General Certificate of Education (Advanced Level) – Grade 12

UNIT TEST – MARKING SCHEME

Physics II – Mechanics

competency levels 2.1 – 2.5 · 140 questions · 214 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 – Relative motion (parallel paths)

Syllabus 2.1

Q	Ans	Key reason	Mk
A1	**(4)**	Motion is always described relative to a frame of reference.	**(01)**
A2	**(1)**	—	**(01)**
A3	**(1)**	25 − 20 = 5 m s⁻¹ in the direction of motion.	**(01)**
A4	**(5)**	$v_B - v_A = (-15) - 20 = -35$ m s⁻¹ → 35 m s⁻¹ west.	**(01)**
A5	**(4)**	Relative speed 10 m s⁻¹; 150/10 = 15 s.	**(01)**
A6	**(3)**	Relative speed 50 m s⁻¹; distance 250 m → 5 s.	**(01)**
A7	**(4)**	Time = 250/10 = 25 s; ground distance = 30 × 25 = 750 m.	**(01)**

A8. *[4 marks]*

(a) How long does he take to reach the end if he walks forward?

v = 2.5 m s⁻¹; t = 60/2.5 = 24 s **(01)**

(b) How long would he take if he walked backward (against the walkway)?

v = 0.5 m s⁻¹ forward; t = 120 s **(01)**

(c) How long if he simply stands?

60/1.5 = 40 s **(01)**

(d) A jogger runs on the ground beside the walkway at 3.0 m s⁻¹ in the same direction. Find the man's velocity (walking forward) relative to the jogger.

2.5 − 3.0 = −0.5 m s⁻¹ (0.5 m s⁻¹ backwards) **(01)**

Total 04

SECTION B – Graphs of motion

Syllabus 2.1

Q	Ans	Key reason	Mk
B1	**(4)**	—	**(01)**

B2	**(1)**	—	**(01)**
B3	**(1)**	Gradient (acceleration) zero.	**(01)**
B4	**(3)**	½(4)(20) + 6(20) + ½(5)(20) = 210 m.	**(01)**
B5	**(2)**	(30 − 10)/5 = 4 m s⁻².	**(01)**
B6	**(2)**	v falls linearly → s–t is an inverted parabola, maximum when v = 0.	**(01)**
B7	**(5)**	Constant gradient → constant velocity; negative → negative direction.	**(01)**
B9	**(5)**	Area above = ½(2)(10) = 10 m, area below = 10 m → displacement 0, distance 20 m.	**(01)**

B8. *[6 marks]*

(a) Sketch the velocity–time graph, marking the values.

Correct shape **(01)**

Values 20 m s⁻¹, 10 s, 30 s, 38 s marked **(01)**

(b) Find the acceleration and the deceleration.

a = 2.0 m s⁻² **(01)**

deceleration = 20/8 = 2.5 m s⁻² **(01)**

(c) Find the total distance travelled and the average speed.

100 + 400 + 80 = 580 m **(01)**

580/38 = 15.3 m s⁻¹ **(01)**

Total 06

B10. *[6 marks]*

(a) Find when A catches B.

$s_A = ½(2)t^2 = t^2$; $s_B = 20t$ **(01)**

$t^2 = 20t \rightarrow t = 20$ s **(01)**

(b) How far have they travelled then, and what is A's speed?

400 m **(01)**

$v_A = 2 \times 20 = 40$ m s⁻¹ **(01)**

(c) Find the greatest distance between them before A catches B.

Greatest when $v_A = v_B \rightarrow t = 10$ s **(01)**

200 − 100 = 100 m **(01)**

Total 06

SECTION C – Equations of motion (line, vertical, incline)

Syllabus 2.1

Q	Ans	Key reason	Mk
C1	**(5)**	—	**(01)**
C2	**(1)**	g ≈ 10 m s⁻² downward, whatever the mass.	**(01)**
C3	**(3)**	s = ½(20 + 0)(4) = 40 m.	**(01)**
C4	**(3)**	½(10)(9) = 45 m.	**(01)**
C5	**(3)**	u²/2g = 900/20 = 45 m.	**(01)**
C6	**(3)**	½a(3² − 2²) = 2.5a = 9.	**(01)**
C7	**(5)**	s = 60 − 45 = 15 m; up 20 m then down 5 m → 25 m.	**(01)**
C8	**(3)**	a = g sin30° = 5; v² = 100.	**(01)**

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C9	**(3)**	$a = -5\ m\ s^{-2}$; $0 = 100 - 10s \rightarrow s = 10$ m.	**(01)**
C11	**(4)**	$h \propto t^2 \rightarrow t' = t/\sqrt{2}$.	**(01)**
C12	**(5)**	The stone starts with $5\ m\ s^{-1}$ upward: $-30 = 5t - 5t^2 \rightarrow t = 3$ s.	**(01)**

C10. *[4 marks]*

(a) Find the time taken to reach the ground.

