ESAT-style practice paper

Set B Physics

TIME ALLOWED
40
MINUTES

27 multiple-choice questions

An average of 89 seconds per question.

Instructions

- Attempt all 27 questions.
- Calculators are *not* permitted.
- No formula booklet is provided.
- Use scrap paper or a whiteboard for rough working.

Information

- Each question has one correct answer and is worth one mark.
- No marks are deducted for incorrect answers.
- The questions are not arranged in order of difficulty.
- The ESAT itself is taken on a computer, with erasable sheets for rough working.

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Thermal Physics

1. A fixed mass of gas is held at a constant temperature.
At a pressure of 200 kPa, the gas occupies a volume of 3 cm^3.
The gas is then compressed until its volume is 600 mm^3.
What is the new pressure of the gas, in kPa?

A 1

B 10

C 40

D 100

E 1000

Atomic Physics & Radioactivity

2. An ion of $^{27}_{13}$Al contains 10 electrons.

An ion of $^{56}_{26}$Fe has the same electric charge as the aluminium ion.

Which row gives the numbers of neutrons and electrons in the iron ion?

	Number of neutrons	**Number of electrons**
A	26	23
B	30	23
C	30	26
D	30	29
E	33	23

Mechanics

3. A skydiver and equipment have total mass m.

The skydiver is falling vertically at a constant speed u.

The drag force is modelled as kv^2, where v is the speed and k is a constant.

At this speed, the skydiver opens a parachute, which changes the constant in the model to $4k$.

The gravitational field strength is g.

What are the magnitude of the acceleration immediately after the parachute opens and the new terminal speed?

	acceleration magnitude	**new terminal speed**
A	$3g$	$\frac{u}{4}$
B	$3g$	$\frac{u}{2}$
C	$3g$	$2u$
D	$4g$	$\frac{u}{4}$
E	$4g$	$\frac{u}{2}$
F	$5g$	$\frac{u}{2}$

Waves & Optics

4. A student stands on flat ground between two tall, vertical, parallel cliff faces. The student is closer to one cliff than to the other, on the line perpendicular to both cliff faces.

The student claps once.

Sound reflects completely from each cliff face, and no reflections from anything else reach the student. Every sound that reaches the student is loud enough to be heard.

The first echo is heard 1.2 s after the clap, and the second echo is heard 2.0 s after the clap.

Echoes that reach the student at the same instant are heard as a single echo.

How long after the clap is the fourth echo heard?

A 2.4 s

B 2.8 s

C 3.2 s

D 4.0 s

E 4.4 s

F 5.2 s

G 6.4 s

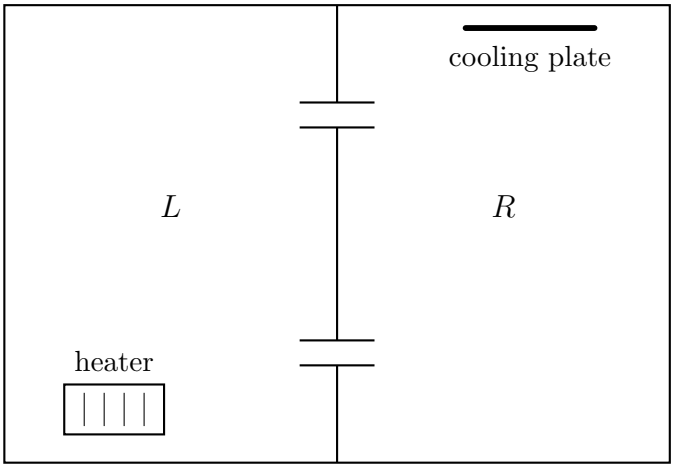
Thermal Physics

5. Two sealed compartments contain air and are connected only by a narrow upper passage and a narrow lower passage.

A heater warms the air at the bottom of compartment L. A cooling plate cools the air at the top of compartment R.

The diagram shows a vertical cross-section through the two sealed compartments.

After sufficient time, which of the following best describes the net movement of air through the two passages?



A Upper passage: from R to L; lower passage: from L to R

B Upper passage: from L to R; lower passage: from R to L

C Both passages: from L to R

D Both passages: from R to L

E There is no sustained net movement through either passage.

F The direction of net movement through each passage repeatedly reverses.

