Unit 15 · Earth and the Universe

HARDER PRACTICE QUESTIONS · ANSWER KEY

Full marks 43

Give the marks for the points in the marking scheme; an answer in other words that says the same is right.

1 Spot the error

ANSWER U · 3

In each half-life, half of **what is left** decays, not half of the starting amount. After the first 5,730 years ½ is left; after the next, half of that, **¼**.
51,570 years is 9 half-lives: $(½)^9 = 1/512$, **about 0.2%**. The amount never quite reaches zero; it becomes too small to measure.

MARKING SCHEME

- ✓ Half of what is left decays each half-life.
- ✓ ¼ is left after 11,460 years.
- ✓ About 0.2% (1/512) after 51,570 years.

2 Between two half-lives

ANSWER A · 4

i. 35% lies between 50% (1 half-life) and 25% (2 half-lives): between **5,730 and 11,460 years**.
ii. 35% is 15/25 = 0.6 of the way from 50% to 25%, so about $5{,}730 + 0.6 \times 5{,}730 \approx$ **9,200 years**. The real curve falls steeply first and flattens, so it reaches 35% sooner than the straight line: the real age is **less** (about 8,700 years by the exact curve).
iii. **More than 50%**: 2,600 years is less than one half-life (about 73% is left).

MARKING SCHEME

- ✓ Between 1 and 2 half-lives: 5,730 to 11,460 years.
- ✓ About 9,200 years by the straight line.
- ✓ The real age is less, since the curve falls fastest at first.
- ✓ More than 50% for less than one half-life.

3 Two layers of ash

ANSWER A · 4

i. By superposition B lies above the 7.2 million-year ash and below the 6.8 million-year ash, so the tooth is **between 7.2 and 6.8 million years old**.
ii. By cross-cutting it is younger than everything it cuts, so **younger than mudstone C**, and so younger than 6.8 million years.
iii. That layer is probably of about the same age (faunal succession): it works best for a fossil that lived for only a short span and was found widely, an index fossil.

MARKING SCHEME

- ✓ Superposition: the tooth lies between the two ashes.
- ✓ Between 7.2 and 6.8 million years.
- ✓ The igneous rock is younger than all the layers, so younger than 6.8 million years.
- ✓ The far layer is of about the same age, if the fossil is an index fossil.

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4 The rock's clock

ANSWER A · 4

i. 1 part of 8 is left: ⅛ = (½)^3, 3 half-lives, so 3 × 1,250 = **3,750 million years**.
ii. ¼ left, 2 half-lives: **2,500 million years**.
iii. ¼ of the uranium left means 2 half-lives, 8,940 million years: **older than the Earth** (4,540 million years). (Unless the grain had lead in it from the start, or lost uranium.)

MARKING SCHEME

✓ ⅛ left.
✓ 3,750 million years.
✓ 2,500 million years.
✓ 8,940 million years, older than the Earth.

5 Show that

ANSWER HA · 3

i. Each half-life multiplies what is left by ½; in time t there are n = t/T half-lives, so the fraction is ½ × ½ × … (n times) = (½)C= (½)^(t/T).
ii. Every parent atom that decays becomes a daughter, so daughter = 1 − parent = 1 − (½)^(t/T). They are equal when (½)^(t/T) = ½, that is t/T = 1: **t = T**.

MARKING SCHEME

✓ n = t/T half-lives, each multiplying by ½.
✓ Daughter = 1 − (½)^(t/T), since each decayed atom becomes a daughter.
✓ Equal when (½)^(t/T) = ½, so t = T.

6 The Earth in a day

ANSWER A · 4

1 million years = 1,440 ÷ 4,540 minutes = 0.317 minute.
i. 66 × 0.317 = **about 21 minutes** before midnight.
ii. 2.6 × 0.317 = 0.82 minute = **about 49 seconds**.
iii. 0.05 × 0.317 = 0.016 minute = **about 1 second**.

MARKING SCHEME

✓ 0.317 minute for each million years.
✓ About 21 minutes.
✓ About 49 seconds.
✓ About 1 second.

