General Certificate of Education (Advanced Level) – Grade 12

UNIT TEST – MARKING SCHEME

Physics I – Measurement

competency levels 1.1 – 1.5 · 121 questions · 179 marks

Notes for marking

- Multiple-choice questions carry **1 mark** each (01). The key reason is given so the marker can explain the answer.
- Structured questions follow the Physics Paper II scheme: **(01)** for each marking point shown at the right. Part totals and a boxed question total are given.
- Give the answer mark only for the correct value **with the correct unit**. Accept answers within the rounding stated.
- Any equivalent correct physical method earns full marks. A correct final answer with no supporting working earns only the answer mark.
- For sketches and diagrams, marks are for correct shape, correct labels and correct key values.
- Where marks depend on an earlier wrong value, allow follow-through for the method mark only.

SECTION A – Physics and the scientific method

Syllabus 1.1

Q	Ans	Key reason	Mk
A1	**(4)**	Observe, propose a testable hypothesis, test it by experiment, then conclude.	**(01)**
A2	**(1)**	This is the NIE description of physics (1.1).	**(01)**
A3	**(3)**	Ultrasound imaging uses sound waves – a physics application.	**(01)**

A4. *[4 marks]*

(a) Name the independent variable.

Length of the string **(01)**

(b) Name the dependent variable.

Time for one oscillation (period) **(01)**

(c) Name two variables that must be kept constant.

Any two: mass of the bob, amplitude (angle), place/value of g **(01)**

(d) Why should a conclusion be based on several measurements rather than one?

Advances in physics rest on repeated observations; repeating reduces random error and makes the inference reliable **(01)**

Total 04

SECTION B – Physical quantities and SI units

Syllabus 1.2

Q	Ans	Key reason	Mk
B1	**(3)**	Candela (cd) is the base unit.	**(01)**
B2	**(5)**	Plane angle (rad) and solid angle (sr).	**(01)**
B3	**(3)**	Density = mass/volume, derived.	**(01)**
B4	**(5)**	Refractive index is a ratio of speeds. (Plane angle has the unit rad.)	**(01)**
B5	**(2)**	1000 W × 3600 s = 3.6×10^6 J.	**(01)**
B6	**(2)**	Units multiplied are separated by a space; 'ms' would mean millisecond.	**(01)**

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B7	**(5)**	1 g cm^{-3} = 10^{-3} kg / 10^{-6} m^3 = 10^3 kg m^{-3}.	**(01)**
B8	**(4)**	250 × 10^{-6} = 2.5 × 10^{-4} A.	**(01)**
B9	**(2)**	J = N m = kg m s^{-2} × m.	**(01)**
B11	**(1)**	N s / kg = kg m s^{-1}/kg = m s^{-1}.	**(01)**
B12	**(4)**	(A) false – e.g. refractive index has no unit.	**(01)**
B13	**(4)**	Both in N s (kg m s^{-1}).	**(01)**

B10. *[4 marks]*

(a) 108 km h^{-1} to m s^{-1}

108 × 1000/3600 = 30 m s^{-1} **(01)**

(b) 13.6 g cm^{-3} to kg m^{-3}

13.6 × 10^3 = 1.36 × 10^4 kg m^{-3} **(01)**

(c) 5 mm^2 to m^2

5 × (10^{-3})^2 = 5 × 10^{-6} m^2 **(01)**

(d) 2 litres (2 dm^3) to m^3

2 × (10^{-1})^3 = 2 × 10^{-3} m^3 **(01)**

Total 04

B14. *[3 marks]*

(a) Rearrange the equation to make G the subject.

G = F r^2 / (m$_1$ m$_2$) **(01)**

(b) Hence find the SI unit of G in terms of the newton, and then in SI base units.

N m^2 kg^{-2} **(01)**

= kg m s^{-2} m^2 kg^{-2} = kg^{-1} m^3 s^{-2} **(01)**

Total 03

SECTION C – Significant figures and scientific notation

Syllabus 1.2

Q	Ans	Key reason	Mk
C1	**(4)**	2, 0, 5, 0 – the trailing zero after a decimal point is significant.	**(01)**
C2	**(4)**	a × 10^n with 1 ≤ a < 10.	**(01)**
C3	**(2)**	Leading zeros are not significant: 4, 7, 0 → 3.	**(01)**
C4	**(4)**	Next digit 5 → round up.	**(01)**
C5	**(5)**	Product is limited by 2.5 (2 s.f.) → 8.6 cm^2.	**(01)**
C6	**(1)**	Sum is limited by the fewest decimal places (one).	**(01)**

C7. *[3 marks]*

(a) Explain why the student should write 2.10 cm and not 2.1 cm.

