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TEN-YEAR SERIES · ANSWERS AND WORKED SOLUTIONS

2023 A-Level H1 Physics Paper 1

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ANSWER KEY

1 **C**	2 **A**	3 **C**	4 **D**	5 **D**	6 **C**	7 **D**	8 **B**	9 **C**	10 **A**
11 **D**	12 **A**	13 **B**	14 **D**	15 **D**	16 **B**	17 **D**	18 **B**	19 **A**	20 **C**
21 **B**	22 **A**	23 **D**	24 **D**	25 **B**	26 **B**	27 **B**	28 **B**	29 **B**	30 **A**

WORKED SOLUTIONS

Q1 Answer C

Power is energy per unit time.

- J s^{-1} and kJ min^{-1} are energy divided by time, so they are units of power.
- kW is a unit of power.
- kW h is a power multiplied by a time, so it is a unit of energy, not power.

Q2 Answer A

The volume of the stone is a difference, $V = V_{w+s} - V_w$.

For a sum or a difference, the absolute uncertainties add (they never subtract):

$$\Delta V = \Delta V_{w+s} + \Delta V_w$$

Percentage uncertainties are added only for products and quotients.

Q3 Answer C

Speed is a scalar, so it has magnitude only. Acceleration, displacement and velocity are vectors, which have direction.

Q4 Answer D

For constant acceleration,

$$v^2 = u^2 + 2as$$

Compare with $y = c + mx$, where $y = v^2$ and $x = s$: the intercept is u^2 and the gradient is $2a$.

Q5 Answer D

The aeroplane starts from rest:

$$s = \frac{1}{2}at^2 \quad \Rightarrow \quad a = \frac{2s}{t^2} = \frac{2(560)}{35^2} = 0.91 \ \text{m s}^{-2}$$

$$v = at = (0.914)(35) = 32 \ \text{m s}^{-1}$$

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Q6 Answer **C**

For isolated objects, momentum is conserved in every collision, and total energy is always conserved.

In an inelastic collision, some kinetic energy is converted into other forms (heat, sound, deformation), so kinetic energy is not conserved.

Q7 Answer **D**

Speed just before impact (falling 3.0 m from rest):

$$v_1 = \sqrt{2gh_1} = \sqrt{2(9.81)(3.0)} = 7.67 \text{ m s}^{-1} (\text{downwards})$$

Speed just after the bounce (rising 2.0 m):

$$v_2 = \sqrt{2gh_2} = \sqrt{2(9.81)(2.0)} = 6.26 \text{ m s}^{-1} (\text{upwards})$$

Taking upwards as positive, the change in momentum is

$$\Delta p = (0.050)(6.26) - (0.050)(-7.67) = 0.697 \text{ kg m s}^{-1}$$

$$F = \frac{\Delta p}{\Delta t} = \frac{0.697}{10 \times 10^{-3}} = 70 \text{ N}$$

Q8 Answer **B**

The object is in equilibrium, so W, F and T form a closed triangle with arrows head to tail.

- W acts vertically downwards and F horizontally to the right.
- T acts along the string, upwards and to the left, at 30° to the vertical.

Because T is at 30° to the vertical, $F = W \tan 30° = 0.58W$, so the horizontal side of the triangle is shorter than the vertical side.

In B, W points down, F continues to the right from its head, and T closes the triangle back up and to the left at 30° to the vertical. In D the arrows are head to tail, but T is at about 60° to the vertical. In A and C, T points downwards.

Q9 Answer **C**

From the graph, the length increases from 5 cm to 30 cm when 400 g is added:

$$x = 30 - 5 = 25 \text{ cm} = 0.25 \text{ m}, \qquad F = (0.400)(9.81) = 3.92 \text{ N}$$

$$k = \frac{F}{x} = \frac{3.92}{0.25} = 16 \text{ N m}^{-1}$$

Q10 Answer **A**

Take moments about the hinge at the wall.

