Diploma Programme
Programme du diplôme
Programa del Diploma

Physics
Higher level
Paper 2

Friday 17 May 2019 (afternoon)

Candidate session number

2 hours 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 **[90 marks]**.

2219 – 6514

25 pages

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

1. A student strikes a tennis ball that is initially at rest so that it leaves the racquet at a speed of $64\,m\,s^{-1}$. The ball has a mass of 0.058 kg and the contact between the ball and the racquet lasts for 25 ms.

(a) Calculate the

(i) average force exerted by the racquet on the ball. [2]

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(ii) average power delivered to the ball during the impact. [2]

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(b) The student strikes the tennis ball at point P. The tennis ball is initially directed at an angle of 7.00° to the horizontal.

diagram not to scale

The following data are available.

Height of P	= 2.80 m
Distance of student from net	= 11.9 m
Height of net	= 0.910 m
Initial speed of tennis ball	= $64\,m\,s^{-1}$

(This question continues on the following page)

(Question 1 continued)

(i) Calculate the time it takes the tennis ball to reach the net. [2]

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(ii) Show that the tennis ball passes over the net. [3]

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(iii) Determine the speed of the tennis ball as it strikes the ground. [2]

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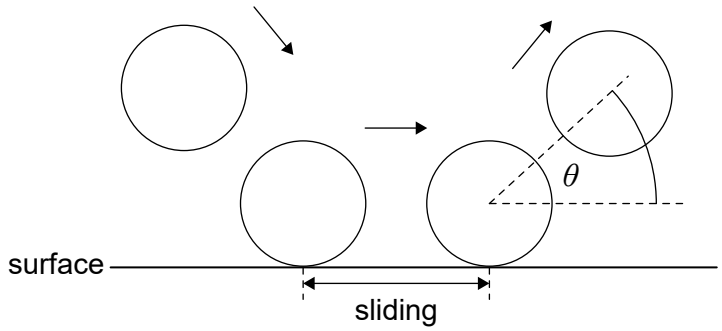
(Question 1 continued)

(c) The student models the bounce of the tennis ball to predict the angle θ at which the ball leaves a surface of clay and a surface of grass.



The model assumes

- during contact with the surface the ball slides.
- the sliding time is the same for both surfaces.
- the sliding frictional force is greater for clay than grass.
- the normal reaction force is the same for both surfaces.

Predict for the student's model, without calculation, whether θ is greater for a clay surface **or** for a grass surface. [3]

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2. A container of volume $3.2 \times 10^{-6}\,m^3$ is filled with helium gas at a pressure of $5.1 \times 10^5\,Pa$ and temperature 320 K. Assume that this sample of helium gas behaves as an ideal gas.

(a) The mass of a helium atom is 6.6×10^{-27} kg. Estimate the average speed of the helium atoms in the container. [2]

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(b) Show that the number of helium atoms in the container is 4×10^{20}. [2]

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(This question continues on the following page)

(Question 2 continued)

(c) A helium atom has a volume of $4.9 \times 10^{-31}\,m^3$.

(i) Calculate the ratio $\frac{\text{volume of helium atoms}}{\text{volume of helium gas}}$. [1]

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(ii) Discuss, by reference to the kinetic model of an ideal gas and the answer to (c)(i), whether the assumption that helium behaves as an ideal gas is justified. [2]

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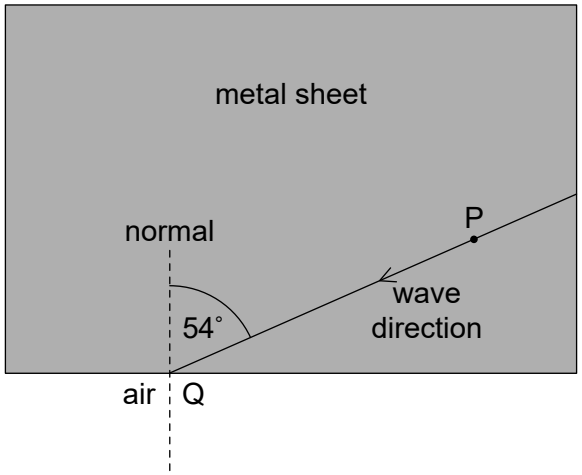
3. The diagram shows the direction of a sound wave travelling in a metal sheet.