The final zero shows the reading is to 0.01 cm (least count of the vernier) – it is a significant figure **(01)**

(b) Calculate the volume of the cube to the correct number of significant figures.

V = 2.10^3 = 9.261 cm^3 **(01)**

= 9.26 cm^3 (3 s.f.) **(01)**

Total 03

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SECTION D – Dimensions

Syllabus 1.3

Q	Ans	Key reason	Mk
D1	**(1)**	$m\ s^{-1} \rightarrow LT^{-1}$.	**(01)**
D2	**(4)**	$F = ma \rightarrow MLT^{-2}$.	**(01)**
D3	**(1)**	$\mu = F/R$ is a ratio of forces.	**(01)**
D4	**(5)**	$F/A = MLT^{-2}/L^2$.	**(01)**
D5	**(1)**	Work/time $= ML^2T^{-2}/T$.	**(01)**
D6	**(5)**	Both F × distance $\rightarrow ML^2T^{-2}$. (Note: they are still different quantities.)	**(01)**
D8	**(1)**	ωt must be dimensionless (an angle) $\rightarrow \omega$ in s^{-1} (rad s^{-1}).	**(01)**
D9	**(3)**	ct^2 has the dimensions of P $\rightarrow c = ML^{-1}T^{-2}/T^2$.	**(01)**
D10	**(1)**	$k = F/v = kg\ m\ s^{-2}/(m\ s^{-1}) = kg\ s^{-1}$.	**(01)**
D13	**(2)**	(C) false.	**(01)**
D14	**(1)**	$F = ma = m\ V/T \rightarrow m = F\ T\ V^{-1}$.	**(01)**

D7. *[3 marks]*

(a) Show that the equation $v^2 = u^2 + 2as$ is dimensionally correct.

LHS: $(LT^{-1})^2 = L^2T^{-2}$; u^2: L^2T^{-2} **(01)**

2as: $(LT^{-2})(L) = L^2T^{-2} \rightarrow$ all terms the same **(01)**

(b) Explain why a dimensionally correct equation may still be wrong.

Dimensionless constants (e.g. ½, 2) cannot be checked **(01)**

Total 03

D11. *[4 marks]*

(a) Write the dimensional equation.

$T = M^x L^y (LT^{-2})^z$ **(01)**

(b) Equate the powers of M, L and T.

M: $x = 0$; L: $y + z = 0$ **(01)**

T: $-2z = 1$ **(01)**

(c) Hence obtain the expression for T.

$z = -½$, $y = ½$, $x = 0 \rightarrow T = k\sqrt{(l/g)}$ **(01)**

Total 04

D12. *[4 marks]*

$f = k\ l^x\ T^y\ \mu^z$; $T^{-1} = L^x (MLT^{-2})^y (ML^{-1})^z$ **(01)**

M: $y + z = 0$; L: $x + y - z = 0$; T: $-2y = -1$ **(01)**

$y = ½$, $z = -½$ **(01)**

$x = -1 \rightarrow f = (k/l)\sqrt{(T/\mu)}$ **(01)**

Total 04

SECTION E – Errors in measurement

Syllabus 1.4

Q	Ans	Key reason	Mk

E1	**(1)**	It shifts every reading by the same amount.	**(01)**
E2	**(4)**	View straight on.	**(01)**
E3	**(3)**	0.1 cm/20.0 cm × 100 = 0.5 %.	**(01)**
E4	**(1)**	0.01/2.50 = 0.004.	**(01)**
E5	**(2)**	Averaging reduces random scatter.	**(01)**
E6	**(5)**	Percentages: 0.83, 0.67, 0.40, 0.20, 0.33 % → 50.0 cm is best. A long length with a coarse instrument can beat a short one with a fine instrument.	**(01)**
E8	**(5)**	All true.	**(01)**
E10	**(5)**	Close together (precise) but all about 0.12 cm high – a systematic error, so not accurate.	**(01)**

E7. *[4 marks]*

(a) Find the period.

