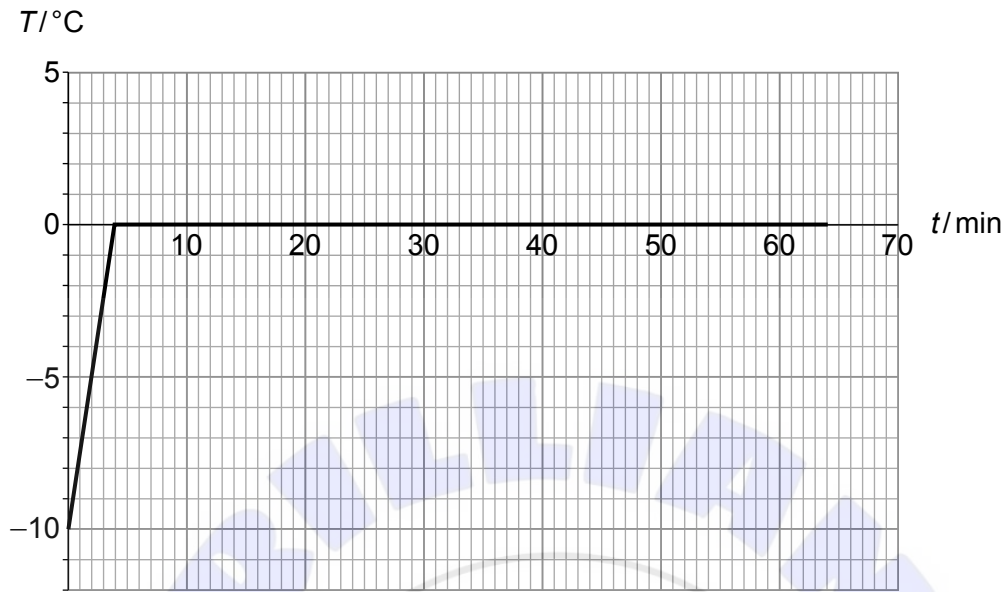
.....

.....

.....



2. Crushed ice of mass 35 g at temperature -10°C is placed in a warm room. The graph shows the variation of the temperature T of the ice with time t .



The specific heat capacity of ice is $2100\text{ J kg}^{-1}\text{ K}^{-1}$.

- (a) (i) Show that the average rate at which thermal energy is being transferred into the ice is about 3 W. [2]

.....
.....
.....

- (ii) Estimate the specific latent heat of fusion of ice. [2]

.....
.....
.....

(This question continues on the following page)



(Question 2 continued)

- (b) Between 4 minutes and 64 minutes solid ice and liquid water coexist at 0 °C. Compare and contrast, during this time, the internal energy of solid ice to that of an equal mass of liquid water. [2]

.....

.....

.....

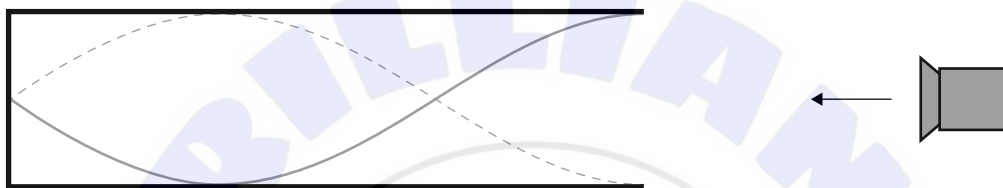
.....



3. (a) Outline what is meant by a travelling wave. [2]

.....
.....
.....
.....

(b) A loudspeaker emits sound of frequency 210 Hz into a pipe with one open and one closed end. The diagram shows a representation of the standing wave established in the pipe.



The length of the pipe is 1.20 m.

(i) Outline how the standing wave is formed in the pipe. [2]

.....
.....
.....
.....

(ii) Determine the wavelength of the wave. [1]

.....
.....
.....