The bar meets the shelf 20 cm from the wall, at 40° to the horizontal. Only the vertical component of its push has a moment about the hinge:

$$F_\text{v} = 50 \sin 40° = 32.1 \text{ N}$$

The weight of the shelf (10 N) acts at its centre, 15 cm from the wall. The load L is at X, 25 cm from the wall.

$$(32.1)(20) = (10)(15) + L(25)$$

$$L = \frac{643 - 150}{25} = 20 \text{ N}$$

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Q11 Answer **D**

The object falls from rest with constant acceleration, so the distance fallen is proportional to t^2. At time $t/2$ it has fallen $\frac{1}{4}$ of the height h.

Its height above the ground is then $\frac{3}{4}h$:

$$\text{P.E.} = mg\left(\frac{3h}{4}\right) = \frac{3E}{4}, \qquad \text{K.E.} = E - \frac{3E}{4} = \frac{E}{4}$$

Q12 Answer **A**

An angle in radians is arc length divided by radius:

$$\theta = \frac{s}{r}$$

Q13 Answer **B**

The centripetal force is provided by gravity:

$$F = \frac{GMm}{r^2}$$

$$F\prime = \frac{G(3M)(2m)}{(4r)^2} = \frac{6}{16}\frac{GMm}{r^2} = 0.375F$$

Q14 Answer **D**

The rock stays above the same point, so its period equals the length of the Martian day, $T = 8.86 \times 10^4$ s. Its orbital radius is

$$r = 3.40 \times 10^6 + 1.72 \times 10^7 = 2.06 \times 10^7 \ \text{m}$$

Gravity provides the centripetal force:

$$\frac{GM}{r^2} = \omega^2 r \quad \Rightarrow \quad GM = \omega^2 r^3 = \left(\frac{2\pi}{8.86 \times 10^4}\right)^2 (2.06 \times 10^7)^3 = 4.40 \times 10^{13} \ \text{N m}^2 \text{ kg}^{-1}$$

At the surface ($R = 3.40 \times 10^6$ m):

$$g = \frac{GM}{R^2} = \frac{4.40 \times 10^{13}}{(3.40 \times 10^6)^2} = 3.80 \ \text{m s}^{-2}$$

Q15 Answer **D**

The satellite's direction of motion changes continuously, so its velocity is changing and it is accelerating. There is a resultant force on it (the gravitational force, towards the Earth), so it is not in equilibrium.

The gravitational force is the centripetal force. It is not balanced by a separate centripetal force, so B is wrong.

Q16 Answer **B**

$$F = \frac{mv^2}{r} \quad \Rightarrow \quad v = \sqrt{\frac{Fr}{m}} = \sqrt{\frac{(2.3 \times 10^{-8})(1.1 \times 10^{-10})}{9.11 \times 10^{-31}}} = 1.7 \times 10^6 \ \text{m s}^{-1}$$

Q17 Answer **D**

$$R = \frac{\rho l}{\pi r^2} \quad \Rightarrow \quad R \propto \frac{l}{r^2}$$

- A: $1/(1/2)^2 = 4$, so $4R$
- B: $1/2^2 = 1/4$, so $R/4$
- C: $2/(1/2)^2 = 8$, so $8R$
- D: $2/2^2 = 1/2$, so $R/2$

Q18 Answer **B**

The charge passing per second is 43 C. Each electron carries 1.60×10^{-19} C:

$$N = \frac{43}{1.60 \times 10^{-19}} = 2.7 \times 10^{20}$$

The 12 V is not needed.

Q19 Answer **A**

As R decreases, the total resistance decreases, so the current increases: the ammeter reading increases.

The voltmeter measures the p.d. across R, which is the terminal p.d., $E - Ir$. A larger current means larger lost volts Ir, so the voltmeter reading decreases.

