Unit 26 · Recent Trends in Physics

HARDER PRACTICE QUESTIONS · ANSWER KEY

Full marks 29

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

He used the **up** quark's charge for the **anti-up** quark. An antiquark has the opposite charge: $\bar{u}$ has $-\frac{2}{3}e$. So $Q = -\frac{2}{3}e - \frac{1}{3}e = \mathbf{-e}$, as its name says. (A meson's charge is always a whole number of e.)

MARKING SCHEME

- ✓ The error: $\bar{u}$'s charge taken as $+\frac{2}{3}e$.
- ✓ An antiquark has the opposite charge: $-\frac{2}{3}e$.
- ✓ $Q = -e$.

2 Work backwards

ANSWER A · 3

$z = \Delta\lambda/\lambda_0 = 13.9 \div 486.1 = 0.0286$; $v = zc = 0.0286 \times 3.0 \times 10^5$ km/s = 8,580 km/s. $d = v/H_0 = 8{,}580 \div 70 =$ **about 120 Mpc**.

MARKING SCHEME

- ✓ $z = 0.0286$.
- ✓ $v = 8{,}580$ km/s.
- ✓ $d \approx 120$ Mpc.

3 Check the readings

ANSWER HA · 3

v/d is 70, 70, 70, 50, 70 km/s per Mpc: $\mathbf{H_0 = 70}$ **km/s per Mpc**. The galaxy at **60 Mpc** doesn't fit; by Hubble's law it should move at $70 \times 60 =$ **4,200 km/s**.

MARKING SCHEME

- ✓ v/d worked out: $H_0 = 70$ km/s per Mpc.
- ✓ The 60 Mpc reading doesn't fit.
- ✓ It should be 4,200 km/s.

4 Can it happen?

MARKING SCHEME A · 3

- ✓ i. Baryon number $2 \rightarrow 3$.
- ✓ i. can't happen.
- ✓ ii. both conserved, so it can happen.

5 A real setting

ANSWER A · 3

i. $R(S) = 2GM/c^2 = 2 \times 6.67 \times 10^{-11} \times 4 \times 10^6 \times 1.99 \times 10^{30} \div (3.0 \times 10^8)^2 = \mathbf{1.2 \times 10^{10}}$ **m**.

ii. $1.5 \times 10^{11} \div 1.2 \times 10^{10} \approx 13$: its horizon would fit **well inside the Earth's orbit**, about a thirteenth of the way to the Sun, for four million Suns' mass.

MARKING SCHEME

- ✓ $R = 2GM/c^2$ with $M = 4 \times 10^6 \times$ the Sun's mass.
- ✓ 1.2×10^{10} m.
- ✓ About a thirteenth of the Earth–Sun distance.

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6 Estimate it

ANSWER A · 2

$R = 2GM/c^2 = 2 \times 6.67 \times 10^{-11} \times 6.0 \times 10^{24} \div 9.0 \times 10^{16} =$ **8.9×10^{-3} m**, about 9 mm: the whole Earth in a ball the size of a marble.

MARKING SCHEME

- ✓ $R = 2GM/c^2$.
- ✓ About 9 mm.

7 Predict, then explain

ANSWER HA · 3

67 gives the older universe: the age is about $1/H_0$, so a smaller H_0 (slower expansion) means longer to reach today's distances. 67 km/s per Mpc $= 2.17 \times 10^{-18}$ s^{-1}: $1/H_0 = 4.6 \times 10^{17}$ s $\approx$ **14.6 billion years**; 73 km/s per Mpc $= 2.36 \times 10^{-18}$ s^{-1}: **13.4 billion years**.

MARKING SCHEME

- ✓ The smaller H_0 (67) gives the older universe, since $T \approx 1/H_0$.
- ✓ 14.6 billion years for 67.
- ✓ 13.4 billion years for 73.

8 Which explanation?

ANSWER HA · 2

Smriti. It is space itself that is stretching, everywhere at once. From any galaxy, all the others are moving away, faster the farther they are, as every dot on an expanding balloon sees. By the cosmological principle the universe looks the same from everywhere: it has no center.

MARKING SCHEME

- ✓ Smriti: space stretches everywhere, so every galaxy sees the others moving away.
- ✓ The universe has no center (the cosmological principle).

9 Correct the misconceptions

ANSWER U · 3

1. Neutrinos **do have mass**, though very little: less than about a millionth of the electron's.
2. A boson has any **whole-number** spin, odd or even: the photon's spin is 1.
3. Dark matter neither gives out nor absorbs light: it has **never been seen**, only detected by its **gravity**, such as on the speeds of stars round galaxies.

MARKING SCHEME

- ✓ Neutrinos have a tiny mass.
- ✓ Bosons have any whole-number spin (the photon has 1).
- ✓ Dark matter is known only from its gravity, never seen.

10 Think

ANSWER HA · 2

Fast electrons fired at protons bounce off as if from three small, hard charges inside, and the charges and baryon numbers of all the hadrons come out right from just six quarks. Pulling two quarks apart takes so much energy that it makes a new quark–antiquark pair, so they always appear bound in hadrons.

MARKING SCHEME

- ✓ Evidence: scattering shows small charges inside protons; quark combinations explain every hadron's charge and baryon number.
- ✓ Separating quarks makes new quark–antiquark pairs, so they are never seen alone.

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11 Make your own

ANSWER HA · 2

For example the baryon **uus**: $\frac{2}{3} + \frac{2}{3} - \frac{1}{3} = +e$, $B = +1$ (the Σ^+). The meson **u** $\bar{\mathbf{s}}$: $\frac{2}{3} + \frac{1}{3} = +e$, $B = 0$ (the K^+). Any three-quark baryon and quark–antiquark meson adding to +e is right.

MARKING SCHEME

- ✓ A baryon of three quarks with charge +e and $B = +1$.
- ✓ A meson of a quark and an antiquark with charge +e and $B = 0$.

Marks by level	Knowledge	Understanding	Application	Higher ability	Total
Marks	0	6	11	12	**29**

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