

Chapter 7: Engineering Physics

Technical & Professional Knowledge for NICL AO (Scale I) 2026, Risk Engineer: Phase II (Main) exam (working title)

Contents

Chapter opener.....	2
7.1 Measurement and the SI defining constants.....	5
7.2 Oscillations and waves.....	10
7.3 Sound.....	16
7.4 Electromagnetic waves and the spectrum.....	20
7.5 Reflection and mirrors.....	23
7.6 Refraction, lenses, prisms and dispersion.....	28
7.7 Temperature, thermometers and thermal expansion.....	35
7.8 Kinetic theory of gases.....	40
7.9 Blackbody radiation, photons and the photoelectric effect.....	43
7.10 Atomic structure, spectra and X-rays.....	48
7.11 Lasers and optical fibres.....	53
7.12 Radioactivity and nuclear energy.....	57
7.13 Energy bands in solids.....	62
7.14 Ultrasonics, acoustics and non-destructive testing.....	65
Revision kit.....	70
Practice set: 100 questions.....	78
Answer key.....	96

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Chapter opener

What this chapter covers

Fourteen units run from measurement, waves and sound through light, heat and kinetic theory to photons, atoms, lasers, nuclei, energy bands and non-destructive testing (topic map below). Each unit has a **core** part and, where useful, an **Optional recall** box; the 100 practice questions test only the core.

Why physics basics matter to a risk engineer. Cracks found by ultrasound, hot spots seen by thermal cameras, radioactive sources in gauges and machines shaken by resonance all rest on this physics.

Learning objectives

After this chapter, you should be able to:

1. Explain the 2019 SI defining constants, accuracy, precision and kinds of error.
2. Describe simple harmonic motion, resonance, waves and sound, including the Doppler effect.
3. Order the electromagnetic spectrum, with its uses and hazards.
4. Apply reflection, refraction and the mirror and lens equations (New Cartesian).
5. Convert temperatures, choose a thermometer, and explain expansion and kinetic theory.
6. Explain blackbody spectra, photons, and photoemission against the photovoltaic effect.
7. Explain energy levels, line spectra, X-rays, lasers and optical fibres.
8. Explain radioactive decay, binding energy, fission, fusion and band theory.
9. Explain pulse-echo testing, choose an NDT method, and relate absorption to reverberation.

Topic map

Unit	Practice questions
7.1 Measurement and the SI defining constants	Q1–Q5, Q91
7.2 Oscillations and waves	Q6–Q11, Q92
7.3 Sound	Q12–Q17, Q93
7.4 Electromagnetic waves and the spectrum	Q18–Q23
7.5 Reflection and mirrors	Q24–Q28
7.6 Refraction, lenses, prisms and dispersion	Q29–Q37, Q94
7.7 Temperature, thermometers and thermal expansion	Q38–Q44, Q96, Q97
7.8 Kinetic theory of gases	Q45–Q49
7.9 Blackbody radiation, photons and the photoelectric effect	Q50–Q57, Q98
7.10 Atomic structure, spectra and X-rays	Q58–Q63, Q95

Unit	Practice questions
7.11 Lasers and optical fibres	Q64–Q70
7.12 Radioactivity and nuclear energy	Q71–Q79, Q99
7.13 Energy bands in solids	Q80–Q84
7.14 Ultrasonics, acoustics and non-destructive testing	Q85–Q90, Q100

Exam context

- **The section:** 50 questions, 50 marks, 35 minutes: an *average* of 42 seconds a question.
- **Marking:** +1 correct, –0.25 wrong, 0 blank.
- **No calculators:** every calculation here is chosen to be done in the head or with short working on paper (such as $1240/2.55$ in Example 7.23). The inverse-sine angles at the end of Examples 7.13 and 7.25 are supplied as values to read, not to work out.

Source: the NICL recruitment notice dated 07/10/2026, as transcribed for this book. These 100 questions are a learning set, not an NICL paper.

Should you guess?

If p is your honest chance of being right, the expected mark from answering is

$$\text{Expected mark} = p - 0.25(1 - p) = 1.25p - 0.25$$

The break-even point is $p = 20\%$, a blind pick among five options. If the options you rule out really are wrong, one option out gives +0.063 per guess, two out +0.167, three out +0.375. Ruling out the right answer by mistake reverses the gain.