diagram not to scale



(a) Particle P in the metal sheet performs simple harmonic oscillations. When the displacement of P is 3.2 μm the magnitude of its acceleration is 7.9 m s^{-2}. Calculate the magnitude of the acceleration of P when its displacement is 2.3 μm. [2]

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(b) The wave is incident at point Q on the metal–air boundary. The wave makes an angle of 54° with the normal at Q. The speed of sound in the metal is 6010 m s^{-1} and the speed of sound in air is 340 m s^{-1}. Calculate the angle between the normal at Q and the direction of the wave in air. [2]

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(This question continues on the following page)

(Question 3 continued)

(c) The frequency of the sound wave in the metal is 250 Hz. Determine the wavelength of the wave in air. [1]

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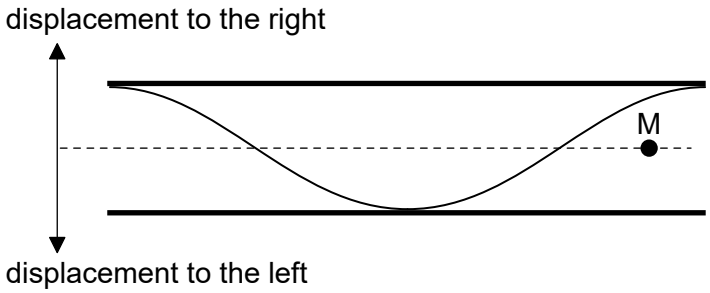
(d) The sound wave in air in (c) enters a pipe that is open at both ends. The diagram shows the displacement, at a particular time *T*, of the standing wave that is set up in the pipe.



A particular air molecule has its equilibrium position at the point labelled M.

On the diagram, at time *T,*

(i) draw an arrow to indicate the acceleration of this molecule. [1]

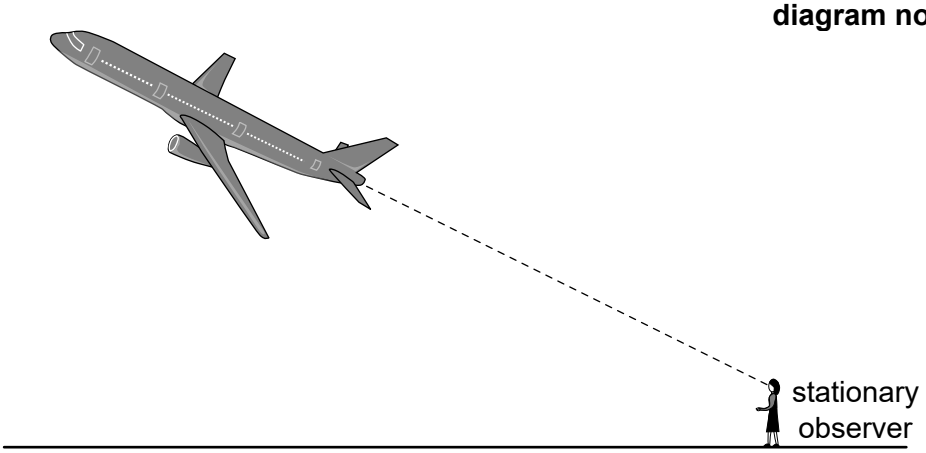
(ii) label with the letter C a point in the pipe that is at the centre of a compression. [1]

(This question continues on the following page)

(Question 3 continued)

(e) Sound of frequency $f = 2500\,\text{Hz}$ is emitted from an aircraft that moves with speed $v = 280\,\text{m s}^{-1}$ away from a stationary observer. The speed of sound in still air is $c = 340\,\text{m s}^{-1}$.

diagram not to scale



Calculate the

(i) frequency heard by the observer. [2]

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(ii) wavelength measured by the observer. [1]

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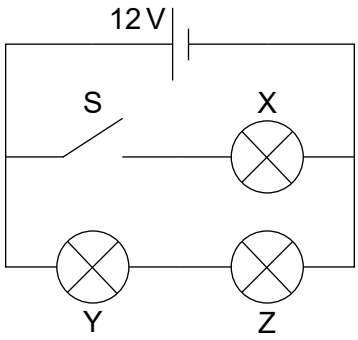
4. Three identical light bulbs, X, Y and Z, each of resistance $4.0\,\Omega$ are connected to a cell of emf 12 V. The cell has negligible internal resistance.