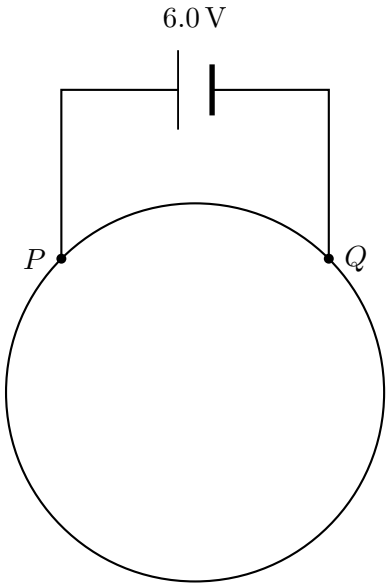
Electricity

6. A uniform wire of total resistance $16\,\Omega$ is bent into a circular ring. The two ends of the wire are joined at a point, so the ring is a complete conducting loop.

Two terminals are connected to the ring at points P and Q. These points divide the circumference of the ring into two arcs whose lengths are in the ratio $1 : 3$.

A cell of voltage $6.0\,\text{V}$ and negligible internal resistance is connected between P and Q by leads of negligible resistance.

What is the current supplied by the cell?



A 0.375 A

B 0.50 A

C 0.75 A

D 1.5 A

E 2.0 A

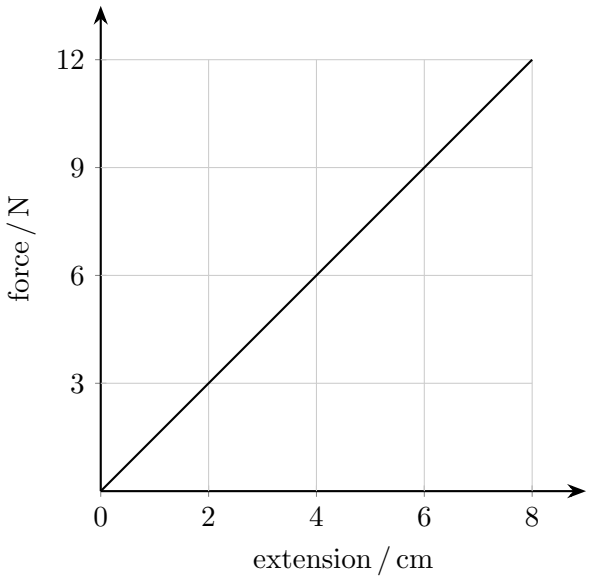
F 3.0 A

Mechanics

7. The graph below shows the force required to hold a spring at different extensions, all within its elastic limit.

The extension of the spring is increased slowly from 2.0 cm to 6.0 cm.

What is the increase in the elastic energy stored in the spring?



A 0.12 J

B 0.18 J

C 0.24 J

D 0.27 J

E 0.36 J

F 0.48 J

Thermal Physics

8. A fixed mass of ideal gas is trapped in a cylinder by a frictionless, freely moving piston. The piston is acted on by a constant downward load, and the atmospheric pressure remains constant.

The gas is initially at thermal equilibrium with its surroundings. It is heated and the piston moves upwards until it is again at rest. The piston is then fixed in this new position. The gas is allowed to cool back to its initial temperature.

Compared with their initial values, how do the final pressure, volume and density of the gas differ?

	pressure	**volume**	**density**
A	lower	greater	greater
B	lower	greater	lower
C	unchanged	greater	lower
D	greater	greater	lower
E	greater	unchanged	unchanged

Mechanics

9. A trailer is towed by a car along a straight, horizontal road at a constant velocity of $12\,\mathrm{m\,s^{-1}}$.

The trailer is attached to the car by a horizontal coupling.

The total horizontal resistive force acting on the trailer is 400 N.

Consider the following statements about the trailer and the coupling:

1 The towing force and the total resistive force acting on the trailer form a Newton's third-law pair

2 The force the trailer exerts on the coupling and the force the coupling exerts on the trailer are equal in magnitude and opposite in direction

3 The power supplied to the trailer by the towing force is 4.8 kW

Which statements are correct?

A 1 only

B 2 only

C 3 only

D 1 and 2 only

E 1 and 3 only

F 2 and 3 only

G 1, 2 and 3

Atomic Physics & Radioactivity

10. A nucleus of neptunium-237, $^{237}_{93}\text{Np}$, decays through a series of steps to a nucleus of the stable nuclide bismuth-209, $^{209}_{83}\text{Bi}$.

In each step, the nucleus emits either an alpha particle or a beta (β^-) particle.

Gamma rays may also be emitted along the way.

