

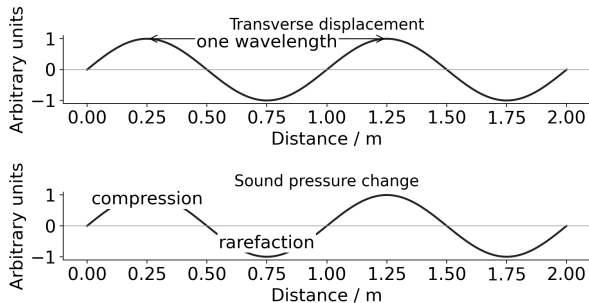
Unit 2: Waves and Electricity

WPH12 · Issue 3 · statements 33–80 · sheets 2.1–2.7

One unit, two forms of energy transfer

- Waves carry energy without transporting matter along the wave.
- Circuits transfer energy through charge flow.
- Use the reference, then skill sheets 2.1–2.7, then authentic sets.

Two graphs, two horizontal axes



- Read the horizontal axis before measuring a peak separation.
- A distance graph gives wavelength; a time graph gives period.

Sound moves energy, not air from source to listener

- Longitudinal: molecules vibrate parallel to propagation.
- Transverse: vibration is perpendicular to propagation.
- Compression means higher pressure and density.

Your turn: count cycles

- 12 cycles take 0.030 s; wave speed is 340 m/s.
- Find frequency, period and wavelength before advancing.

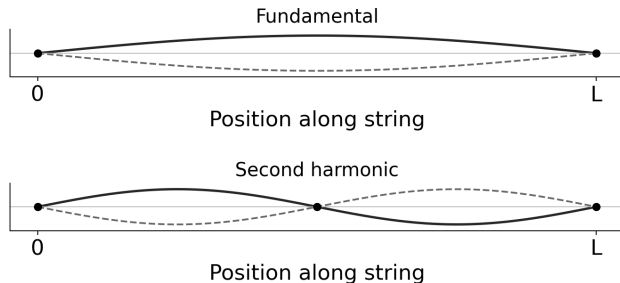
Cycle count to wavelength

- 1 **Frequency** $f = N/t = 12/0.030 = 400 \text{ Hz}$
- 2 **Period** $T = 1/f = 0.0025 \text{ s}$
- 3 **Wavelength** $\lambda = v/f = 340/400 = 0.85 \text{ m}$

Phase is a stage in the cycle

- Coherent sources have constant phase difference and the same frequency.
- Path difference adds phase: $\Delta\phi = 360^\circ \Delta x / \lambda$.
- Include any initial source phase difference.

Standing waves: identify what stays still



- Locate end nodes and internal nodes.
- Compare two opposite snapshots without treating either as a travelling path.

The end conditions choose the wavelength

- Fixed string fundamental: $L = \lambda/2$.
- Closed tube fundamental: $L_{\text{effective}} = \lambda/4$.
- Sound pressure nodes and displacement nodes are different.

Core practical 4: compare two signals

- Reference channel: signal generator; second channel: microphone.
- Consecutive in-phase microphone positions differ by one wavelength.
- Read period using time base, then calculate $v = f\lambda$.

Core practical 5: vary one cause

Vary	Keep fixed	Straight-line plot
Tension T	L, μ, mode	f^2 against T
Length L	T, μ, mode	f against $1/L$
Linear density μ	T, L, mode	f^2 against $1/\mu$

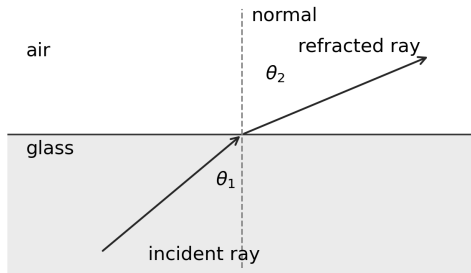
Intensity needs an area conversion

- 1 **Convert** $A = 25 \times 10^{-4} = 0.0025 \text{ m}^2$
- 2 **Incident** $P = IA = 800 \times 0.0025 = 2.0 \text{ W}$
- 3 **Useful** $P_{out} = \eta P = 0.20 \times 2.0 = 0.40 \text{ W}$

Decision

A 0.50 W device cannot run from this useful output.