Q20 Answer **C**

To vary the p.d. across the lamp all the way from 0 to E, the circuit must be a potential divider: a potentiometer connected across the whole battery, with the lamp connected between one end and the sliding contact.

In C, with the slider at one end the lamp has the full E across it, and with the slider at the other end it has zero.

In A and B a fixed resistor is always in series with part of the circuit, so the lamp can never reach E (or zero). D is a variable resistor in series with the lamp, which can reduce the p.d. but never to zero.

Q21 Answer **B**

The terminal p.d. is 12 V, which is half the e.m.f., so the lost volts across the internal resistance are also 12 V. The external resistance must equal the internal resistance, 6.0 Ω.

- Two 4.0 Ω resistors give either 8.0 Ω (series) or 2.0 Ω (parallel).
- Three resistors: one in series with two in parallel gives $4.0 + 2.0 = 6.0\ \Omega$.

The least number is 3.

Q22 Answer **A**

From the graph, at 50 °C the thermistor's resistance is 1.0 kΩ.

The output V is the p.d. across the thermistor. The 20.0 V is shared in the ratio of the resistances:

$$V = \frac{1.0}{1.0 + 5.00}(20.0) = 3.3\ \text{V}$$

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Q23 Answer **D**

An α-particle has charge $2e = 3.20 \times 10^{-19}$ C.

$$E = \frac{F}{q} = \frac{35}{3.20 \times 10^{-19}} = 1.1 \times 10^{20} \text{ N C}^{-1}$$

The gold nucleus is positive, so its field points away from it, to the right at X.

Q24 Answer **D**

A magnetic field exerts a force only on a moving charge ($F = Bqv \sin\theta$). The charge is stationary, so the force is zero.

Q25 Answer **B**

Parallel wires with currents in opposite directions repel. Y is pushed away from X, so the force on Y is to the right (direction B).

Q26 Answer **B**

The force on the electron is perpendicular to its velocity.

- A magnetic force is perpendicular to both the velocity and the field. A field perpendicular to the velocity and to F gives exactly this (B). A field along F (A) would give a force perpendicular to F, not along it.
- An electric force on an electron is along the field line (opposite to the field). For C, the force would be perpendicular to F. For D, the force would be along the velocity, not at right angles to it.

Q27 Answer **B**

In every valid equation, both the nucleon numbers and the proton numbers must balance.

- A: $210 = 206 + 4$, $83 = 81 + 2$ ✗
- B: $208 = 208 + 0$ ✓, but $82 \neq 81 + (-1) = 80$ ✗
- C: $212 = 208 + 4$, $84 = 82 + 2$ ✗
- D: $208 = 208 + 0$, $81 = 82 + (-1)$ ✗

(β^--decay increases the proton number by 1, so lead cannot become thallium this way.)

Q28 Answer **B**

An α-particle has 2 protons and 2 neutrons.

$$\Delta m = 2(1.6726 \times 10^{-27}) + 2(1.6749 \times 10^{-27}) - 6.6442 \times 10^{-27}$$

$$\Delta m = 6.6950 \times 10^{-27} - 6.6442 \times 10^{-27} = 5.080 \times 10^{-29} \text{ kg}$$

Q29 Answer **B**

Only a very massive, concentrated positive charge can turn an α-particle back through more than 90° , and the fact that only a small number did so shows that the nucleus is very small compared with the atom.

A shows that most of the atom is empty space, but not that there is a small massive nucleus. C and D are features of how the experiment is carried out.

Q30 Answer **A**

Subtract the background count of 50 min^{-1} to get the count rate due to the sample.

- At $t = 0$: $250 - 50 = 200$ min^{-1}.
- Half of this is 100 min^{-1}, which is a measured count of $100 + 50 = 150$ min^{-1}. From the graph this occurs at $t = 50$ s.

(Check: a quarter, 50 min^{-1}, is a measured 100 min^{-1} at $t = 100$ s, one more half-life.)

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