$-20 = 15t - 5t^2 \rightarrow t^2 - 3t - 4 = 0$ **(01)**

$t = 4$ s **(01)**

(b) Find its speed on reaching the ground.

$v = 15 - 10(4) = -25 \rightarrow 25\ m\ s^{-1}$ **(01)**

(c) Find the greatest height above the ground.

$20 + 15^2/20 = 31.25$ m **(01)**

Total 04

C13. *[5 marks]*

(a) Sketch the velocity–time graph.

Trapezium shape with $20\ m\ s^{-1}$ marked **(01)**

(b) Find the distances covered while accelerating and decelerating.

$t_1 = 40$ s, $s_1 = 400$ m **(01)**

$t_3 = 20$ s, $s_3 = 200$ m **(01)**

(c) Find the total journey time.

$s_2 = 1400$ m $\rightarrow t_2 = 70$ s **(01)**

Total = 130 s **(01)**

Total 05

SECTION D – Projectile motion

Syllabus 2.1

Q	Ans	Key reason	Mk
D1	**(4)**	No horizontal force.	**(01)**
D2	**(1)**	—	**(01)**
D3	**(2)**	$t = 0.5$ s; $x = 1.5$ m.	**(01)**
D4	**(2)**	$(u \sin\theta)^2/2g = 400/20 = 20$ m.	**(01)**
D5	**(4)**	$u^2 \sin2\theta/g = 1600 \times 0.866/10 \approx 139$ m.	**(01)**
D6	**(4)**	(A) false – horizontal velocity remains at the top.	**(01)**
D7	**(5)**	$\sin60° = \sin120° \rightarrow$ equal ranges; height $\propto \sin^2\theta$.	**(01)**
D9	**(1)**	The packet keeps the plane's horizontal velocity, so relative to the plane it falls straight down.	**(01)**

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D8. *[4 marks]*

(a) Find the horizontal and vertical components of the initial velocity.

15 m s^{-1} and 20 m s^{-1} **(01)**

(b) Find the time to reach the wall and the height of the ball there.

t = 30/15 = 2.0 s **(01)**

y = 20(2) − 5(4) = 20 m **(01)**

(c) Find its velocity on reaching the wall and comment.

v_y = 0 → 15 m s^{-1} horizontal; it is at its highest point **(01)**

Total 04

D10. *[5 marks]*

(a) Find the time of flight.

$45 = 5t^2$ → t = 3.0 s **(01)**

(b) Find the horizontal distance from the foot of the cliff.

20 × 3 = 60 m **(01)**

(c) Find the speed and direction of the ball just before landing.

v_y = 30 m s^{-1} ; $v = \sqrt{(20^2 + 30^2)}$ = 36 m s^{-1} **(01)**

tan α = 30/20 → α ≈ 56° below the horizontal **(01)**

(d) At what time is the velocity directed at 45° below the horizontal?

$v_y = v_x$ = 20 → t = 2.0 s **(01)**

Total 05

SECTION E – Resultant of forces

Syllabus 2.2

Q	Ans	Key reason	Mk
E1	**(5)**	(The balancing force is the equilibrant.)	**(01)**
E2	**(5)**	Range 1 N to 7 N.	**(01)**
E3	**(1)**	$F^2 + F^2 + 2F^2 \cos 120° = F^2$.	**(01)**
E4	**(4)**	10 E + 10 N = 10√2 NE, cancelled by 10√2 SW.	**(01)**
E6	**(1)**	Each force must be ≤ the sum of the other two (they form a closed triangle); 4 > 1 + 2.	**(01)**
E7	**(4)**	Resultant of 6 and 8 must be 10 → $6^2 + 8^2 = 10^2$ → 90°.	**(01)**

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E5. *[5 marks]*

(a) State the parallelogram law of forces.

If two forces acting at a point are represented in magnitude and direction by two adjacent sides of a parallelogram, **(01)**

the diagonal through that point represents their resultant **(01)**

(b) Find W.

$W = \sqrt{(6^2 + 8^2)} = 10$ N **(01)**

(c) Find the angle the 8 N string makes with the vertical.

$\tan\alpha = 6/8 \rightarrow \alpha \approx 37°$ **(01)**

(d) State one precaution in this experiment.