Constants used. Exact values of the SI defining constants fixed in 2019 and CODATA 2022 values of the measured constants, checked on 15 October 2026 against the SI Brochure (9th edition) and NIST.

How to use this chapter

Study a unit, try its questions, check the key; use the revision kit before attempting all 100.

Conventions used in this chapter

- **Units:** SI throughout; $g = 9.81 \text{ m/s}^2$ in the theory, and no numerical uses g . Absolute temperatures in kelvin; differences and everyday readings in degrees Celsius.
- **Mirrors and lenses:** the New Cartesian convention, as NCERT uses. Distances are measured from the pole or optical centre; light travels left to right, and distances in that direction are positive. Mirror: $1/v + 1/u = 1/f$, $m = -v/u$. Thin lens: $1/v - 1/u = 1/f$, $m = v/u$ (Table 7.9).
- **Symbols that differ from earlier chapters.** f is a frequency, but a focal length in 7.5–7.6. T is a period (7.2), an absolute temperature (7.7–7.9), a half-life as $T_{1/2}$ and a reverberation time as T_{60} . c , h , k_B , e and N_A are the speed of light and the Planck, Boltzmann, elementary-charge and Avogadro constants (in Chapter 5, c was a specific heat and h an enthalpy). R is the molar

gas constant, not Chapter 5's specific R; "rms" in 7.8 is a molecular speed, not Chapter 4's alternating-current value.

- **Abbreviations:** SI International System of Units; EM electromagnetic; TIR total internal reflection; LED light-emitting diode; NA numerical aperture; rms root mean square; eV electronvolt; u unified atomic mass unit; Bq becquerel; dB decibel; MSD and VSD main-scale and vernier-scale divisions; PZT lead zirconate titanate; NDT non-destructive testing; UT, RT, PT, MT and ET ultrasonic, radiographic, penetrant, magnetic particle and eddy-current testing; CODATA Committee on Data of the International Science Council.

7.1 Measurement and the SI defining constants

In a nutshell. Since 2019 every SI unit rests on seven constants with exact values. Measurements still carry errors: systematic errors shift every reading, random errors scatter them, and an instrument's least count limits what it can resolve.

7.1.1 The 2019 SI and its seven defining constants

For more than a century the kilogram was the mass of one metal cylinder kept near Paris, so any change in that cylinder changed the kilogram itself.

Since 20 May 2019 the SI has defined all its units by fixing exact numerical values of seven defining constants, among them the speed of light c and the Planck constant h (Table 7.1). Each base unit follows from one or more of them: the caesium frequency fixes the second; with the second, c fixes the metre and e the ampere.

The kilogram is defined by fixing the numerical value of the Planck constant h , together with the definitions of the metre and the second; it no longer depends on the international prototype of the kilogram. Because h is in $\text{J s} = \text{kg m}^2 \text{s}^{-1}$, fixing its number fixes the kilogram.

Defining constant	Exact value	Unit it fixes (with the other constants)
$\Delta\nu_{\text{Cs}}$, the unperturbed ground-state hyperfine transition frequency of the caesium-133 atom	9 192 631 770 Hz	second
c , the speed of light in vacuum	299 792 458 m/s	metre (with the second)
h , the Planck constant	$6.626\,070\,15 \times 10^{-34} \text{ J s}$	kilogram (with the metre and second)
e , the elementary charge	$1.602\,176\,634 \times 10^{-19} \text{ C}$	ampere (with the second)
k_{B} , the Boltzmann constant	$1.380\,649 \times 10^{-23} \text{ J/K}$	kelvin (with the kilogram, metre and second)
N_{A} , the Avogadro constant	$6.022\,140\,76 \times 10^{23} \text{ mol}^{-1}$	mole
K_{cd} , the luminous efficacy of monochromatic radiation of frequency $540 \times 10^{12} \text{ Hz}$	683 lm/W	candela (with h , c and $\Delta\nu_{\text{Cs}}$)

Table 7.1. The seven defining constants and the units they fix.

Exact and measured constants. A defining constant has an exact value with no measurement uncertainty, because the units are chosen to make it so. Other constants, such as the gravitational constant G , remain measured values with uncertainty.

7.1.2 Accuracy, precision and errors

Picture darts thrown at a target (Figure 7.1).