T = 32.4/20 = 1.62 s **(01)**

(b) Find the percentage error in the measured time.

0.2/32.4 × 100 = 0.62 % **(01)**

(c) What would the percentage error be if only one oscillation (1.6 s) were timed?

0.2/1.6 × 100 = 12.5 % **(01)**

(d) Hence explain why many oscillations are timed.

The same absolute error is spread over a larger reading → smaller percentage error **(01)**

Total 04

E9. *[4 marks]*

(a) Find the mean observed reading.

(4.52 + 4.53 + 4.51 + 4.52)/4 = 4.52 cm **(01)**

(b) Find the corrected diameter.

4.52 − (−0.03) = 4.55 cm **(01)**

(c) Which type of error was reduced by (a) and which was removed by (b)?

(a) random error **(01)**

(b) systematic (zero) error **(01)**

Total 04

SECTION F – Metre ruler and choosing the right instrument

Syllabus 1.4

Q	Ans	Key reason	Mk
F1	**(4)**	Smallest division is 1 mm.	**(01)**
F2	**(3)**	Small length, needs 0.01 mm.	**(01)**
F3	**(5)**	Worn end → end error.	**(01)**
F5	**(5)**	4.8 cm/500 = 0.0096 cm = 0.096 mm; error 0.1/4.8 = 2.1 % (same % for one sheet).	**(01)**

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F4. *[6 marks]*

(a) The thickness of a sheet of glass about 2 mm thick

Micrometer screw gauge **(01)**

(b) The depth of a hollow cylinder about 4 cm deep

Vernier caliper (depth bar) **(01)**

(c) The radius of curvature of a watch glass

Spherometer **(01)**

(d) The internal diameter of a capillary tube

Travelling microscope **(01)**

(e) The mass of a 0.250 g piece of foil

Scientific electronic balance **(01)**

(f) The period of a simple pendulum

Stopwatch (digital) – timing many oscillations **(01)**

Total 06

SECTION G – Vernier caliper

Syllabus 1.4

Q	Ans	Key reason	Mk
G1	**(1)**	Vernier principle: LC = 1 MSD − 1 VSD.	**(01)**
G2	**(1)**	—	**(01)**
G3	**(2)**	—	**(01)**
G4	**(3)**	1 − 0.9 = 0.1 mm.	**(01)**
G5	**(2)**	1 − 19/20 = 0.05 mm.	**(01)**
G6	**(2)**	1/50 = 0.02 mm.	**(01)**
G7	**(3)**	Vernier zero after 23 mm; 7th division coincides → 23 + 0.7 = 23.7 mm.	**(01)**
G8	**(3)**	41 mm + 7 × 0.05 = 41.35 mm.	**(01)**
G9	**(4)**	Vernier zero to the right of main zero; 3rd division coincides → +0.3 mm.	**(01)**
G10	**(2)**	Corrected = 3.56 − 0.04 = 3.52 cm.	**(01)**
G11	**(2)**	Negative error = −(10 − 6) × 0.1 = −0.4 mm.	**(01)**
G12	**(4)**	25.3 − (−0.4) = 25.7 mm.	**(01)**
G13	**(1)**	0.5/50 = 0.01 mm.	**(01)**
G15	**(5)**	0.1/0.30 × 100 ≈ 33 % – far too large; use a micrometer.	**(01)**
G16	**(2)**	1 VSD = 1.95 mm; LC = 2 MSD − 1 VSD = 0.05 mm.	**(01)**
G17	**(3)**	LC = 0.5/n = 0.02 → n = 25.	**(01)**
G19	**(3)**	Corrected D − d = (22.0 − 0.2) − (18.4 − 0.2) = 3.6 mm → thickness 1.8 mm. The zero errors cancel.	**(01)**
G20	**(2)**	True side = 2.00 + 0.02 = 2.02 cm; ρ = 21.6/2.02³ = 2.62 g cm⁻³ (2.70 is the uncorrected trap).	**(01)**

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G14. *[4 marks]*

(a) Name the part of the vernier used for each of D, d and h.