Pulleys must be frictionless / knot free of the board / read directions with the eye directly above **(01)**

Total 05

SECTION F – Moments, couples and parallel forces

Syllabus 2.2

Q	Ans	Key reason	Mk
F1	**(5)**	—	**(01)**
F2	**(1)**	—	**(01)**
F3	**(2)**	40 × 0.25 = 10 N m.	**(01)**
F4	**(3)**	F × d = 4 N m about any point.	**(01)**
F5	**(2)**	Perpendicular distance = 0.5 sin30° = 0.25 m → 5 N m.	**(01)**
F6	**(5)**	30x = 20(1 − x) → x = 0.4 m.	**(01)**
F7	**(2)**	(C) false – only another couple can balance it.	**(01)**

F8. *[3 marks]*

(a) Find the moment of the couple.

15 × 0.40 = 6.0 N m **(01)**

(b) Explain why the wheel does not move sideways.

The resultant force of a couple is zero, so there is no translation (only rotation) **(01)**

(c) Explain why a couple cannot be replaced by a single force.

A single force always has a non-zero resultant and would cause translation **(01)**

Total 03

SECTION G – Centre of gravity and centre of mass

Syllabus 2.2

Q	Ans	Key reason	Mk
G1	**(5)**	—	**(01)**
G2	**(1)**	(one-third of the height from the base)	**(01)**
G3	**(3)**	(0.2 × 30)/0.3 = 20 cm.	**(01)**
G4	**(1)**	At the centre of the ring – empty space.	**(01)**
G5	**(2)**	(¼/¾) × 10√2 = 4.7 cm away from the cut.	**(01)**
G7	**(2)**	(C) false.	**(01)**

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G8	**(2)**	Hole has ¼ of the mass: x = (¼ × R/2)/(¾) = R/6, on the side away from the hole.	**(01)**

G6. *[3 marks]*

(a) Find the position of the centre of gravity.

x = (1×0 + 2×30 + 3×60)/6 **(01)**

= 40 cm mark **(01)**

(b) Where should a single support be placed to keep the rod horizontal?

At the 40 cm mark (under the centre of gravity) **(01)**

Total 03

G9. *[3 marks]*

Hang the lamina freely from a point near its edge with a plumb line from the same point; mark the vertical line **(01)**

Repeat from a second (and third) point **(01)**

The point where the lines cross is the centre of gravity, because when freely suspended G lies vertically below the point of suspension **(01)**

Total 03

SECTION H – Inertia and Newton's laws

Syllabus 2.3

Q	Ans	Key reason	Mk
H1	**(4)**	—	**(01)**
H2	**(1)**	—	**(01)**
H3	**(1)**	—	**(01)**
H4	**(5)**	—	**(01)**
H5	**(2)**	—	**(01)**
H6	**(4)**	Action–reaction pairs act on different bodies and are of the same type.	**(01)**
H7	**(5)**	R = m(g + a) = 720 N.	**(01)**
H8	**(5)**	Slowing while moving down = acceleration upward → 720 N.	**(01)**
H9	**(5)**	All true.	**(01)**
H10	**(4)**	Such frames are inertial frames.	**(01)**
H12	**(1)**	—	**(01)**

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H11. *[5 marks]*

(a) at rest

500 N **(01)**

(b) accelerating upward at 2 m s⁻²

50(10 + 2) = 600 N **(01)**

(c) moving upward at a constant 3 m s⁻¹

500 N (a = 0) **(01)**

(d) falling freely (cable broken). Explain the result.

0 – the person and scale fall together with acceleration g (apparent weightlessness) **(01)**

(e) Draw a free-body diagram for the person in (b).

Weight 500 N down, normal reaction 600 N up, net force up **(01)**

Total 05

SECTION I – Momentum, impulse and conservation of momentum

Syllabus 2.3

Q	Ans	Key reason	Mk
I1	**(4)**	(= N s)	**(01)**
I2	**(4)**	—	**(01)**
I3	**(2)**	—	**(01)**
I4	**(3)**	Ft = mv → 15 = 2v.	**(01)**
I5	**(5)**	Δp = 0.2 × 18 = 3.6 N s → 72 N.	**(01)**
I6	**(2)**	—	**(01)**
I7	**(3)**	0.02 × 400 = 4.0 v.	**(01)**
I8	**(5)**	(12 − 6)/5 = 1.2 m s⁻¹ east.	**(01)**
I9	**(1)**	Total momentum stays zero.	**(01)**
I10	**(3)**	Impulse = area of F–t triangle = ½(200)(0.04) = 4 N s → v = 8 m s⁻¹.	**(01)**

I11. *[4 marks]*

(a) Find the impulse on the ball.