Refraction: measure from the normal



- Frequency stays constant at the boundary.
- Higher refractive index means lower speed and shorter wavelength.

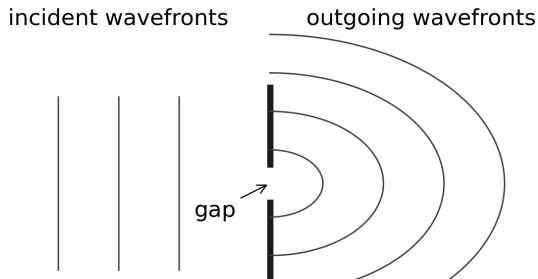
Total internal reflection needs both conditions

- Travel from higher index to lower index.
- Incidence must exceed C , where $\sin C = n_2/n_1$.
- At C , the refracted ray runs along the boundary.

Measure index; test polarisation

- Ray box: reconstruct internal ray and plot $\sin i$ against $\sin r$.
- Polarisers: rotate the second; minimum at perpendicular transmission directions.
- Longitudinal waves cannot be plane polarised.

Huygens: build the next wavefront



- Points at the opening supply secondary wavelets.
- Their forward envelope gives the next wavefront.
- A gap comparable to wavelength produces strong spreading.

Grating method: spacing before angle

- Normal incidence: $k\lambda = d\sin\theta$.
- 600 lines/mm gives $d = 1.67 \times 10^{-6}$ m.
- Screen geometry: $\tan\theta = x/D$, not exactly $\sin\theta = x/D$.

Electrons: evidence and calculation are different

- Diffraction supports wave behaviour.
- $\lambda = h/p$: increasing momentum decreases wavelength.
- Use $p = mv$ only in the non-relativistic model.

Echoes: separate distance and resolution

- Delay includes outward and return travel: $s = vt/2$.
- Shorter pulses separate closer echo arrival times.
- Shorter wavelengths help distinguish smaller features.

Why light needs two descriptions

- Interference and diffraction support wave models.
- Photons describe discrete energy transfer: $E = hf$.
- New models must explain old successful evidence too.

Photoelectric effect: follow one photon

- Work function is the minimum energy needed to escape.
- $hf = \phi + E_{k,max}$; below threshold there is no ordinary single-photon emission.
- Maximum energy is not the energy of every emitted electron.

Frequency and intensity change different things

Change	Photon energy	Maximum electron energy
Intensity rises; frequency fixed	Unchanged	Unchanged
Frequency rises	Increases	Increases above threshold

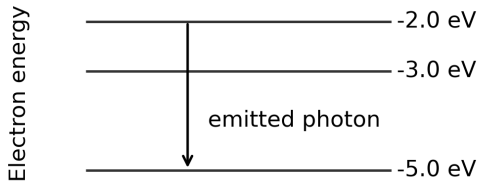
Your turn: convert before subtracting

- $f = 8.0 \times 10^{14} \text{ Hz}$; $\phi = 2.0 \text{ eV}$.
- Use $h = 6.63 \times 10^{-34} \text{ J s}$ and $e = 1.60 \times 10^{-19} \text{ C}$.
- Find maximum kinetic energy and stopping potential.

Photoelectron energy to stopping potential

- 1 **Convert** $\phi = 2.0 \times 1.60 \times 10^{-19} = 3.20 \times 10^{-19} \text{ J}$
- 2 **Subtract** $E_{k,max} = hf - \phi = 2.10 \times 10^{-19} \text{ J}$
- 3 **Stop** $V_s = E_{k,max}/e = 1.3 \text{ V}$

Atomic transitions produce particular frequencies



- Photon energy equals the level difference.
- Largest downward gap gives shortest wavelength.
- Absorption and re-emission need not eject a surface electron.