(This question continues on the following page)



(Question 3 continued)

- (iii) Calculate the speed of sound in the pipe stating the answer to an appropriate number of significant figures. [2]

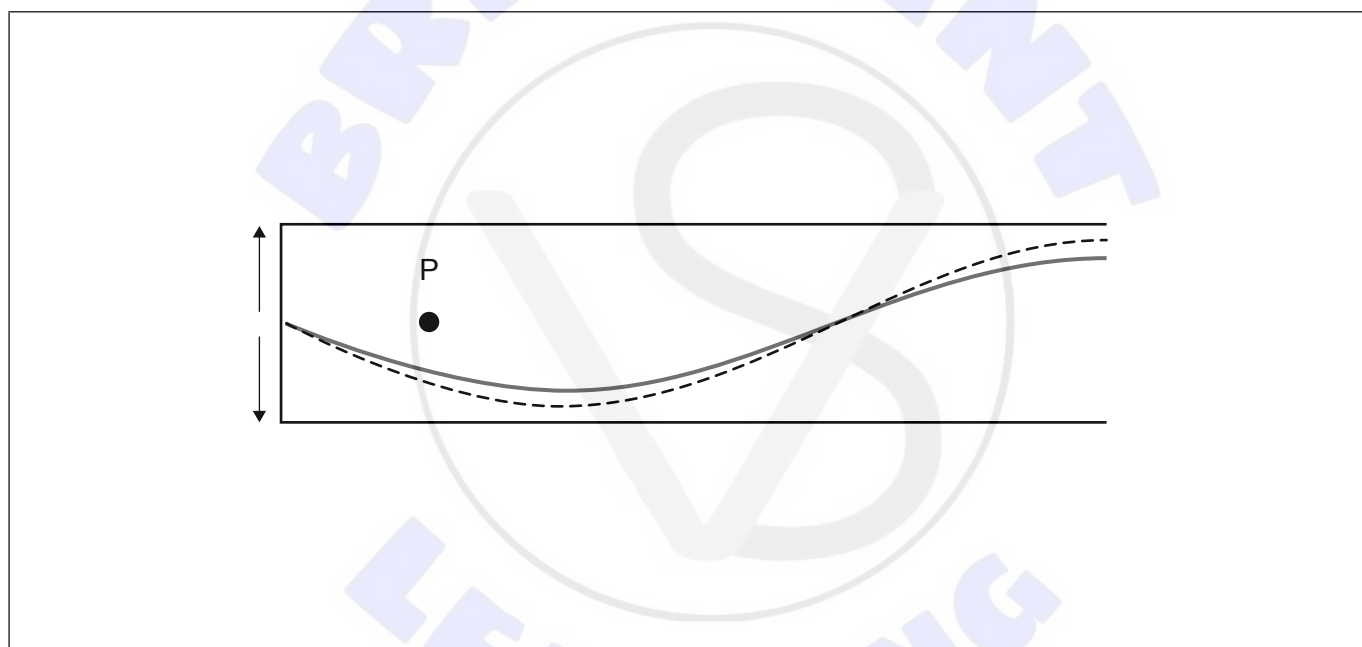
.....

.....

.....

.....

- (c) The solid line represents the standing wave at time t and the dotted line represents the standing wave at an instant later. The dot is the **equilibrium** position of a particle P in the pipe. The up arrow indicates displacements to the right and the down arrow displacements to the left.



On the diagram, draw

- (i) a dot to indicate the approximate position of P at time t , [1]
- (ii) an arrow to indicate the velocity of P at time t . [1]

(This question continues on page 11)





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

Answers written on this page
will not be marked.



(Question 3 continued)

- (d) The frequency of sound is reduced to 140Hz. Explain why a standing wave will not be formed in the pipe. [2]

.....

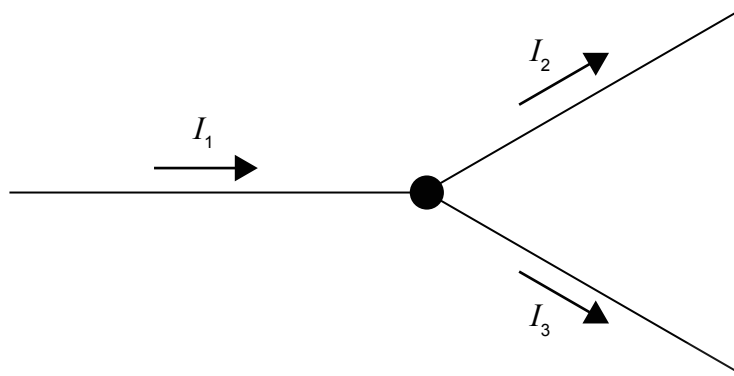
.....

