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Answers

Practice exam questions

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Earthquake magnitudes

1 **a** P-waves (longitudinal): particle oscillations are parallel to the direction of wave propagation.

S-waves (transverse): particle oscillations are perpendicular to the direction of the wave.

b 1851 km

c 4.00 km

d Transverse waves require shear forces to propagate. Liquids cannot support shear stress, so S-waves are absorbed. Longitudinal waves rely on compressions and rarefactions, which liquids can support, so P-waves can pass through.

2 **a i** M = 2.3

ii Logarithmic scale compresses large ranges of amplitude into manageable values, allowing easy comparison across vastly different earthquakes.

b i M = 3.3

ii As the two magnitudes differ by 1.0, this corresponds to 30 times more energy increase.

c Frequency affects how structures resonate, while amplitude determines displacement and energy delivered. The Richter scale focuses on amplitude because it directly relates to energy release and destructive potential.

Detecting gravitational waves

1 **a** Accelerating charges produce electromagnetic radiation. Similarly, accelerating masses disturb spacetime, producing gravitational waves.

b Fractional change:

$$\frac{\Delta L}{L} = \frac{(1.0 \times 10^{-18})}{(4.00 \times 10^{3})}$$

= 2.50×10^{-22}

c Phase difference:

$$\Delta\phi = \frac{2\pi\Delta L}{\lambda} = \frac{2\pi(1.0 \times 10^{-18})}{1.064 \times 10^{-6}} \approx 5.90 \times 10^{-12} rad$$

d Gravitational waves produce displacements far smaller than atomic dimensions. Noise from seismic vibrations, thermal fluctuations and quantum shot noise must be reduced. Methods include isolating mirrors from ground vibrations, using vacuum tubes, and employing multiple detectors for correlation.

2 **a** 1.67×10^{-22}

b 2.03×10^{-12} rad

c Original gravitational force with 0.500 m separation = 1.07×10^{-9} N

New gravitational force with (0.500 m + 2.0×10^{-17} m) separation

= original gravitational force − 8.54×10^{-26} N

Fractional change in force = change/original = -8.00×10^{-17}

(Negative sign indicates the decrease in force as separation increases)

d Note how the gravitational wave strain is 1.67×10^{-22}, while the fractional change in a lab gravitational force under similar tiny displacements is 8.00×10^{-17}.

The implication is that interferometric detection must resolve signals roughly 10^5 times smaller in fractional terms than even minuscule Newtonian force changes. This demands kilometre-scale baselines, ultra-stable lasers, vacuum operation, seismic isolation and advanced noise suppression.

Hydrogen: a potential fuel of the future

1 **a** 3.60 kC

b 32.4 kJ

c 37.3×10^{-3} mol

d 74.6 mg

2 **a** $E = 1.73 \times 10^5$ J

b $E_{chem} = 2.66 \times 10^5$ J

c n = 0.149 mol

d $m = 0.298$g

e Since the electrical power available (96.0 W) is more than the motor power required (80.0 W), the fuel cell provides sufficient power to meet the demand.