In total, how many alpha particles and how many beta particles are emitted?

	number of alpha particles	**number of beta particles**
A	4	7
B	5	0
C	7	4
D	7	10
E	7	24
F	14	18

Electricity

11. A battery of electromotive force 12 V and negligible internal resistance is connected to a resistor X in series with a parallel combination of two identical resistors Y and Z.

Each of X, Y and Z has resistance R.

Resistor Z is then disconnected from the circuit, leaving X and Y in series with the battery.

What is the ratio

$$\frac{\text{power dissipated in } Y \text{ after } Z \text{ is disconnected}}{\text{power dissipated in } Y \text{ before } Z \text{ is disconnected}}$$

A $\frac{4}{9}$

B $\frac{3}{4}$

C $\frac{4}{3}$

D $\frac{3}{2}$

E $\frac{9}{4}$

F 4

Mechanics

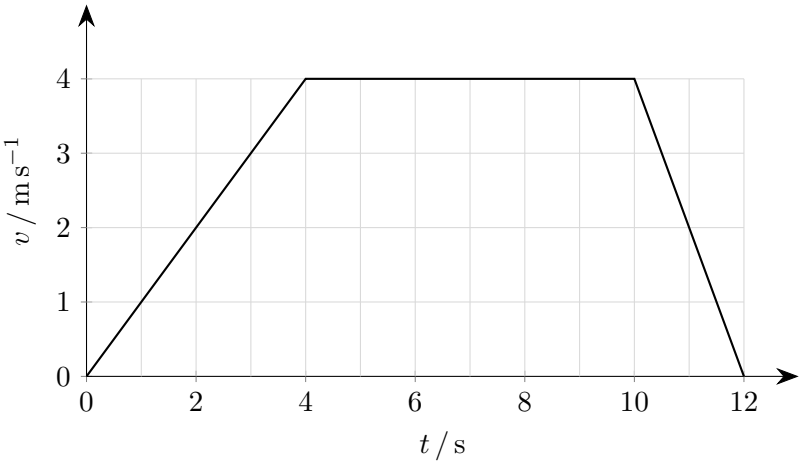
12. A passenger of mass 60 kg stands on the floor of a lift.

The lift moves vertically upwards from rest and comes to rest again.

The graph shows how the upward velocity v of the lift varies with time t during the journey.

Take the gravitational field strength g to be $10\,\mathrm{N\,kg^{-1}}$.

What is the greatest normal contact force exerted on the passenger by the floor of the lift during the journey?



A 60 N

B 120 N

C 480 N

D 540 N

E 600 N

F 660 N

G 720 N

Waves & Optics

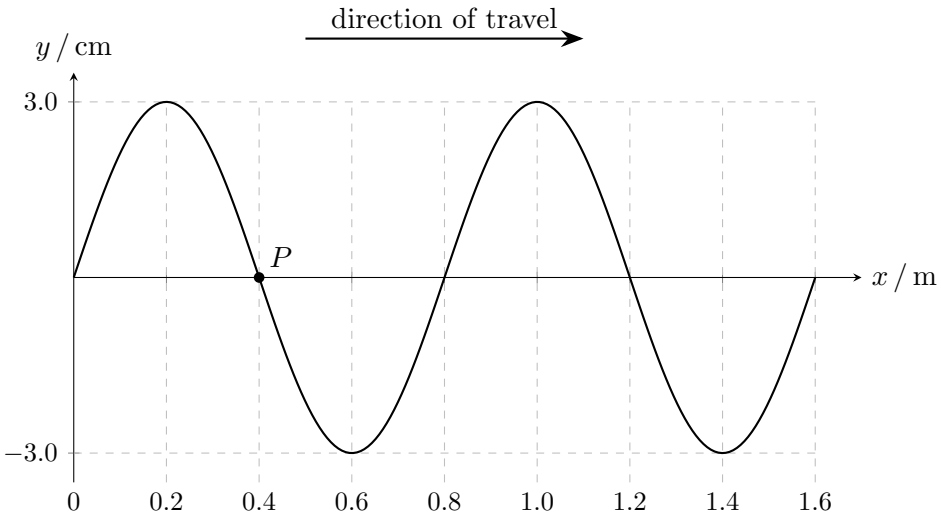
13. A transverse wave travels along a long rope.

The graph below shows the displacement y of the rope against the distance x along the rope at time $t = 0$.

The wave travels in the direction of increasing x at a speed of $4.0\,\text{m}\,\text{s}^{-1}$.

The point P on the rope is at $x = 0.40\,\text{m}$.