D – outer jaws; d – inner jaws; h – depth bar (all three) **(01)**

(b) Find the thickness of the wall.

(3.84 − 3.22)/2 = 0.31 cm **(01)**

(c) Find the volume of water the cylinder can hold.

$V = \pi d^2 h /4 = 3.14 \times 3.22^2 \times 4.50/4$ **(01)**

$= 36.6\ cm^3$ **(01)**

Total 04

G18. *[5 marks]*

(a) How many vernier divisions are needed, and what total length of the main scale should they cover?

n = 1/0.05 = 20 divisions **(01)**

covering 19 mm **(01)**

(b) A reading has the vernier zero between 54 mm and 55 mm and the 13th vernier division coinciding. Find the observed reading.

54 + 13 × 0.05 = 54.65 mm **(01)**

(c) With jaws closed the vernier zero is to the left of the main zero and the 18th division coincides. Find the zero error.

−(20 − 18) × 0.05 = −0.10 mm **(01)**

(d) Find the corrected reading of (b).

54.65 − (−0.10) = 54.75 mm **(01)**

Total 05

SECTION H – Micrometer screw gauge

Syllabus 1.4

Q	Ans	Key reason	Mk
H1	**(5)**	—	**(01)**
H2	**(3)**	0.5/50 = 0.01 mm.	**(01)**
H3	**(3)**	Prevents over-tightening.	**(01)**
H4	**(4)**	Sleeve 7.5 mm (half mark visible) + 23 × 0.01 = 7.73 mm.	**(01)**
H5	**(3)**	Sleeve 4.0 mm + 47 × 0.01 = 4.47 mm.	**(01)**
H6	**(2)**	1/100 = 0.01 mm.	**(01)**
H7	**(4)**	—	**(01)**
H8	**(4)**	Zero error = −(50 − 46) × 0.01 = −0.04 mm; 3.27 − (−0.04) = 3.31 mm.	**(01)**
H9	**(4)**	0.01/0.50 × 100 = 2 %.	**(01)**
H11	**(3)**	The 0.5 mm mark after 5 mm is visible → 5.5 + 0.02 = 5.52 mm. 5.02 is the common trap.	**(01)**
H13	**(1)**	0.01/1.2 = 0.83 %; vernier 0.05/1.2 = 4.2 %.	**(01)**

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H10. *[5 marks]*

(a) Find the mean reading and the corrected diameter.

Mean = 0.52 mm **(01)**

Corrected = 0.52 − 0.02 = 0.50 mm **(01)**

(b) Find the cross-sectional area of the wire in m².

$A = \pi r^2 = 3.14 \times (0.25 \times 10^{-3})^2$ **(01)**

$= 1.96 \times 10^{-7}$ m² **(01)**

(c) Why are readings taken in two perpendicular directions?

The wire may not be perfectly circular in cross-section **(01)**

Total 05

H12. *[6 marks]*

(a) Find the pitch.

2.5/5 = 0.5 mm **(01)**

(b) Find the least count.

0.5/50 = 0.01 mm **(01)**

(c) With the jaws closed, the zero of the circular scale is 3 divisions below the reference line. State the zero error.

+0.03 mm **(01)**

(d) A steel ball gives a main scale reading of 6.5 mm and a circular scale reading of 37. Find the corrected diameter.

Observed = 6.5 + 0.37 = 6.87 mm **(01)**

Corrected = 6.84 mm **(01)**

(e) Find the volume of the ball in mm³. (π = 3.14)

$(4/3)\pi(3.42)^3 = 167$ mm³ **(01)**

Total 06

SECTION I – Spherometer

Syllabus 1.4

Q	Ans	Key reason	Mk
I1	**(1)**	—	**(01)**
I2	**(3)**	—	**(01)**
I3	**(2)**	0.5/100 = 0.005 mm.	**(01)**
I4	**(2)**	2.73 − 1.25 = 1.48 mm.	**(01)**
I5	**(3)**	9.00/0.900 + 0.075 = 10.08 ≈ 10.1 cm.	**(01)**
I7	**(1)**	R ∝ 1/h; h is 1.3 % too large, so R is about 1.3 % too small.	**(01)**
I8	**(3)**	11.97/0.600 + 0.05 ≈ 20.0 cm.	**(01)**

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I6. *[5 marks]*

(a) The reading on a plane glass plate is 2.36 mm and on the mirror 1.86 mm. Find h.

h = 2.36 − 1.86 = 0.50 mm **(01)**

(b) The distance between the legs is l = 4.50 cm. Find R using R = l²/6h + h/2.