Define current, voltage and resistance separately

- $I = \Delta Q / \Delta t$: charge flow per second.
- $V = W / Q$: energy transfer per coulomb.
- $R = V / I$ defines resistance; Ohm's law adds constant physical conditions.

Conservation builds the circuit rules

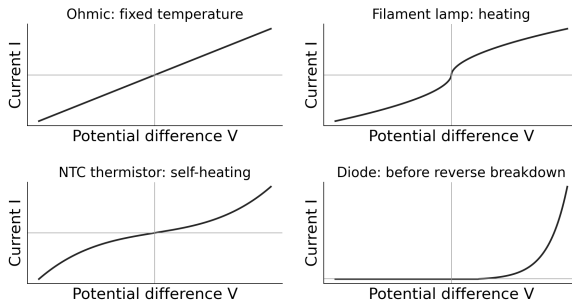
- Series: current is shared; voltage drops add.
- Parallel: voltage is shared; branch currents add.
- Current is not used up by a component.

$$R_s = R_1 + R_2 \qquad \frac{1}{R_p} = \frac{1}{R_1} + \frac{1}{R_2}$$

Reduce the circuit; then restore each branch

- 1 **Combine** $R_p = (1/6 + 1/3)^{-1} = 2 \Omega$
- 2 **Total** $I = 12/(4 + 2) = 2 \text{ A}$
- 3 **Branch voltage** $V_p = IR_p = 4 \text{ V}$
- 4 **Branch currents** $I_6 = 4/6 = 0.67 \text{ A}$; $I_3 = 4/3 = 1.33 \text{ A}$

Component curves: state the temperature condition



- Read current vertically and voltage horizontally.
- For a curved graph, V/I uses the origin-to-point line.

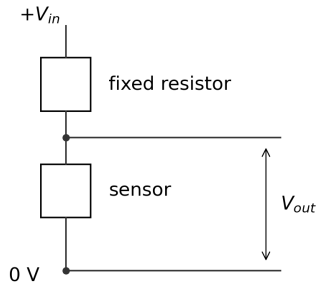
Core practical 7: measure material resistivity

- Measure wire diameter repeatedly; $A = \pi d^2/4$.
- Plot resistance against contact separation.
- Use $\rho = A \times \text{gradient}$ and limit heating.

Drift speed is a small directed average

- $I = nqvA$ counts mobile carriers crossing an area.
- Series wires carry the same current.
- Different carrier density or area requires a different drift speed.

Uniform wire to potential divider



- Uniform current-carrying wire: voltage drop is proportional to distance.
- An unloaded divider shares voltage in proportion to resistance.
- A significant load changes the output branch resistance.

A sensor explanation must reach the named output

- Heating an NTC thermistor increases carrier density and lowers resistance.
- Illumination increases LDR carrier density and lowers resistance.
- Heating a metal increases lattice scattering and raises resistance.

E.m.f. supplies energy; internal resistance uses some

- $\mathcal{E} = V + Ir$: supply equals external plus internal energy per coulomb.
- $I = \mathcal{E}/(R + r)$ includes internal resistance.
- Source power splits into external power and internal heating.

Core practical 8: intercept and negative gradient

1 **Model** $V = \mathcal{E} - Ir$

2 **Gradient** $r = -\Delta V / \Delta I = -(1.20 - 1.40) / (0.60 - 0.20) = 0.50 \, \Omega$

3 **Intercept** $\mathcal{E} = V + Ir = 1.40 + 0.20 \times 0.50 = 1.50 \, \text{V}$

Check yourself

- Explain why a standing-wave node stays still.
- Distinguish increasing photon frequency from increasing intensity.
- Explain why a loaded divider needs a parallel combination.