What is the displacement of the point P at time $t = 0.35\,\text{s}$?



A $-3.0\,\text{cm}$

B $-1.5\,\text{cm}$

C $0\,\text{cm}$

D $+1.5\,\text{cm}$

E $+3.0\,\text{cm}$

Mechanics

14. A train accelerates uniformly from rest to $12\,\mathrm{m\,s^{-1}}$ in 20 s, then travels at this steady speed. It then brakes uniformly to rest in 30 s.
The total distance travelled during the journey is 900 m.
What is the total time taken for the journey?

A 75 s

B 85 s

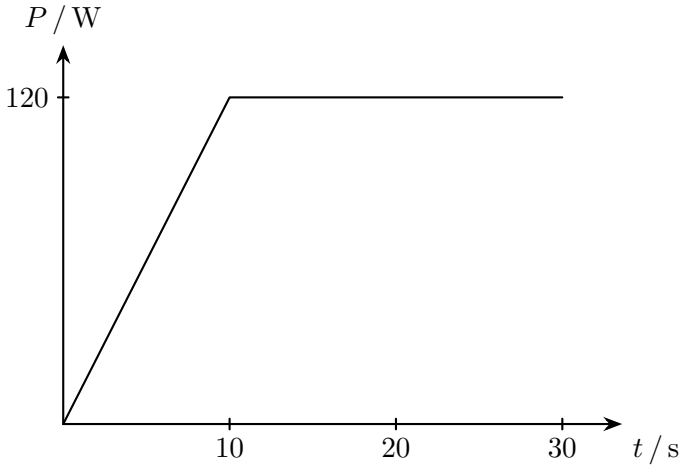
C 90 s

D 100 s

E 125 s

Electricity

15. A device is connected to a battery that maintains a constant voltage of 24 V across the device. The graph shows how the power P supplied to the device varies with time t over a period of 30 s. What is the total charge that flows through the device during these 30 s?



A 25 C

B 100 C

C 125 C

D 150 C

E 3000 C

Magnetism

16. Two long, straight, parallel wires, X and Y, are separated by a distance d.

A straight line perpendicular to the wires passes through both wire X and wire Y.

The magnetic field strength B at a distance r from a long straight wire carrying a current I is directly proportional to I and inversely proportional to r.

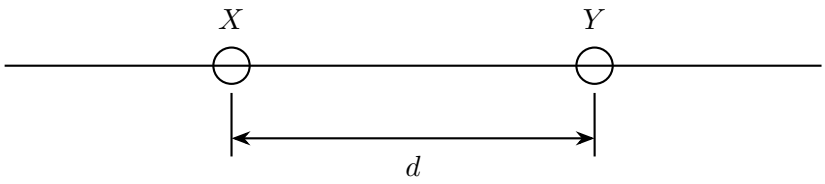
Wire X carries a constant current I, and wire Y carries a constant current $3I$, initially flowing in the same direction.

At a point P_1 on the line, the resultant magnetic field due to the two currents is zero.

The direction of the current in wire Y is then reversed, while the current in wire X remains unchanged.

The resultant magnetic field is now zero at a point P_2 on the line.

What is the distance between P_1 and P_2?



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

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

C $\frac{3}{4}d$

D d

E $\frac{5}{4}d$

F $\frac{7}{4}d$

Thermal Physics

17. A metal block of mass 0.50 kg at 80 °C is lowered into 0.25 kg of water at 20 °C in an insulated container.

The block and water reach a common temperature of 30 °C without any change of state.

The container absorbs negligible energy, and no energy is transferred to the surroundings.

The specific heat capacity of water is $4200\,\mathrm{J\,kg^{-1}\,°C^{-1}}$.

What is the specific heat capacity of the metal?

A $210\,\mathrm{J\,kg^{-1}\,°C^{-1}}$

B $350\,\mathrm{J\,kg^{-1}\,°C^{-1}}$

C $420\,\mathrm{J\,kg^{-1}\,°C^{-1}}$

D $700\,\mathrm{J\,kg^{-1}\,°C^{-1}}$

E $2100\,\mathrm{J\,kg^{-1}\,°C^{-1}}$

Magnetism

18. An ideal transformer has 400 turns on its primary coil and 100 turns on its secondary coil. The primary coil is connected to an alternating supply of voltage 240 V.

The secondary coil is connected to two identical lamps in parallel. Each lamp has a constant resistance of 30 Ω.