R = 4.50²/(6 × 0.050) + 0.025 **(01)**

= 67.5 cm **(01)**

(c) Why can the term h/2 often be neglected?

h is very small compared with l²/6h **(01)**

(d) How is l found in practice?

Press the legs on paper, measure the three distances between marks and take the mean **(01)**

Total 05

SECTION J – Travelling microscope

Syllabus 1.4

Q	Ans	Key reason	Mk
J1	**(5)**	—	**(01)**
J2	**(5)**	—	**(01)**
J3	**(2)**	0.5/50 = 0.01 mm.	**(01)**
J4	**(5)**	—	**(01)**
J6	**(2)**	D = 6.52 mm, d = 3.22 mm; (6.52 − 3.22)/2 = 1.65 mm.	**(01)**

J5. *[4 marks]*

(a) Horizontal readings: 3.452 cm and 3.506 cm. Vertical readings: 6.215 cm and 6.161 cm. Find the mean internal diameter and radius.

Diameters: 0.054 cm and 0.054 cm → mean 0.054 cm **(01)**

Radius = 0.027 cm **(01)**

(b) Why are both horizontal and vertical diameters measured?

Bore may not be circular **(01)**

(c) Why is the microscope moved in only one direction between the two readings?

To avoid backlash error **(01)**

Total 04

SECTION K – Balances, stopwatches and the digital multimeter

Syllabus 1.4

Q	Ans	Key reason	Mk
K1	**(3)**	It compares masses.	**(01)**
K2	**(2)**	—	**(01)**
K3	**(2)**	—	**(01)**
K4	**(3)**	100 + 20 + 5 + 0.6 = 125.6 g.	**(01)**
K5	**(1)**	—	**(01)**
K6	**(4)**	Reaction error dominates; timing many oscillations reduces its percentage effect.	**(01)**
K7	**(1)**	Last digit is in the 0.01 V place.	**(01)**

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SECTION L – Scalars and vectors

Syllabus 1.5

Q	Ans	Key reason	Mk
L1	**(5)**	—	**(01)**
L2	**(5)**	—	**(01)**
L3	**(3)**	√(36 + 64) = 10 N.	**(01)**
L4	**(1)**	50 cos37° = 40 N, 50 sin37° = 30 N.	**(01)**
L5	**(5)**	|12 − 5| to 12 + 5.	**(01)**
L6	**(4)**	R = 2F cos30° = 17.3 N.	**(01)**
L7	**(1)**	Symmetric – they form a closed triangle.	**(01)**
L8	**(4)**	A + (−B): 3 east + 4 south.	**(01)**
L9	**(4)**	$F^2 = 2F^2 + 2F^2\cos\theta \rightarrow \cos\theta = -½$.	**(01)**
L11	**(4)**	$P^2 + Q^2 = 100$, P − Q = 2 → 8 N and 6 N.	**(01)**
L12	**(5)**	Net 3 N east, 4 N north → 5 N, tanθ = 4/3 → 53° N of E.	**(01)**

L10. *[4 marks]*

(a) Use the parallelogram law to find the magnitude of the resultant.

$R^2 = 16 + 36 + 2(4)(6)\cos60°$ **(01)**

$= 76 \rightarrow R = 8.7$ N **(01)**

(b) Find the angle the resultant makes with the 4 N force.

$\tan\alpha = 6\sin60°/(4 + 6\cos60°) = 5.20/7$ **(01)**

$\alpha \approx 37°$ **(01)**

Total 04

L13. *[4 marks]*

(a) Resolve each force into x and y components and find the resultant (magnitude and direction).

$\Sigma F_x = 10 + 10\cos60° = 15$ N **(01)**

$\Sigma F_y = 10\sin60° = 8.66$ N **(01)**

$R = \sqrt{(15^2 + 8.66^2)} = 17.3$ N at 30° to the x-axis **(01)**

(b) State the single force that would keep the point in equilibrium.

17.3 N at 210° (opposite to R) **(01)**

Total 04

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