Unit 26 · Recent Trends in Physics

ANSWER KEY · FOR TEACHERS

Full marks 36

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. antiparticle
2. hadrons
3. baryon
4. meson
5. leptons
6. redshift
7. principle
8. horizon

K · 4

Each carries 0.5 mark.

2 Label the diagram

1. distant stars
2. nearby star
3. φ
4. Sun

K · 2

Each carries 0.5 mark.

3 Multiple choice

i. **c.** −e — A · 1

Each strange quark has −⅓e: 3 × (−⅓e) = −e. Three quarks make it a baryon.

ii. **b.** 0 — A · 1

A quark (+⅓) and an antiquark (−⅓) add to 0.

iii. **d.** a photon — U · 1

The photon has spin 1, a whole number: a boson. Electrons, protons and neutrinos have spin ½: fermions.

iv. **b.** twice as fast — U · 1

$v = H_0 d$: speed is proportional to distance.

v. **a.** 5 % — K · 1

Ordinary matter about 5 %, dark matter about 27 %, dark energy about 68 %.

4 Very short answers

a. MARKING SCHEME — K · 1

✓ All six named.

b. MARKING SCHEME — K · 1

✓ 2.7 K.

c. MARKING SCHEME — U · 1

✓ No light escapes from it.

5 Short answers

a. MARKING SCHEME — A · 2

✓ Charge: $-\frac{2}{3}e + \frac{1}{3}e + \frac{1}{3}e = 0$.

✓ Baryon number: $3 \times (-\frac{1}{3}) = -1$ (an antibaryon).

Science Playground, Katunje, Bhaktapur
Book a class visit: https://science-playground.com/booking

b. MARKING SCHEME U · 2

- ✓ Any one: by the stars racing round them, by the X-rays from gas pulled off a companion star.
- ✓ Any second: by the shadow they cast (the Event Horizon Telescope), by gravitational waves when two merge.

c. MARKING SCHEME U · 2

- ✓ It was the beginning of the expansion of space itself, which happened everywhere at once.
- ✓ The galaxies are carried apart as the space between them stretches; there is no center or edge.

6 Long answer

ANSWER U · 4

Hubble's law: the recessional speed v of a galaxy is directly proportional to its distance d from us, $v = H_0 d$. The lines in a distant galaxy's spectrum are at longer wavelengths than the same lines measured in a laboratory: it is redshifted, and $z = \Delta\lambda/\lambda_0 \approx v/c$ gives its speed away from us. Almost every galaxy is redshifted, and the farther ones more, so the galaxies are moving apart: the space between them is stretching, and the universe is expanding. Running this backwards, everything was once together in a hot, dense state at one moment, the Big Bang, about $1/H_0$ ago.

MARKING SCHEME

- ✓ Hubble's law, $v = H_0 d$ ($v \propto d$).
- ✓ Redshift: lines at longer wavelengths; $z = \Delta\lambda/\lambda_0 \approx v/c$ gives the speed.
- ✓ Nearly all galaxies redshifted, more the farther they are: the universe is expanding.
- ✓ Run backwards, it began in a hot, dense state, the Big Bang (about $1/H_0$ ago).

7 Numerical problems

a. ANSWER A · 3

$v = H_0 d = 70 \times 200 =$ **14,000 km/s** (1.4×10^7 m/s).
$z = v/c = 1.4 \times 10^7 \div 3.0 \times 10^8 =$ **0.047**.
$\lambda = \lambda_0(1 + z) = 656.3 \times 1.047 =$ **687 nm**.

MARKING SCHEME

- ✓ v = 14,000 km/s.
- ✓ z = 0.047.
- ✓ λ = 687 nm.

b. ANSWER A · 3

$d = 1/\varphi = 1 \div 0.38 =$ **2.6 pc**; $\times 3.26 =$ **8.6 light years**. The light left it about **8.6 years** ago.

MARKING SCHEME

- ✓ $d = 1/\varphi$ = 2.6 pc.
- ✓ 8.6 light years.
- ✓ The light left 8.6 years ago.

c. ANSWER A · 3

Charge: +e + e = +e + 0 + Q, so **Q = +e**. Baryon number: 1 + 1 = 1 + 1 + B, so **B = 0**: X is a meson, a quark and an antiquark. A charge of +e needs $+\frac{2}{3}e + \frac{1}{3}e$: $u\bar{d}$, the π^+.

MARKING SCHEME

- ✓ Q = +e.
- ✓ B = 0, a meson.
- ✓ $u\bar{d}$ (a π^+).

Science Playground, Katunje, Bhaktapur
Book a class visit: https://science-playground.com/booking

8 Think

ANSWER HA · 3

In the Big Bang model the universe has a finite age, about 13.8 billion years, so we can see only the light that has had time to reach us: the stars beyond that distance are hidden, and there are not enough nearer ones to cover the sky. The expansion also redshifts the light from distant galaxies, weakening it: the oldest light, the cosmic microwave background, has been stretched to microwaves our eyes can't see.

MARKING SCHEME

- ✓ The universe has a finite age: light from beyond about 13.8 billion light years hasn't reached us.
- ✓ So not every line of sight ends on a star we can see.
- ✓ The expansion redshifts and weakens distant light (the background is now microwaves).

9 Activity: Hubble's law on a balloon (Activity 26.1)

(not marked)

WHAT STUDENTS SHOULD FIND

Every dot moves away, and the increase is proportional to the starting distance: a straight line through the origin, Hubble's law. The same happens from any dot: every "galaxy" sees all the others moving away, so none is the center.

Marks by level	Knowledge	Understanding	Application	Higher ability	Total
Marks	9	11	13	3	**36**

Science Playground, Katunje, Bhaktapur
Book a class visit: https://science-playground.com/booking