One lamp is then removed, and the secondary coil is rewound so that it has 200 turns. The remaining single lamp stays connected across the secondary coil. The primary coil and supply are unchanged.

What is the ratio

$$\frac{\text{current in the primary coil after the changes}}{\text{current in the primary coil before the changes}}$$

A $\frac{1}{4}$

B $\frac{1}{2}$

C 1

D 2

E 4

F 8

Mechanics

19. A cyclist freewheels down a straight, sloping road without pedalling.

The total mass of the cyclist and bicycle is 80 kg.

The speed of the cyclist increases from $4.0\,\mathrm{m\,s^{-1}}$ to $6.0\,\mathrm{m\,s^{-1}}$ while the cyclist travels 100 m along the road.

Over this 100 m, the road descends through a vertical height of 5.0 m.

What is the average total resistive force acting on the cyclist and bicycle along the road over this 100 m?

(gravitational field strength = $10\,\mathrm{N\,kg^{-1}}$)

A 8.0 N

B 32 N

C 38 N

D 40 N

E 48 N

F 640 N

Waves & Optics

20. Five sounds, V, W, X, Y and Z, travel through sea water.

The speed of sound in sea water is $1500\,\mathrm{m\,s^{-1}}$.

The wavelength of each sound in sea water is given below.

V 1.5 mm

W 6.0 cm

X 100 m

Y 50 cm

Z 10 cm

A sound is audible if its frequency is within the range of human hearing, 20 Hz to 20 kHz.

A sound is ultrasound if its frequency is above 20 kHz.

Which row of the table correctly identifies all the audible sounds and all the ultrasound sounds?

	audible	**ultrasound**
A	X, Y and Z	V and W
B	Y and Z	V and W
C	Y only	V, W and Z
D	Y and Z	V, W and X
E	W, Y and Z	V only
F	Z only	V and W

Mechanics

21. A bottle has a mass of 200 g when empty.

When the bottle is completely filled with water, the total mass is 1000 g.

When the bottle is completely filled with another liquid, the total mass is 840 g.

The density of water is $1000\,\mathrm{kg\,m^{-3}}$.

What is the density of the other liquid?

A $640\,\mathrm{kg\,m^{-3}}$

B $800\,\mathrm{kg\,m^{-3}}$

C $840\,\mathrm{kg\,m^{-3}}$

D $1050\,\mathrm{kg\,m^{-3}}$

E $1300\,\mathrm{kg\,m^{-3}}$

Mechanics

22. A radium nucleus $^{226}_{88}\text{Ra}$ is at rest.

It decays by emitting an alpha particle, and a radon nucleus $^{222}_{86}\text{Rn}$ is formed.

No other particle or radiation is emitted in the decay.

The mass of the alpha particle is 4.0 u and the mass of the radon nucleus is 222 u, where u is the atomic mass unit.

What is the approximate value of

$$\frac{\text{kinetic energy of the alpha particle}}{\text{kinetic energy of the radon nucleus}}$$

immediately after the decay?

A 0.018

B 1.0

C 7.5

D 55.5

E 56.5

F 3080

Waves & Optics

23. A straight dipper vibrates at 4.0 Hz in a ripple tank and produces straight wavefronts.

The wavefronts are parallel to a straight boundary between deep water and shallow water, so the waves travel at right angles to the boundary.

The dipper is 24 cm from the boundary, and the wavelength in the deep water is 3.0 cm.

The shallow water extends 12 cm beyond the boundary to the wall of the tank, and the wavelength in the shallow water is 2.0 cm.

How long does a wavefront take to travel from the dipper to the wall?

A 3.0 s

B 3.5 s

C 3.6 s

D 4.0 s

E 4.5 s

Mechanics

24. A solid concrete block measures $40\,\text{cm} \times 20\,\text{cm} \times 10\,\text{cm}$.
The density of the concrete is $2500\,\text{kg}\,\text{m}^{-3}$.
The block rests on a horizontal floor on its smallest face.
Take the gravitational field strength g to be $10\,\text{N}\,\text{kg}^{-1}$.
What is the pressure that the block exerts on the floor?

A $250\,\text{Pa}$

B $1000\,\text{Pa}$

C $2500\,\text{Pa}$

D $5000\,\text{Pa}$

E $10\,000\,\text{Pa}$

F $100\,000\,\text{Pa}$

Atomic Physics & Radioactivity

25. A radioactive source is placed 1 cm from a radiation detector in air.

With the source removed, the detector records a background count rate of 30 counts per minute.