0.15(30 − (−20)) = 7.5 N s **(01)**

(b) Find the average force from the bat.

7.5/0.010 = 750 N **(01)**

(c) Name the law that gives the force of the ball on the bat, and state its size.

Newton's third law; 750 N opposite **(01)**

(d) Explain why a person jumping down from a wall bends the knees on landing.

Same change of momentum over a longer time → smaller force **(01)**

Total 04

SECTION J – Friction and self-adjusting forces

Syllabus 2.3

Q	Ans	Key reason	Mk
J1	**(4)**	—	**(01)**

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J2	**(4)**	Weight = mg is fixed.	**(01)**
J3	**(3)**	0.40 × 50 = 20 N.	**(01)**
J4	**(3)**	15 N < 20 N → box stays; friction self-adjusts to 15 N.	**(01)**
J5	**(3)**	25 > 20 → moves; friction = 0.25 × 50 = 12.5 N; a = 12.5/5.	**(01)**
J6	**(3)**	$\mu_s = \tan\theta$.	**(01)**
J7	**(3)**	(B) false.	**(01)**
J8	**(3)**	Max is 25 N but friction only needs to balance the weight, 20 N.	**(01)**
J9	**(3)**	$\mu_s mg = ma \rightarrow a = 3\ m\ s^{-2}$.	**(01)**

J10. *[6 marks]*

(a) Draw the free-body diagram of the block just before it slides.

W down, R normal to plank, F up the plank – all labelled **(01)**

(b) Show that $\mu_s = \tan\theta$ and find it.

$F = mg\sin\theta$, $R = mg\cos\theta$, $F = \mu_s R \rightarrow \mu_s = \tan\theta$ **(01)**

$= 0.75$ **(01)**

(c) While sliding at 37°, $a = 1.6\ m\ s^{-2}$. Find μ_k.

$12 - 16\mu_k = 2 \times 1.6$ **(01)**

$\mu_k = 0.55$ **(01)**

(d) Find the friction on the block at rest when the plank is at 20° (sin20° = 0.34).

$20 \times 0.34 = 6.8$ N (self-adjusting) **(01)**

Total 06

SECTION K – Applying Newton's laws: connected bodies

Syllabus 2.3

Q	Ans	Key reason	Mk
K1	**(2)**	a = 20/5 = 4; T = 3 × 4 = 12 N.	**(01)**
K2	**(2)**	a = (20 − 6)/5 = 2.8; T = 3(2.8) + 6 = 14.4 N.	**(01)**
K3	**(2)**	a = 10/5 = 2; T = 2(10 + 2) = 24 N.	**(01)**
K4	**(2)**	$a = 5\ m\ s^{-2}$; F = 2 × 5.	**(01)**
K6	**(2)**	$(30 - 2 \times 10 \times 0.5)/5 = 4\ m\ s^{-2}$.	**(01)**
K7	**(4)**	$a = 2\ m\ s^{-2}$; that coupling pulls two wagons: 20 000 × 2 = 40 kN.	**(01)**

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K5. *[6 marks]*

(a) Draw separate free-body diagrams for A and B.

A: 30 N forward, P backward, friction 8 N backward, weight and normal reaction **(01)**

B: P forward, friction 4 N backward, weight and normal reaction **(01)**

(b) Find the acceleration.

$30 - 12 = 6a$ **(01)**

$a = 3.0\ m\ s^{-2}$ **(01)**

(c) Find the force of A on B and state the force of B on A.

$P - 4 = 2 \times 3 \rightarrow P = 10\ N$ **(01)**

B pushes A with 10 N backward (Newton's third law) **(01)**

Total 06

SECTION L – Equilibrium

Syllabus 2.4

Q	Ans	Key reason	Mk
L1	**(5)**	—	**(01)**
L2	**(4)**	—	**(01)**
L3	**(4)**	$30 \times 30 = m \times 10 \rightarrow 90$ g.	**(01)**
L4	**(1)**	—	**(01)**
L5	**(1)**	Otherwise a net moment would exist.	**(01)**
L6	**(1)**	$T = 40\cos60° = 20$ N (strings at 90°).	**(01)**
L7	**(2)**	Moments about A: $4R_B = 200 \times 2 + 400 \times 1 \rightarrow R_B = 200$ N.	**(01)**
L10	**(3)**	Moments about the hinge: $T\sin30° \times 1 = 20 \times 0.5 \rightarrow T = 20$ N.	**(01)**
L11	**(5)**	All true.	**(01)**

L8. *[5 marks]*

(a) Why is the knife edge kept at G?

