Unit 25 · Recent Trends in Physics

STUDY NOTES

WHAT NEB'S GRADE 12 EXAM ASKS

- **CDC's grid (2078):** Modern Physics (Units 20–25 together): 19 of 75 marks
- **The paper:** 11 MCQs × 1 · 8 short × 5 · 3 long × 8; 3 hours; 1 mark per expected point
- **CDC's model paper:** MCQ (1): the point inside the Earth where an earthquake starts: the **hypocenter** (focus), not the epicenter
- **MCQ (1 mark)**
  - fastest seismic wave, first on a seismograph: P
  - through solids, liquids and gases: P
  - Love wave: side to side
  - gravitational waves: Einstein; speed of light
  - Higgs: confirmed at CERN's LHC; its field gives mass
  - nanomaterial: a dimension under 100 nm
- **Short and long (5 or 8 marks, in parts)**
  - seismology; the four seismic waves compared (motion, speed, medium, damage)
  - Gorkha 2015: parameters, effects, why so destructive
  - gravitational waves: what, causes, how LIGO detects them, types
  - Higgs boson: what, why it matters, how found
  - nanotechnology: definition, history, four uses

Key terms

Earthquake: sudden shaking of the ground when stressed rock slips along a fault, letting go stored energy as seismic waves.

Fault: break in the crust where rock on one side can move against the other.

Focus (hypocenter): point inside the Earth where the rock first slips.

Epicenter: point on the surface directly above the focus.

Foreshocks / aftershocks: smaller tremors before / after the main shock.

Magnitude: measure of the energy released at the source (logarithmic).

Seismology: study of earthquakes and seismic waves; a **seismograph** records the shaking.

Seismic waves: elastic waves from an earthquake or explosion.

Gravitational waves: ripples of space-time made by accelerating huge masses, travelling at the speed of light.

Higgs field: field filling the universe; particles that interact with it gain mass; its particle is the **Higgs boson**.

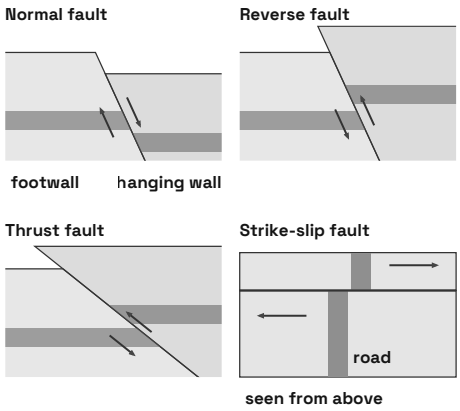
Nanotechnology: science and engineering of matter at 1–100 nm ($1\ \text{nm} = 10^{-9}$ m).

Formulas

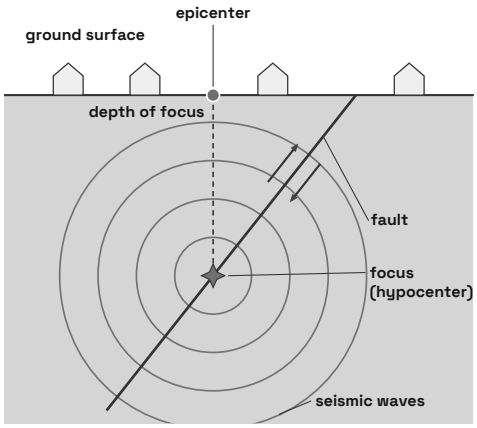
$\frac{E_1}{E_2} = 10^{1.5(M_1 - M_2)}$	one step: ×10 wave height, ×32 energy **Use:** magnitudes
$t = \frac{d}{v}$, $\text{gap} = \frac{d}{v_S} - \frac{d}{v_P}$	P 6–8, S 3–4.5 km/s **Use:** arrival times

Earthquakes

- rocks held by friction; stress builds for years; slip → bent rock springs back → energy out
- faults by how the blocks move: hanging wall above a sloping fault, footwall below



Normal (hanging wall down: crust pulled apart), reverse (hanging wall up: squeezed), thrust (reverse at under 45°: Nepal's), strike-slip (blocks slide sideways).



The focus (hypocenter) inside the Earth where the slip starts; the epicenter on the surface right above it; waves spread out from the focus.