With the source in place, different absorbers are placed in turn between the source and the detector. Each count rate in the table is an average over a long time.

absorber	**counts per minute**
none	410
a sheet of paper	410
aluminium, 3 mm thick	80
lead, 2 cm thick	55

Which row of the table correctly shows the types of radiation emitted by the source?

	alpha	**beta**	**gamma**
A	yes	yes	yes
B	yes	yes	no
C	yes	no	yes
D	yes	no	no
E	no	yes	yes
F	no	yes	no
G	no	no	yes

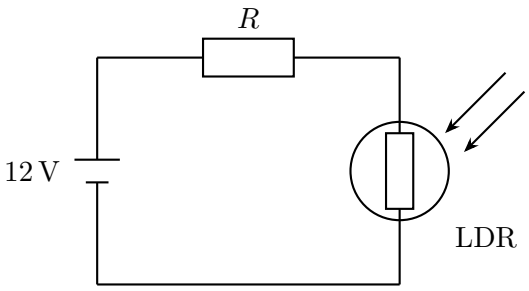
Electricity

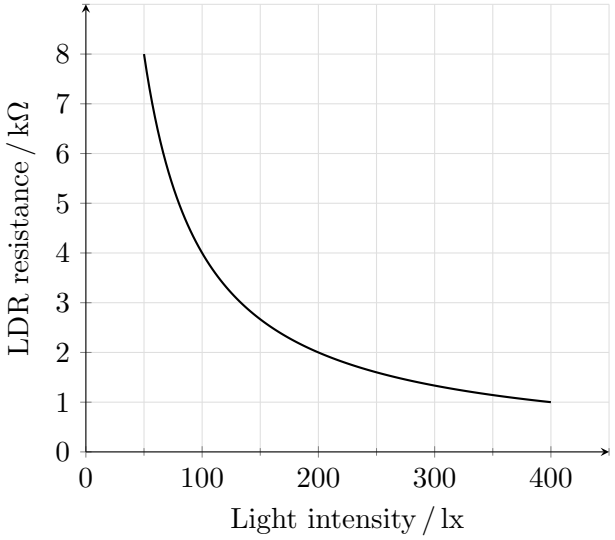
26. An LDR is connected in series with a fixed resistor R and a 12 V battery of negligible internal resistance.

The graph below shows how the resistance of the LDR varies with light intensity.

At a light intensity of 100 lx, the current in the circuit is 2.0 mA.

What is the potential difference across R at a light intensity of 400 lx?





A 2.0 V

B 4.0 V

C 6.0 V

D 8.0 V

E 10 V

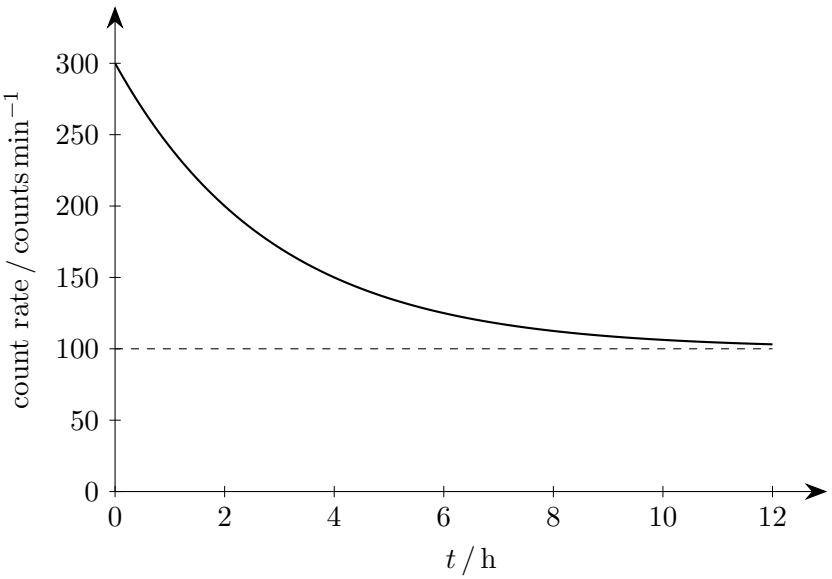
Atomic Physics & Radioactivity

27. A radioactive sample is placed next to a detector.

The graph below shows how the measured count rate varies with time.

The count rate levels off at a constant background count rate.

What is the half-life of the sample?



A 1 h

B 2 h

C 4 h

D 6 h

E 8 h