Unit 15 · Earth and the Universe

ANSWER KEY · FOR TEACHERS

Full marks 46

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

1 Key words

1. geochronology
2. relative
3. half-life
4. paleontology
5. index
6. trace
7. lithification
8. planetarium

Each carries 0.5 mark. **K · 4**

2 Label the diagram

1. the dome, a white screen
2. a beam for each star
3. seats tipped back
4. star ball, lamp inside

Each carries 0.5 mark. **K · 2**

3 True or false

i. ✗ **False**: Carbon dating works only up to about 50,000 years; such bones are dated by slower clocks in the rocks around them. **U · 3**

ii. ✓ **True**

iii. ✗ **False**: It is now known to be *Sivapithecus*, an ape related to the orangutan.

iv. ✓ **True**

v. ✗ **False**: That is an observatory; a planetarium shows a copy of the sky on a dome.

vi. ✓ **True**

Each carries 0.5 mark.

4 Multiple choice

i. **b.** geochronology **K · 1**

Geo (the Earth) + *chronos* (time) + *logos* (study): geochronology. Paleontology studies fossils, seismology earthquakes, and geomorphology the shapes of the land.

ii. **c.** a dinosaur's footprint **U · 1**

A footprint is something the animal did, not part of its body: a trace fossil. The others are the remains, or copies of the remains, of the living things themselves.

iii. **c.** nitrogen-14 **K · 1**

A neutron hitting a nitrogen-14 nucleus turns it into carbon-14 and a proton: $^{14}\mathrm{N} + \mathrm{n} \rightarrow {}^{14}\mathrm{C} + \mathrm{p}$. Nitrogen is the commonest gas in the air.

iv. **b.** 5,730 years **K · 1**

About 5,730 years (measured more recently as 5,700 ± 30). 4,470 million years is the half-life of uranium-238.

v. **b.** 1957 **K · 1**

The Soviet Union launched Sputnik 1 on 4 October 1957, starting the space age. 1961 was Gagarin's flight and 1969 the first landing on the Moon.

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5 Very short answers

a. MARKING SCHEME — K · 1

✓ Ammonites.

b. MARKING SCHEME — K · 1

✓ Nepal's first satellite.

c. MARKING SCHEME — A · 1

✓ ⅛.

6 Short answers

a. MARKING SCHEME — U · 2

✓ Sedimentary rocks form from layers laid down gently, often in water, which can bury remains quickly and keep them.

✓ Igneous rocks form from molten rock, which would burn or melt any remains.

b. MARKING SCHEME — U · 2

✓ 50,000 years is nearly nine half-lives, leaving about 0.2% of the carbon-14.

✓ Too little to measure reliably; a trace of modern carbon would spoil the result.

c. MARKING SCHEME — K · 2

✓ A mold is a hollow print left when a buried shell dissolves; a cast is a stone copy made when minerals fill a mold.

✓ A mold shows the shape in reverse; a cast shows the shape of the original (or: the mold forms first).

d. MARKING SCHEME — K · 2

✓ A planetarium shows a copy of the sky on a dome; an observatory has telescopes for the real sky.

✓ A planetarium works at any time and weather, for teaching; an observatory needs clear, dark nights, for research (or any other correct difference).

7 Long answers

a. ANSWER — U · 4

A fossil is the remains or trace of a living thing of the distant past, preserved in rock.
Formation: a living thing, best one with hard parts such as shells, bones or wood, dies and is buried quickly by mud, sand or ash, which protects it from scavengers and from the oxygen that decay needs. Its soft parts rot; the hard parts remain. More layers pile on, pressing and cementing the sediment into rock (lithification). Water seeping through the rock carries minerals into the spaces of the bone or shell, or replaces it grain by grain, so it turns to stone in its own shape (mineralization); sometimes the shell dissolves and leaves a mold, which may be filled to make a cast. Millions of years later, movements of the Earth lift the rock and erosion wears it away, exposing the fossil. Example: the Kali Gandaki ammonites, buried in the mud of the Tethys Sea, lifted into the Himalaya and washed out by the river.

MARKING SCHEME

✓ A fossil is the remains or trace of a living thing of the distant past, preserved in rock.

✓ It needs hard parts and quick burial, away from scavengers and oxygen; the soft parts rot.

✓ More layers press and cement the sediment into rock; minerals fill or replace the hard parts.

