S5 Physics Practice Paper 3 | Refraction, lenses, standing waves, sound intensity, photoelectric effect and atomic energy levels

Senior Secondary Physics

S5 Physics practice paper 3: refraction, lenses, standing waves, sound intensity, Doppler effect, photoelectric effect and atomic energy levels, with full solutions.

1. Refraction and total internal reflection (18 marks)

Give answers to 3 significant figures and state the formula used.

#	Question	Answer and marking notes
1	(a) Light travels from water (n = 1.33) into air. Find the critical angle.	sin c = 1 / n = 1 / 1.33 = 0.7519, so c = 48.8 degrees.
2	(b) Light in air strikes the water surface at an angle of incidence of 40.0 degrees. Find the angle of refraction.	n1 sin θ1 = n2 sin θ2, so sin θ2 = sin 40.0 / 1.33 = 0.4833 and θ2 = 28.9 degrees.
3	(c) Explain why a diver under water sees everything above the surface within a cone of about 97 degrees.	Light from the air enters water with angles of incidence up to 90 degrees, so by n1 sin θ1 = n2 sin θ2 the refracted angle cannot exceed the critical angle of 48.8 degrees. The whole 180 degree sky is therefore compressed into a cone of 2 x 48.8 = about 97 degrees; outside that cone total internal reflection shows only the water below.
4	(d) An optical fibre has a core of refractive index 1.50 and a cladding of 1.48. Find the critical angle at the core-cladding boundary.	sin c = n2 / n1 = 1.48 / 1.50 = 0.9867, so c = 80.6 degrees. Light striking the boundary above this angle is totally internally reflected and stays in the core.

2. Lens images and magnification (16 marks)

Use 1/f = 1/u + 1/v and m = -v/u; virtual images have negative v.

#	Question	Answer and marking notes
5	(a) A convex lens of focal length 10.0 cm has an object 30.0 cm away. Find the image distance and magnification, and describe the image.	1/v = 1/f - 1/u = 1/10 - 1/30, so v = 15.0 cm and m = -v/u = -0.50. The image is real, inverted and diminished, on the far side of the lens.
6	(b) The same convex lens now has the object 5.0 cm away. Find the image distance and magnification, and describe the image.	1/v = 1/10 - 1/5 gives v = -10.0 cm (negative, so a virtual image on the same side as the object) and m = -v/u = 2.00. The image is virtual, upright and magnified, as in a magnifying glass.
7	(c) A concave lens has focal length 15.0 cm (f = -15.0 cm) and the object is 30.0 cm away. Find the image distance and magnification.	1/v = 1/f - 1/u = -1/15 - 1/30 gives v = -10.0 cm and m = -v/u = 0.333. A concave lens always forms a virtual, upright, diminished image.

#	Question	Answer and marking notes
8	(d) A convex lens of focal length 5.0 cm is used as a magnifying glass with a near point of 25 cm. Find the maximum angular magnification.	M = D / f + 1 = 25 / 5 + 1 = 6.0, the maximum value, obtained when the image is at the near point of 25 cm.

3. Standing waves and resonance (16 marks)

The string is fixed at both ends; the closed pipe is open at one end. Take the speed of sound in air as 340 m/s.

#	Question	Answer and marking notes
9	(a) A string 0.80 m long is fixed at both ends. The wave speed is 320 m/s. Find the fundamental frequency and wavelength.	For the fundamental mode λ = 2L = 2 x 0.80 = 1.60 m, so f1 = v / λ = 320 / 1.60 = 200 Hz.
10	(b) Find the frequency of the third harmonic of this string and the number of nodes.	f3 = 3 f1 = 3 x 200 = 600 Hz. The wavelength is 2L/3, giving 4 nodes (including both ends) and 3 antinodes.
11	(c) A closed pipe 0.50 m long (closed at one end) sounds its fundamental. Find the frequency.	For a closed pipe the fundamental has λ = 4L = 4 x 0.50 = 2.00 m, so f = 340 / 2.00 = 170 Hz.
12	(d) Two tuning forks of 440 Hz and 444 Hz sound together. Find the beat frequency.	Beat frequency = |f1 - f2| = 444 - 440 = 4 Hz, so the loudness rises and falls 4 times each second.