.....

.....



4. (a) The diagram shows a junction in a circuit.



The currents in the three wires are related by $I_1 = I_2 + I_3$.

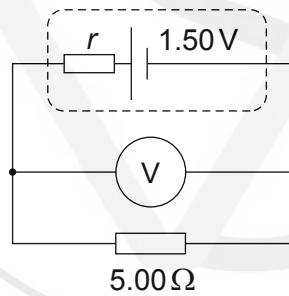
State the fundamental law of Physics from which this relation is derived.

[1]

.....

.....

- (b) A cell of emf 1.50 V and internal resistance r is connected to a resistor of resistance 5.00Ω and an ideal voltmeter V.



The reading of the voltmeter is 1.20 V.

- (i) Determine the internal resistance r of the cell.

[2]

.....

.....

.....

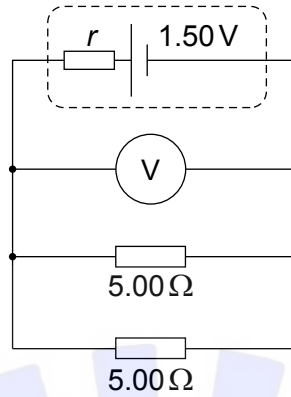
.....

(This question continues on the following page)



(Question 4 continued)

(ii) A second $5.00\ \Omega$ resistor is connected in parallel to the first resistor.



State and explain the change, if any, in the voltmeter reading without further calculation.

[2]

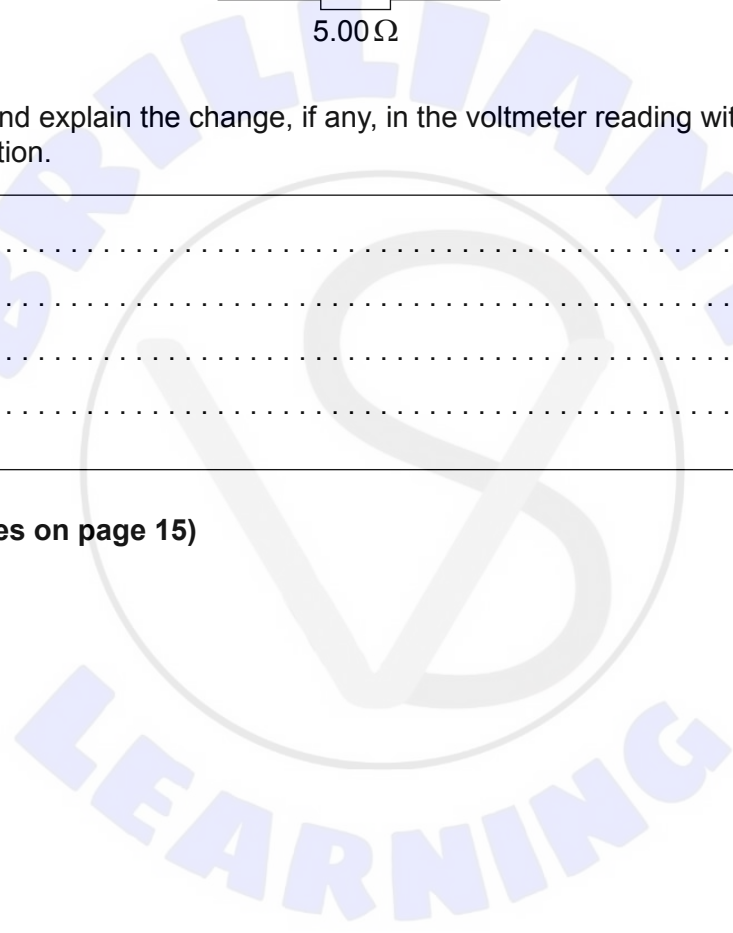
.....