The weight of the rule has no moment about G **(01)**

(b) State the principle of moments.

For equilibrium, sum of clockwise moments = sum of anticlockwise moments about any point **(01)**

(c) Write the relation between a and b.

$W\ a = 1.0\ b$ ($b = W\ a$ with W in N) **(01)**

(d) Find the gradient of b against a and hence W.

Gradient ≈ 1.6 **(01)**

$W \approx 1.6$ N **(01)**

Total 05

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L9. *[8 marks]*

(a) Mark the forces on the ladder.

W at midpoint, S horizontal at the wall, R and F at the floor **(01)**

(b) Find the reaction S at the wall.

Moments about the foot: $4S = 200 \times 1.5$ **(01)**

$S = 75$ N **(01)**

(c) Find R, F and the least coefficient of friction.

$R = 200$ N, $F = 75$ N **(01)**

$\mu_{min} = 0.375$ **(01)**

(d) $\mu = 0.50$. How far up the ladder can a 600 N man climb before it slips?

$R = 800$ N, $F_{max} = 400$ N $= S$ **(01)**

$400 \times 4 = 200 \times 1.5 + 600 \times 0.6x$ **(01)**

$x \approx 3.6$ m **(01)**

Total 08

SECTION M – Work, energy and power

Syllabus 2.5

Q	Ans	Key reason	Mk
M1	**(1)**	$W = Fs\cos90° = 0$.	**(01)**
M2	**(5)**	—	**(01)**
M3	**(2)**	$50 \times 4 \times \cos60°$.	**(01)**
M4	**(3)**	—	**(01)**
M5	**(4)**	—	**(01)**
M6	**(2)**	$\frac{1}{2}kx^2$.	**(01)**
M7	**(3)**	$mgh = \frac{1}{2}mv^2$.	**(01)**
M8	**(3)**	$1\text{ J} = \frac{1}{2}(0.05)v^2 \rightarrow v = \sqrt{40}$.	**(01)**
M9	**(4)**	Output 3000 W; input = 3000/0.6.	**(01)**
M10	**(2)**	$P = Fv$.	**(01)**
M11	**(5)**	$F \times 40 = \frac{1}{2}(1000)(400)$.	**(01)**
M12	**(1)**	$KE = p^2/2m$.	**(01)**
M13	**(2)**	Resistance = 30 000/30 = 1000 N; at 20 m s^{-1} F = 1500 N; a = 500/1000.	**(01)**
M14	**(3)**	$v = \sqrt{(2gh)} = \sqrt{9}$.	**(01)**

M15. *[4 marks]*

(a) Find the loss of potential energy and the gain of kinetic energy.

2500 J **(01)**

1600 J **(01)**

(b) Find the work done against friction and the average frictional force.

900 J **(01)**

90 N **(01)**

Total 04

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M16. *[3 marks]*

(a) Find the useful output power.

PE per second = 1500 W; KE per second = 20 W **(01)**

Output = 1520 W **(01)**

(b) Find the efficiency.

1520/2000 = 76 % **(01)**

Total 03

SECTION N – Collisions and explosions

Syllabus 2.5

Q	Ans	Key reason	Mk
N1	**(1)**	—	**(01)**
N2	**(4)**	—	**(01)**
N3	**(3)**	42 J before, 3.6 J after.	**(01)**
N4	**(3)**	(B) false.	**(01)**
N5	**(3)**	2 kg piece at 10 m s^{-1}: 200 J + 100 J.	**(01)**
N6	**(5)**	Equal masses exchange velocities.	**(01)**
N7	**(3)**	$6 = v_1 + 2v_2$ and $36 = v_1^2 + 2v_2^2 \rightarrow v_2 = 4$ m s^{-1} ($v_1 = -2$ m s^{-1}).	**(01)**

N8. *[5 marks]*

(a) Find the velocity just after impact.

$0.02 \times 300 = 2.00v \rightarrow v = 3.0$ m s^{-1} **(01)**

(b) Find the height the block rises.

$h = v^2/2g = 0.45$ m **(01)**

(c) Find the kinetic energy lost and classify the collision.

900 J − 9 J = 891 J **(01)**

Inelastic **(01)**

(d) Why can energy conservation not be used for the impact itself?

KE is converted to heat/sound/deformation during the impact; only momentum is conserved **(01)**

Total 05

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