(a) The switch S is initially open. Calculate the total power dissipated in the circuit. [2]

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(b) The switch is now closed.

(i) State, without calculation, why the current in the cell will increase. [1]

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(ii) Deduce the ratio $\frac{\text{power dissipated in Y with S open}}{\text{power dissipated in Y with S closed}}$. [2]

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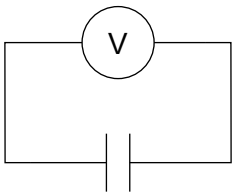
(Question 4 continued)

(c) The cell is used to charge a parallel-plate capacitor in a vacuum. The fully charged capacitor is then connected to an ideal voltmeter.



The capacitance of the capacitor is 6.0 μF and the reading of the voltmeter is 12 V.

Calculate the energy stored in the capacitor. [1]

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(d) When fully charged the space between the plates of the capacitor is filled with a dielectric with double the permittivity of a vacuum.

(i) Calculate the change in the energy stored in the capacitor. [3]

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(ii) Suggest, in terms of conservation of energy, the cause for the above change. [1]

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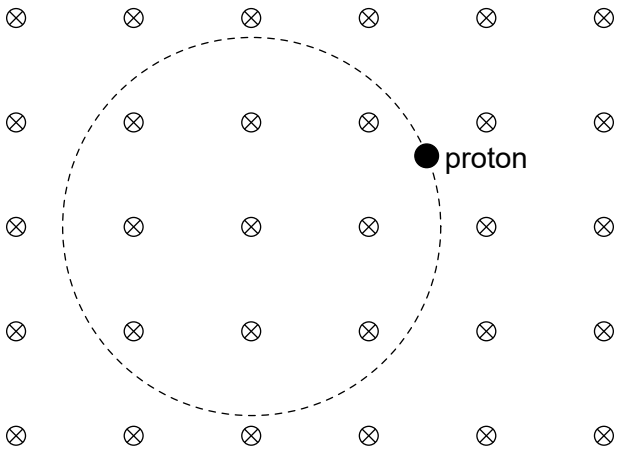
5. A proton moves along a circular path in a region of a uniform magnetic field. The magnetic field is directed into the plane of the page.



(a) Label with arrows on the diagram the

(i) magnetic force F on the proton. [1]

(ii) velocity vector v of the proton. [1]

(b) The speed of the proton is $2.16 \times 10^6\,\text{m s}^{-1}$ and the magnetic field strength is 0.042 T. For this proton,

(i) determine, in m, the radius of the circular path. Give your answer to an appropriate number of significant figures. [3]

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(ii) calculate, in s, the time for one full revolution. [2]

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6. Deuterium, ${}^{2}_{1}\mathrm{H}$, undergoes fusion according to the following reaction.

$$ {}^{2}_{1}\mathrm{H} + {}^{2}_{1}\mathrm{H} \rightarrow {}^{3}_{1}\mathrm{H} + \mathrm{X} $$

(a) Identify particle X. [1]

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(b) The following data are available for binding energies per nucleon.

$$ {}^{2}_{1}\mathrm{H} = 1.12\,\mathrm{MeV} $$
$$ {}^{3}_{1}\mathrm{H} = 2.78\,\mathrm{MeV} $$

(i) Determine, in MeV, the energy released. [2]

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(ii) Suggest why, for the fusion reaction above to take place, the temperature of deuterium must be very high. [2]

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(Question 6 continued)

(c) Particle Y is produced in the collision of a proton with a K^- in the following reaction.

$$K^- + p^+ \rightarrow K^0 + K^+ + Y$$

The quark content of some of the particles involved are

$$K^- = \bar{u}s \quad K^0 = d\bar{s}$$

Identify, for particle Y, the

(i) charge. [1]

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(ii) strangeness. [1]

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7. The average temperature of ocean surface water is 289 K. Oceans behave as black bodies.