.....

.....

.....

(This question continues on page 15)





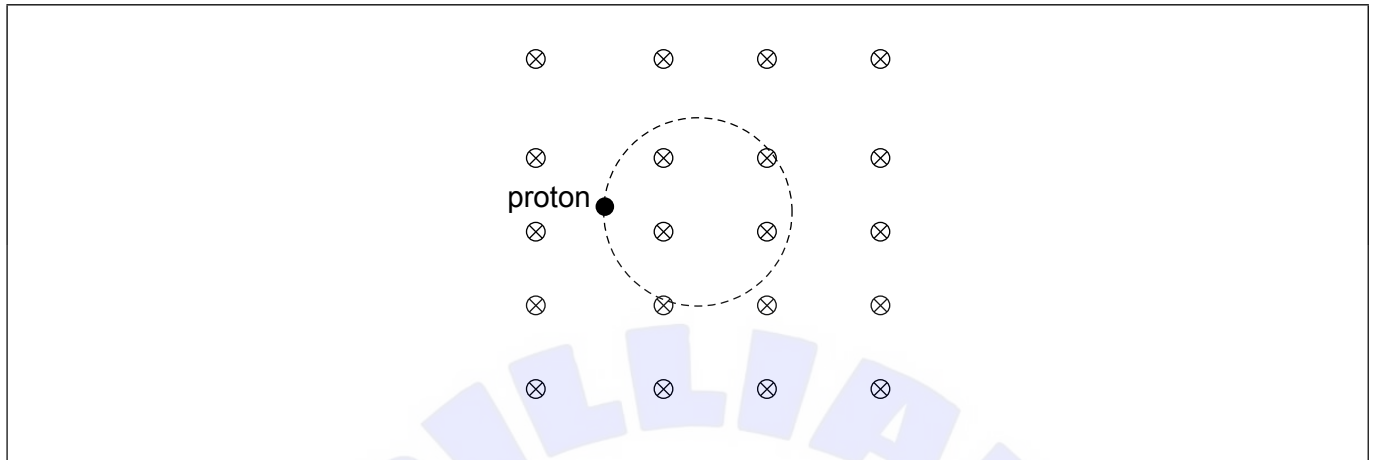
Please **do not** write on this page.

Answers written on this page
will not be marked.



(Question 4 continued)

- (c) A proton moves on a circular path in a region of uniform magnetic field of magnetic flux density B that is directed into the plane of the page.



- (i) On the diagram, draw an arrow to indicate the velocity of the proton at the position shown. [1]
- (ii) Show that the frequency of revolution of the proton is given by $f = \frac{eB}{2\pi m_p}$. [3]

.....

.....

.....

.....

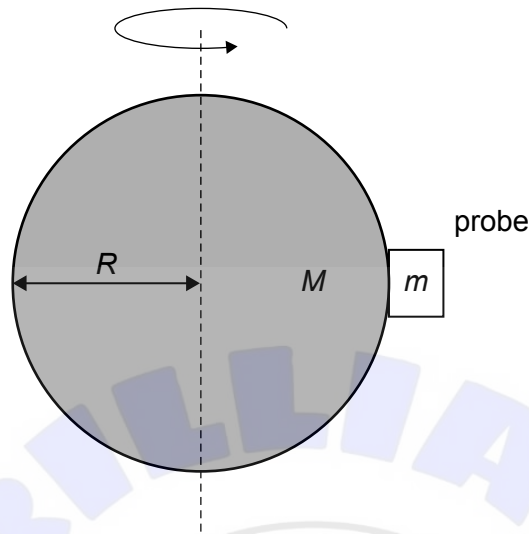
.....

.....



5. A probe of mass m has landed on the equator of a rotating asteroid of mass M and radius R .

diagram not to scale



The asteroid rotates with angular speed ω .

- (a) By drawing a free-body diagram for the probe, show that the normal force, N , on the probe from the asteroid is given by $N = m\left(\frac{GM}{R^2} - \omega^2 R\right)$. [2]

A large rectangular box for drawing a free-body diagram. Inside the box, a small rectangle labeled m is shown with the word "probe" written above it. A large, faint watermark "BRILLIANT LEARNING" is visible in the background.