✓ The rock is lifted and worn away until the fossil is exposed.

b. ANSWER

Carbon dating finds how long ago a living thing died from the carbon-14 left in its remains. Neutrons from cosmic rays turn nitrogen-14 in the air into carbon-14 ($^{14}\mathrm{N} + \mathrm{n} \rightarrow {}^{14}\mathrm{C} + \mathrm{p}$), which becomes carbon dioxide. Plants take it in for photosynthesis and animals eat plants, so every living thing keeps the same share of carbon-14 as the air. At death it takes in no more, and its carbon-14 decays into nitrogen-14 by beta decay with a half-life of 5,730 years. The share left, measured by counting beta particles or carbon-14 atoms and compared with a living sample, gives the number of half-lives: $t = n \times 5{,}730$ years.
Limits: only things that were once alive; only up to about 50,000 years (too little carbon-14 left after

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that); the air's carbon-14 has varied, so results need calibration with tree rings; contamination with younger carbon must be removed. U · 4

MARKING SCHEME

- ✓ Carbon dating finds how long ago a living thing died from the carbon-14 left in it.
- ✓ Cosmic-ray neutrons turn nitrogen-14 into carbon-14; living things take it in and keep the air's share.
- ✓ After death it decays with a half-life of 5,730 years, so the share left gives the age.
- ✓ Limits: only once-living things, up to about 50,000 years, needing calibration and clean samples.

8 Numerical problems

a. **ANSWER** A · 2

$\frac{1}{16} = \left(\frac{1}{2}\right)^4$: 4 half-lives.

$$t = 4 \times 5{,}730 = 22{,}920 \text{ years}$$

About 22,900 years.

MARKING SCHEME

- ✓ $1/16 = (½)^4$: 4 half-lives.
- ✓ $t = 4 \times 5{,}730 = 22{,}920$ years.

b. **ANSWER** A · 2

$\frac{2}{16} = \frac{1}{8} = \left(\frac{1}{2}\right)^3$: 3 half-lives.

$$t = 3 \times 5{,}730 = 17{,}190 \text{ years}$$

About 17,200 years.

MARKING SCHEME

- ✓ $2/16 = 1/8$: 3 half-lives.
- ✓ $t = 17{,}190$ years.

c. **ANSWER** A · 3

$n = \frac{28{,}650}{5{,}730} = 5$: $\left(\frac{1}{2}\right)^5 = \frac{1}{32} = \mathbf{3.125\%}$.

$0.2\% \approx \frac{1}{512} = \left(\frac{1}{2}\right)^9$: after 9 half-lives, $9 \times 5{,}730 =$ **51,570 years**, which is why the method stops at about 50,000 years.

MARKING SCHEME

- ✓ $28{,}650 \div 5{,}730 = 5$ half-lives.
- ✓ $(½)^5 = 1/32 = 3.125\%$.
- ✓ $0.2\% \approx (½)^9$: $9 \times 5{,}730 = 51{,}570$ years.

d. **ANSWER** A · 3

$$\frac{539}{4{,}540} \times 100 = 11.9\%$$

$$0.119 \times 1{,}440 \text{ min} = 171 \text{ min}$$

About 12% of the Earth's history; it would begin about 171 minutes, nearly 3 hours, before midnight: all the animals with shells and bones, the dinosaurs, the forests and ourselves fit into the last three hours of the day.

MARKING SCHEME

- ✓ $539 \div 4{,}540 \times 100 = 11.9\%$.
- ✓ $0.119 \times 1{,}440$ minutes.
- ✓ About 171 minutes before midnight.

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9 Think

ANSWER HA · 3

The Siwalik rocks are about 13 to 1 million years old. Even 1 million years is about 175 half-lives of carbon-14, so none would be left; and the tooth's carbon has been replaced by minerals. Instead:

- the volcanic ash contains minerals with potassium-40 (or uranium), which can be dated by their radioactive clocks; by superposition, the tooth lies below the ash, so it is older than the ash's age, which sets a minimum age; dating an ash or lava layer below the tooth as well would bracket its age between the two;
- the kinds of animals in the layer can be matched with the same fossils in dated Siwalik layers elsewhere (index fossils);
- the direction of the rock's magnetism, matched with the known record of the Earth's field reversals (magnetic dating, as was done in the Surai Khola), can date the layer too.

MARKING SCHEME

✓ Siwalik rocks are 13 to 1 million years old: no carbon-14 is left, and the tooth's carbon has been replaced by minerals.
✓ Date the ash by potassium-40 or uranium; by superposition the tooth is older than the ash.
✓ Or match its animals with dated Siwalik layers elsewhere, or use the rock's magnetism.

10 Activity: Make a mold and a cast

(not marked)

WHAT STUDENTS SHOULD FIND

The shell's print is a mold, the shape in reverse; the plaster is a cast, a copy of the shell itself with none of the shell in it; the leaf's print is like a carbon film without the carbon; the footprints are trace fossils, which show what the animal did, not its shape.

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	16	16	11	3	**46**

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