- **natural**: plates moving (India under Eurasia), volcanoes; **artificial**: blasting, mining, filling dams, pumping fluids underground
- **Richter** (1935): from a seismograph's swing; then M_b, M_s; now **moment magnitude** M_w, from the area of fault slipped and how far
- one step up: waves **10×** taller, energy about **32×** ($10^{1.5}$); two steps: 100× taller, about 1000× energy
- under 3 not felt; over 7 severe; largest, Valdivia, Chile 1960, M_w 9.5

Seismic waves

	P	S	Rayleigh	Love
ground	along	across	ellipse	side to side
km/s	6–8	3–4.5	slowest	a bit faster
through	all	solids	surface	surface
arrives	1st	2nd	last	before Rayleigh

- P (**longitudinal**) and S (**transverse**) are **body** waves (through the Earth); Rayleigh and Love **surface** waves; P least damage, surface waves the most
- S waves never cross the **liquid** outer core (no stiffness to shear)
- surface waves: larger, longer swings → the damage
- e.g. 80 km: P 13.3 s, S 22.9 s → S **9.5 s** later; phone warnings use the gap

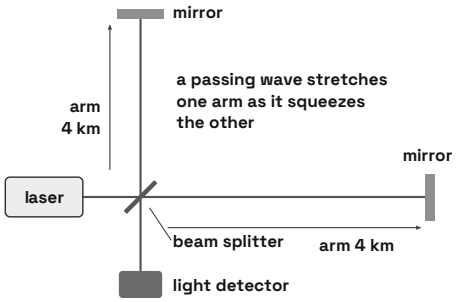
Gorkha earthquake 2015

1. **25 April 2015**, 11:56; M_w **7.8**
2. epicenter **Barpak**, Gorkha (about 80 km NW of Kathmandu)
3. focus about **8 km** deep (shallow; estimates to 15 km)
4. a **thrust** on the **Main Himalayan Thrust**, India sliding under Eurasia
5. rupture about **150 km**, spreading **east** under Kathmandu; shaking 50–60 s

- aftershock **7.3** on 12 May (Dolakha); over 400 of M 4+
- nearly **9,000** dead, about 22,000 injured; homes, schools, health posts destroyed (Gorkha, Sindhupalchowk, Nuwakot, Dhading, Rasuwa …); Everest Base Camp avalanche; Langtang buried; Dharahara and Durbar Square temples fell
- **so destructive**: large and **shallow**, rupture running under the crowded valley for a long time (about 25 s to reach it), weak unreinforced houses; lessons: earthquake-resistant building, safe schools, drills

Gravitational waves

- **Einstein** (1916, general relativity): mass bends space-time; accelerating masses send out ripples at **c**
- first detected **14 September 2015** by **LIGO**: two black holes (about 36 and 29 Suns) merging 1.3 billion light years away; Nobel 2017 (Weiss, Barish, Thorne)



LIGO from above: laser split down two 4 km arms at right angles, mirrors, recombined at the detector; a wave stretches one arm and squeezes the other.

- an **interferometer** (as Michelson's): set so the returning beams **cancel**; a wave changes the arms oppositely → light reaches the detector
- change about 10^{-18} m; two detectors 3000 km apart (Hanford, Livingston): a real wave reaches both within 10 ms
- **causes**: uneven supernovas, neutron-star pairs, black holes merging
- **types**: continuous (lopsided spinning neutron star), burst (supernova), stochastic (random background), compact binary inspiral
- new **gravitational-wave astronomy**: events that give little light

Higgs boson

- **Higgs field** fills the universe; particles that interact with it gain mass (more strongly → heavier); photon not at all → massless; top quark strongly → heavy
- predicted **1964** (Higgs and others); found **2012** at **CERN**'s Large Hadron Collider in proton collisions (ATLAS, CMS)
- hard to find: heavy (125 GeV, 133 protons) and decays in under 10^{-21} s
- completed the **Standard Model**; Nobel 2013 (Higgs, Englert); "God particle" only a nickname
- most of **our** mass is the energy of quarks and gluons inside protons, not the Higgs

Nanotechnology

- 1–100 nm; a hair is 50,000–100,000 nm wide
- new properties: huge **surface** for the volume (better catalysts); **quantum** effects on light (gold nanoparticles red; semiconductor particles glow by size)
- **1959** Feynman, "Plenty of Room at the Bottom"; **1981** scanning tunneling microscope (Binnig, Rohrer); **1985** fullerene C_{60}; then nanotubes, graphene
- **uses**: drugs carried to tumors; rapid tests (gold nanoparticles); chips (transistors tens of nm); solar panels; batteries; water filters; textiles; food packaging; building materials; sunscreens (zinc oxide, titanium dioxide)

COMMON MISTAKES

✗ the epicenter is where the slip starts
✓ the **focus (hypocenter)**; the epicenter is above it.

✗ one magnitude up = 10 times the energy
✓ 10× the wave height, about **32×** the energy.

✗ S waves cross the outer core
✓ solids only: they **don't**.

✗ surface waves arrive first
✓ **P** first, then S, then surface.

✗ gravitational waves are slower than light
✓ travel at **c**.

✗ the Higgs gives us all our mass
✓ only the electrons' and quarks' (about 1% of a proton's).