.....
.....

(This question continues on the following page)



(Question 5 continued)

(b) Another probe orbits the Sun.

(i) The distance between the probe and the Sun is 4 times the distance between the Earth and the Sun. Show that the intensity of the solar radiation at the surface of the probe is 85Wm^{-2} . [2]

.....

.....

.....

.....

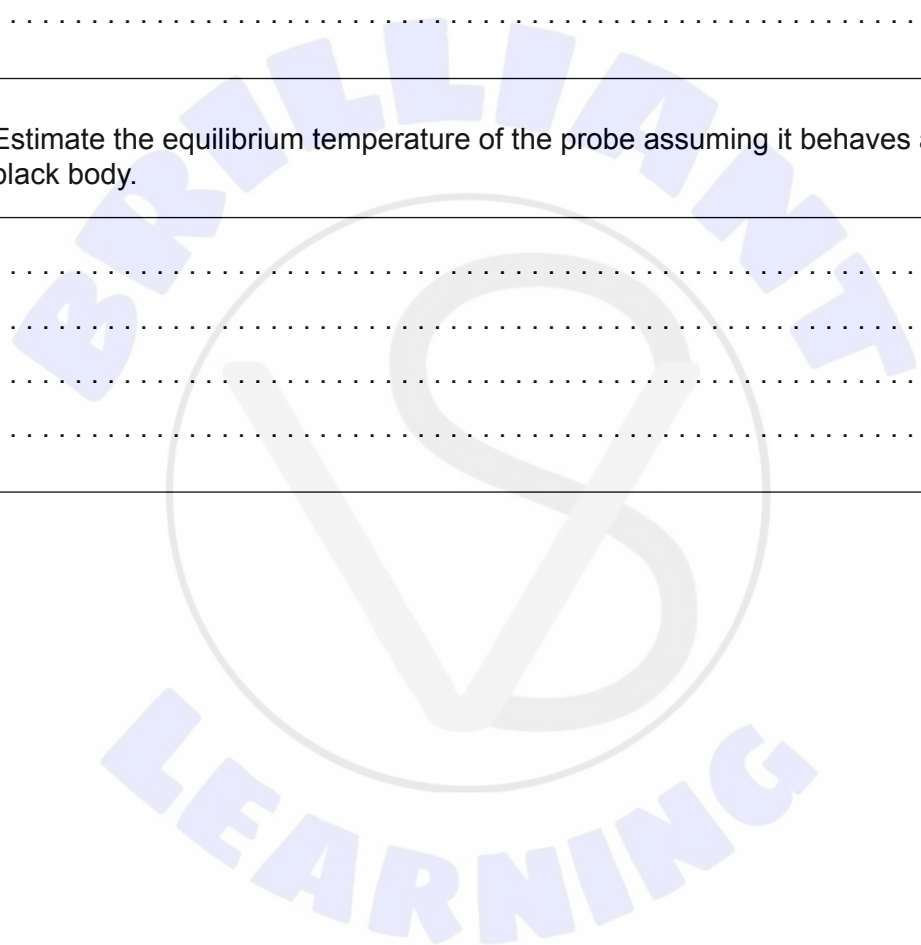
(ii) Estimate the equilibrium temperature of the probe assuming it behaves as a black body. [2]

.....

.....

.....

.....



6. (a) Quarks are elementary particles.

(i) State what is meant by an elementary particle. [1]

.....
.....