7 Read the counts

ANSWER A · 4

(The counts are made up.)
i. B: 3.5/14 = ¼, 2 half-lives, **11,460 years**. C: 1.75/14 = ⅛, 3 half-lives, **17,190 years**.
ii. 13/14 = 93%, much more than half: **far younger** than 5,730 years, a few hundred years (about 600 by the exact curve).
iii. No carbon-14 is left: it is older than about 50,000 years. At 9 million years carbon dating can't give its age at all; its carbon isn't even its own. It is dated from the rocks around it.

MARKING SCHEME

✓ B 11,460 years.
✓ C 17,190 years.
✓ A far younger than one half-life.
✓ D: none left, beyond the method; dated by the rocks.

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8 Into orbit

ANSWER A · 3

i. $7.7 \times 92 \times 60 =$ **about 42,500 km**.
ii. $1{,}440 \div 92 =$ **about 15.7**.
iii. $25{,}000{,}000{,}000 \div 300{,}000 = 83{,}333$ s = **about 23 hours**, nearly a day.

MARKING SCHEME

✓ About 42,500 km.
✓ About 15.7 orbits.
✓ About 23 hours.

9 Put them in order

ANSWER U · 3

Sputnik 1 (1957), Gagarin (1961), Apollo 11 (1969), Salyut 1 (1971), Viking 1 (1976), Hubble (1990), the first crew on the ISS (2000), NepaliSat-1 (2019).

MARKING SCHEME

✓ The first three in order: Sputnik 1, Gagarin, Apollo 11.
✓ Salyut 1 and Viking 1 next.
✓ Hubble, the ISS, then NepaliSat-1.

10 Fair test

MARKING SCHEME A · 3

✓ Changes the hole size; observes each spot's brightness.
✓ Any two things kept the same.
✓ Brighter spots from bigger holes.

11 Correct the misconceptions

ANSWER U · 3

1. A shaligram is about 150 million years old, about 26,000 half-lives: no carbon-14 is left, and its shell has been replaced by minerals.
2. The tooth is of *Sivapithecus* (the animal once called Ramapithecus), an ape related to the orangutan, not a human ancestor.
3. The Tethys rocks formed on the sea floor, far from any shore: they hold sea animals such as ammonites, and no dinosaur bones have been found in Nepal.

MARKING SCHEME

✓ Too old for carbon-14, and its carbon isn't its own.
✓ *Sivapithecus*, an ape, not a human ancestor.
✓ Sea-floor rocks: no dinosaurs found in Nepal.

12 Think

ANSWER HA · 3

Nine half-lives would be 515,700 years, so it could reach back about **500,000 years**.
Worse for recent things: in 100 years only about 0.12% of the carbon-14 would decay (now about 1.2%), too small a change to measure well. A clock suits a stretch of time that is neither far shorter nor far longer than its half-life.

MARKING SCHEME

✓ About 500,000 years (nine half-lives).
✓ Worse for 100 years: far less would have decayed.
✓ A clock suits times near its half-life.

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13 Make your own

ANSWER HA · 2

Any counts in the ratio of a power of ½, for example living carbon 16 counts a minute and a sample 4: $4/16 = ¼ = (½)^2$, so $2 \times 5{,}730 = 11{,}460$ years.

MARKING SCHEME

- ✓ Counts in the ratio $(½)^n$
- ✓ The age $n \times 5{,}730$ years worked out.

See it at Science Playground

Exhibits and plants at the center, Bhaktapur, that go with this unit. Book a class visit at science-playground.com/booking.

- **The Spiral of Life on Earth** (exhibit): Follow Earth's history from its formation at the thin coil at the bottom to today at the outer tip: single cells for most of it, humans only at the end.
- **Tree Ring Cross-Section** (exhibit): Count the rings, one for each year the tree grew: an absolute clock, dendrochronology, that can date wood to the very year.
- **Saturn V - LEGO Model** (exhibit): A model of the rocket that launched Apollo 11 in July 1969, when Armstrong and Aldrin became the first people to walk on the Moon.

Marks by level	Knowledge	Understanding	Application	Higher ability	Total
Marks	0	9	26	8	**43**

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