(a) Show that the intensity radiated by the oceans is about 400 $W m^{-2}$. [1]

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(b) Explain why some of this radiation is returned to the oceans from the atmosphere. [3]

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(c) The intensity in (b) returned to the oceans is 330 $W m^{-2}$. The intensity of the solar radiation incident on the oceans is 170 $W m^{-2}$.

(i) Calculate the additional intensity that must be lost by the oceans so that the water temperature remains constant. [2]

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(ii) Suggest a mechanism by which the additional intensity can be lost. [1]

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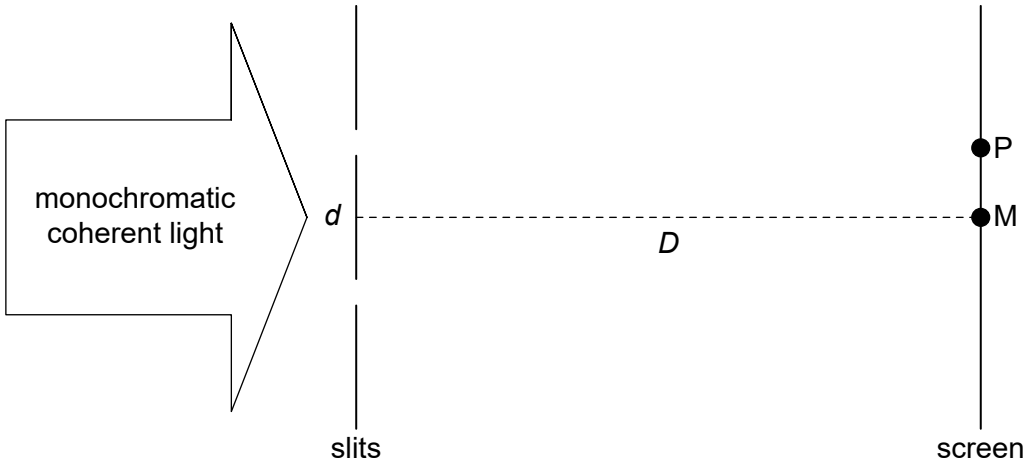
8. Monochromatic coherent light is incident on two parallel slits of negligible width a distance *d* apart. A screen is placed a distance *D* from the slits. Point M is directly opposite the midpoint of the slits.

diagram not to scale



Initially the lower slit is covered and the intensity of light at M due to the upper slit alone is $22\,\text{W m}^{-2}$. The lower slit is now uncovered.

(a) Deduce, in W m^{-2}, the intensity at M. [3]

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(b) P is the first maximum of intensity on **one** side of M. The following data are available.

$d = 0.12\,\text{mm}$
$D = 1.5\,\text{m}$
Distance MP $= 7.0\,\text{mm}$

Calculate, in nm, the wavelength λ of the light. [2]

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(This question continues on the following page)

(Question 8 continued)

(c) The width of each slit is increased to 0.030 mm. D, d and λ remain the same.

(i) Suggest why, after this change, the intensity at P will be less than that at M. [1]

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(ii) Show that, due to single slit diffraction, the intensity at a point on the screen a distance of 28 mm from M is zero. [2]

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9. (a) A planet of mass m is in a circular orbit around a star. The gravitational potential due to the star at the position of the planet is V.

(i) Show that the total energy of the planet is given by the equation shown. [2]

$$E = \frac{1}{2}mV$$

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(ii) Suppose the star could contract to half its original radius without any loss of mass. Discuss the effect, if any, this has on the total energy of the planet. [2]

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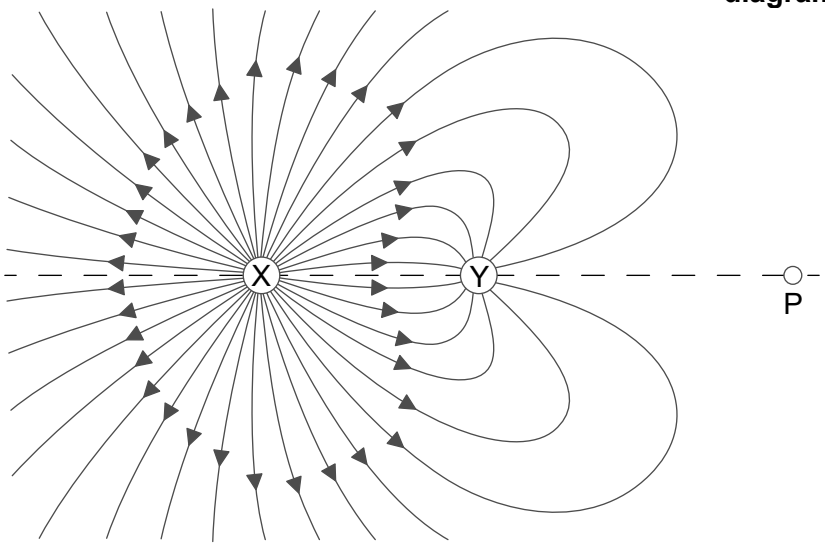
(Question 9 continued)