(ii) List the fundamental forces that act on quarks. [1]

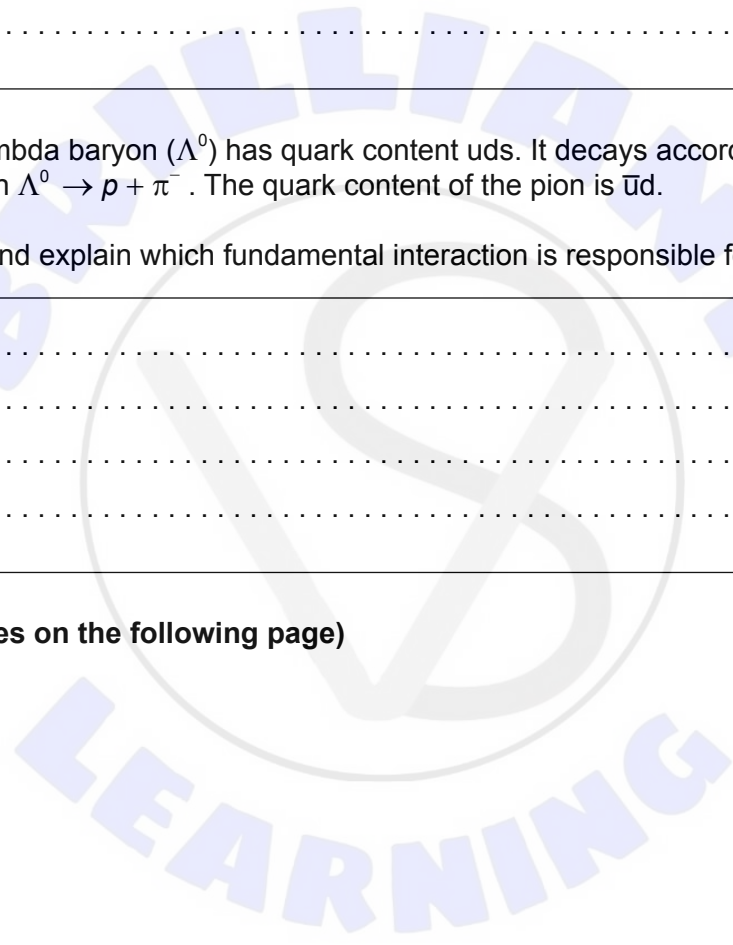
.....
.....

(iii) The lambda baryon (Λ^0) has quark content uds . It decays according to the reaction $\Lambda^0 \rightarrow p + \pi^-$. The quark content of the pion is $\bar{u}d$.

State and explain which fundamental interaction is responsible for this decay. [2]

.....
.....
.....
.....

(This question continues on the following page)



(Question 6 continued)

- (b) (i) By reference to the concept of binding energy, explain why the combined mass of the nucleons of a nucleus is greater than the mass of the nucleus. [2]

.....

.....

.....

.....

- (ii) The following binding energies per nucleon are available:

Th: 7.645074 MeV
Ra: 7.679917 MeV
He: 7.073915 MeV

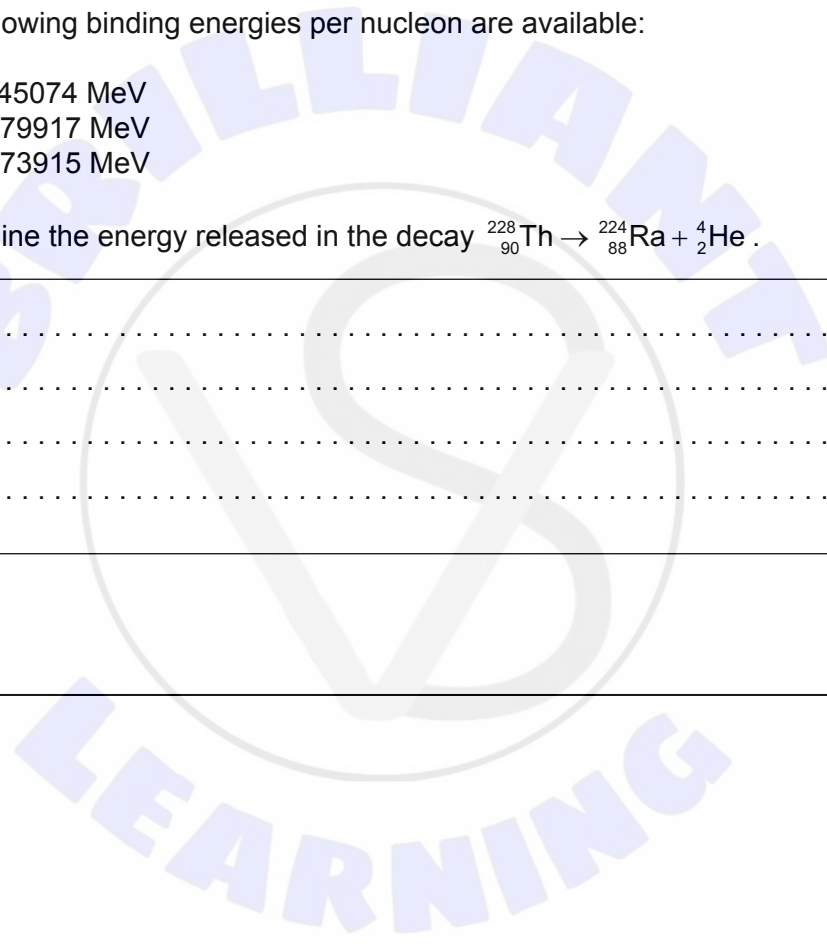
Determine the energy released in the decay ${}_{90}^{228}\text{Th} \rightarrow {}_{88}^{224}\text{Ra} + {}_2^4\text{He}$. [2]