4. Sound intensity, decibels and the Doppler effect (18 marks)

Sound intensity level L = 10 log(I / I0) with I0 = 1.0 x 10^-12 W m^-2; take the speed of sound as 340 m/s.

#	Question	Answer and marking notes
13	(a) The sound intensity at a point is 1.0 x 10^-4 W m^-2. Find the sound intensity level.	L = 10 log(1.0 x 10^-4 / 1.0 x 10^-12) = 10 log 10^8 = 80.0 dB.
14	(b) If the distance from a point source is doubled (no absorption), find the new sound intensity level.	Intensity falls as 1/r^2, so doubling the distance leaves one quarter of the intensity; L drops by 10 log 4 = 6.0 dB to 74.0 dB.
15	(c) An ambulance travelling at 34 m/s towards a stationary observer sounds a 500 Hz siren. Find the observed frequency (v = 340 m/s).	f’ = f v / (v - vs) = 500 x 340 / (340 - 34) = 555.6 Hz, higher than the emitted frequency.
16	(d) After passing, the ambulance moves away at the same speed. Find the observed frequency and explain what the observer hears.	f’ = 500 x 340 / (340 + 34) = 454.5 Hz. The frequency falls from 555.6 Hz to 454.5 Hz, so the pitch drops suddenly by about 101.0 Hz.

5. The photoelectric effect (16 marks)

Use E = hc/λ with hc = 1240 eV nm; the work function is W = 2.30 eV.

#	Question	Answer and marking notes
17	(a) Light of wavelength 400 nm falls on the metal. Find the photon energy and the maximum kinetic energy of the emitted electrons.	E = 1240 / 400 = 3.10 eV, so KEmax = E - W = 3.10 - 2.30 = 0.80 eV.
18	(b) The wavelength is reduced to 300 nm. Find the maximum kinetic energy and the stopping voltage.	E = 1240 / 300 = 4.13 eV, so KEmax = 4.13 - 2.30 = 1.83 eV and the stopping voltage is V0 = KEmax / e = 1.83 V.
19	(c) If the intensity is increased at the same wavelength, does the stopping voltage change? Explain.	No. A higher intensity means more photons per second, so the photocurrent rises, but each photon still carries the same energy; the maximum kinetic energy and the stopping voltage are unchanged.
20	(d) Find the threshold wavelength of the metal.	λ0 = hc / W = 1240 / 2.30 = 539 nm; light of longer wavelength emits no electrons whatever the intensity.

6. Hydrogen energy levels and spectra (16 marks)

Hydrogen levels are En = -13.6/n^2 eV; hc = 1240 eV nm.

#	Question	Answer and marking notes
21	(a) Find the energy and wavelength of the photon emitted when an electron falls from n = 2 to n = 1.	ΔE = 13.6(1/1^2 - 1/2^2) = 10.20 eV, so λ = 1240 / 10.20 = 121.6 nm, in the ultraviolet.
22	(b) What is the ionisation energy of a hydrogen atom? Give a reason.	The ionisation energy is 13.6 eV, the energy needed to move the electron from the ground state (E = -13.6 eV) to n = infinity (E = 0).
23	(c) Explain why the hydrogen emission spectrum consists of discrete lines rather than a continuum.	Atomic energy levels are discrete, so an electron can only jump between particular levels. Each jump emits a photon of one fixed energy, giving lines at the wavelengths that match the level differences.
24	(d) Find the wavelength of the line from n = 3 to n = 2 and name its series.	ΔE = 13.6(1/4 - 1/9) = 1.889 eV, so λ = 1240 / 1.889 = 656 nm, the red line of the Balmer series.