(b) The diagram shows some of the electric field lines for two fixed, charged particles X and Y.

diagram not to scale



The magnitude of the charge on X is Q and that on Y is q. The distance between X and Y is 0.600 m. The distance between P and Y is 0.820 m.

At P the electric field is zero. Determine, to **one** significant figure, the ratio $\frac{Q}{q}$. [2]

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10. A small magnet is dropped from rest above a stationary horizontal conducting ring. The south (S) pole of the magnet is upwards.

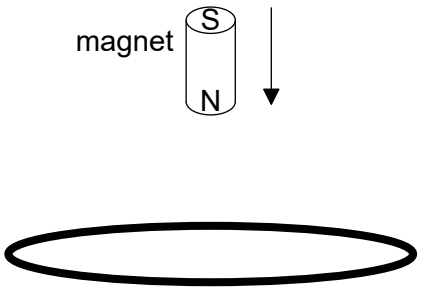

Diagram 1: side view

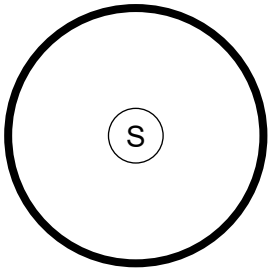

Diagram 2: view from above

While the magnet is moving towards the ring,

(a) state why the magnetic flux in the ring is increasing. [1]

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(b) sketch, using an arrow on **Diagram 2**, the direction of the induced current in the ring. [1]

(c) deduce the direction of the magnetic force on the magnet. [2]

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11. (a) Suggest why de Broglie's hypothesis is **not** consistent with Bohr's conclusion that the electron's orbit in the hydrogen atom has a well defined radius. [2]

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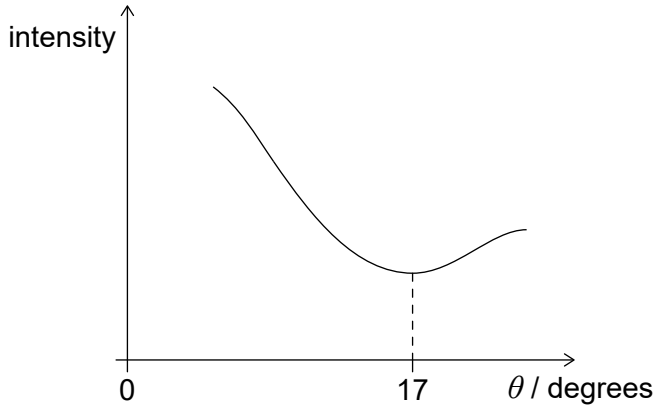
(b) In an experiment to determine the radius of a carbon-12 nucleus, a beam of neutrons is scattered by a thin film of carbon-12. The graph shows the variation of intensity of the scattered neutrons with scattering angle. The de Broglie wavelength of the neutrons is 1.6×10^{-15} m.



(i) Estimate, using the graph, the radius of a carbon-12 nucleus. [2]

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(ii) The ratio $\frac{\text{volume of a nucleus of mass number } A}{\text{volume of a nucleon}}$ is approximately A.

Comment on this observation by reference to the strong nuclear force. [2]

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(Question 11 continued)

(c) A pure sample of copper-64 has a mass of 28 mg. The decay constant of copper-64 is 5.5×10^{-2} hour^{-1}.

(i) Estimate, in Bq, the initial activity of the sample. [2]

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(ii) Calculate, in hours, the time at which the activity of the sample has decreased to one-third of the initial activity. [2]

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