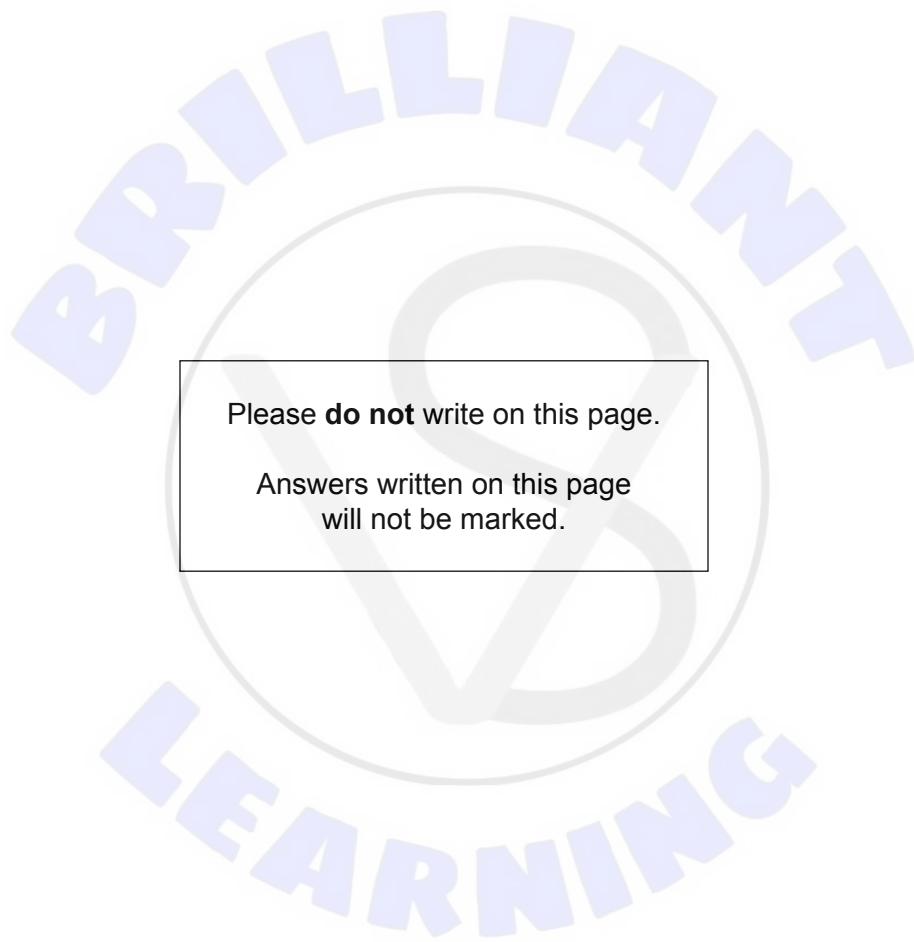
.....

.....

.....

.....





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

Answers written on this page
will not be marked.

