Unit 25 · Recent Trends in Physics

ANSWER KEY · FOR TEACHERS

Full marks 33

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. epicenter → **c.** the point on the Earth's surface straight above where an earthquake begins
2. aftershock → **d.** a smaller earthquake that follows the main shock
3. Love wave → **g.** a surface wave that shakes the ground from side to side
4. gravitational wave → **f.** a ripple of space-time that travels at the speed of light
5. Higgs field → **b.** the field that gives fundamental particles their mass
6. nanotechnology → **e.** work with matter between 1 and 100 nm

Each carries 0.5 mark. K · 3

2 Label the diagram

1. epicenter
2. fault
3. focus (hypocenter)
4. seismic waves

Each carries 0.5 mark. K · 2

3 Multiple choice

i. **b.** 32 A · 1

$E_1/E_2 = 10^{1.5 \times 1} \approx 32$. (10 times is the height of the waves on a seismograph, not the energy.)

ii. **b.** liquid U · 1

S waves pass only through solids: a liquid can't pass on a shear wave. So the outer core, which stops them, is liquid.

iii. **c.** a tiny change in the lengths of its two arms, seen as light reaching its detector K · 1

A passing wave stretches one 4 km arm and squeezes the other; the two returning beams no longer cancel, and light reaches the detector.

iv. **b.** 800 A · 1

80 000 ÷ 100 = 800.

v. **b.** does not interact with the Higgs field U · 1

A particle gains mass by interacting with the Higgs field; the photon doesn't interact with it at all. (Its speed is a result of having no mass, not the reason.)

4 Short answers

a. MARKING SCHEME U · 2

- ✓ Surface waves have larger swings that last longer, at the surface.
- ✓ Rolling (Rayleigh) and sideways (Love) motion of foundations.

b. MARKING SCHEME U · 2

- ✓ A real wave reaches both within about 10 ms.
- ✓ Local disturbances affect only one, so they can be told apart.

c. MARKING SCHEME U · 2

- ✓ Large surface for its volume.
- ✓ More atoms at the surface, so different properties.

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5 Long answer

ANSWER U · 4

LIGO is a laser interferometer. A laser beam is split in two, and the halves go down two arms 4 km long, at right angles, bounce off mirrors and come back to be recombined. The arms are set so that the two returning waves cancel, and no light reaches the detector. A passing gravitational wave stretches space in one direction and squeezes it at right angles, so one arm gets a little longer as the other gets shorter: the returning waves no longer cancel, and light flickers at the detector. It was hard because the waves are unbelievably weak when they reach us: the first changed each 4 km arm by only a few times 10^{-18} m, a few thousandths of a proton's width.

MARKING SCHEME

- ✓ A beam split into two 4 km arms at right angles and recombined.
- ✓ Set so that the returning beams cancel.
- ✓ A wave lengthens one arm and shortens the other, so light reaches the detector.
- ✓ The changes are tiny, about 10^{-18} m: the waves are very weak.

6 Numerical problems

a. **ANSWER** A · 3

The difference is 2 steps. i. Waves: $10^2 = \mathbf{100\ times}$ as tall for A. ii. Energy: $10^{1.5\times 2} = 10^3 = \mathbf{1000\ times}$ as much for A.

MARKING SCHEME

- ✓ A difference of 2 in magnitude.
- ✓ 100 times the wave height.
- ✓ 1000 times the energy.

b. **ANSWER** A · 3

For a distance d, $\frac{d}{4.0} - \frac{d}{7.0} = 20$, so $d\left(\frac{3}{28}\right) = 20$ and d = **187 km**.

MARKING SCHEME

- ✓ The gap is the difference of the travel times.
- ✓ d/4.0 − d/7.0 = 20.
- ✓ d ≈ 187 km.

c. **ANSWER** A · 4

i. 1 cm ÷ 10 nm = $10^{-2} \div 10^{-8} = 10^6$ along each edge, so $(10^6)^3 = \mathbf{10^{18}\ cubes}$.

ii. $6 \times (1\text{ cm})^2 = \mathbf{6\ cm^2}$.

iii. Each has $6 \times (10^{-8}\text{ m})^2 = 6 \times 10^{-16}\text{ m}^2$; all together $10^{18} \times 6 \times 10^{-16} = \mathbf{600\ m^2}$.

iv. $600\text{ m}^2 \div 6 \times 10^{-4}\text{ m}^2 = \mathbf{10^6\ times}$ (a million).

MARKING SCHEME

- ✓ 10^{18} cubes.
- ✓ 6 cm^2.
- ✓ 600 m^2.
- ✓ A million times.

7 Think

ANSWER HA · 3

The S waves take 150 ÷ 4.0 = **37.5 s** to reach the city, and the radio warning arrives almost at once, so the city has about **37 s** to stop trains, shut gas valves and take cover (the surface waves come later still). A town at the epicenter is shaken within a second or two of the start: the warning can't arrive before the shaking.

MARKING SCHEME

- ✓ S waves take 150/4.0 = 37.5 s.
- ✓ About 37 s of warning (radio is almost instant).
- ✓ Near the epicenter the shaking comes at once, so there is no time.

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8 Activity: Cutting a cube

(not marked)

WHAT STUDENTS SHOULD FIND

The totals are 96, 192 and 384 cm^2, the volume staying 64 cm^3: halving the side doubles the surface. Going down to nanometers, the surface becomes enormous for the same amount of material, which is why nanoparticles react and behave so differently.

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.

- **3D Map of Nepal** (exhibit): Find Gorkha and the Kathmandu Valley on the raised map: in 2015 the Main Himalayan Thrust slipped beneath them, over about 150 km running east.

Marks by level	Knowledge	Understanding	Application	Higher ability	Total
Marks	6	12	12	3	**33**