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TEN-YEAR SERIES · ANSWERS AND WORKED SOLUTIONS

# 2021 A-Level H1 Physics Paper 1

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## ANSWER KEY

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

## WORKED SOLUTIONS

### Q1 Answer A

The Avogadro constant is the number of particles in one mole of a substance, $6.02 \times 10^{23}$ mol$^{-1}$. One mole of carbon contains $6.02 \times 10^{23}$ atoms.

- B: 1 kg of carbon is about 83 moles, not 1 mole.
- C: the mass of one mole of carbon-12 divided by one twelfth of the mass of one atom is $12 \times 6.02 \times 10^{23}$, not $6.02 \times 10^{23}$.
- D: the Avogadro constant does not give the volume of an atom.

### Q2 Answer A

The prefix deci (d) means $10^{-1}$, so

$$100\ \text{dW} = 100 \times 10^{-1}\ \text{W} = 10\ \text{W}$$

In base units, $\text{W} = \text{J s}^{-1} = \text{N m s}^{-1} = \text{kg m}^2\ \text{s}^{-3}$.

$$10\ \text{W} = 10\ \text{kg m}^2\ \text{s}^{-3}$$

### Q3 Answer B

A world-class sprinter runs at roughly 10 m s$^{-1}$.

$$t \approx \frac{200}{10} = 20\ \text{s}$$

### Q4 Answer C

The five arrows are close together, so the aim is precise. Their average position is well away from the centre of the target, so the aim is not accurate.

### Q5 Answer C

- P: a zero error shifts every reading by the same amount, so it is systematic.
- Q: a meter that always reads 80% of the true value is wrong by the same fraction every time, so it is systematic.
- R: different people have different reaction times, so the readings scatter. This is random.
- S: poor lighting makes the scale hard to read, so readings scatter either way. This is random.

Random: R and S. Systematic: P and Q.

**Q6** Answer **D**

The horizontal velocity stays at its initial value $u$. The vertical velocity starts at zero and increases steadily, $v_y = at$.

$$\text{speed} = \sqrt{u^2 + (at)^2}$$

- At $t = 0$ the speed is $u$, not zero.
- At first $v_y$ is small compared with $u$, so the speed hardly changes: the graph starts flat.
- Later $v_y$ dominates, so the speed increases almost linearly with gradient $a$.

D shows this shape. B (a straight line from $u$) would need the speed itself to increase at a constant rate.

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**Q7** Answer **A**

Add up the distance moved in each stage, ignoring direction:

- 0 to 2 s: from 0 to 6 m, 6 m
- 2 to 6 s: stationary
- 6 to 7 s: from 6 m to -8 m, 14 m
- 7 to 9 s: stationary
- 9 to 12 s: from -8 m to 0, 8 m

$$\text{distance} = 6 + 14 + 8 = 28 \ \text{m}$$

At 12 s the object is back at 0, so the displacement is zero.

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**Q8** Answer **A**

Take the rebound direction as positive. The initial velocity is $-2.40$ m s$^{-1}$.

$$\Delta p = mv - mu = 0.040v - 0.040(-2.40) = 0.120$$
$$0.040v = 0.120 - 0.096 = 0.024 \quad \Rightarrow \quad v = 0.60 \ \text{m s}^{-1}$$

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**Q9** Answer **B**

No external force acts (the surface is frictionless), so total momentum is conserved in every collision.

In an inelastic collision, some kinetic energy is converted into other forms (heat, sound, deformation), so the total kinetic energy after the collision is less.

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**Q10** Answer **D**

The springs are in series, so each spring carries the full 6.0 N load.

$$x_1 = \frac{6.0}{4.0} = 1.5 \ \text{cm}, \qquad x_2 = \frac{6.0}{1.0} = 6.0 \ \text{cm}$$
$$x = 1.5 + 6.0 = 7.5 \ \text{cm}$$

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**Q11** Answer **D**

The graph is a straight line with a positive intercept on the $y$-axis.

- Within the limit of Hooke's law, extension is proportional to force, which would be a straight line through the origin, so B is wrong.
- Length = original length + extension, so length against force is a straight line whose intercept is the original length. D fits.
- Elastic potential energy is proportional to the square of the extension, so extension or length against energy would not be a straight line. A and C are wrong.

**Q12** Answer **D**

The centre of gravity is the point at which the whole weight of the body may be considered to act.

A describes the centre of mass, B is true only for symmetrical uniform bodies, and C is not a correct definition (equal moments, not equal weights, balance on either side).

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**Q13** Answer **B**

The block is in equilibrium, so $W$, $N$ and $F$ form a closed triangle, with the arrows following each other head to tail.

- $W$ acts vertically downwards.
- $N$ acts perpendicular to the slope, upwards and to the left.
- $F$ prevents sliding down the slope, so it acts along the slope, upwards (up and to the right, at angle $\theta$ to the horizontal).

In B, $W$ points down, $F$ continues from its head up the slope, and $N$ closes the triangle back to the start. In C, $F$ is horizontal, not along the slope. In A, $F$ points down the slope. In D, $W$ points upwards.

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**Q14** Answer **B**

The velocity is constant, so the kinetic energy does not change. The cyclist moves down the hill, so the gravitational potential energy decreases. (The energy is converted into thermal energy by the resistive forces.)

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**Q15** Answer **D**

$$v = \frac{1000}{60} = 16.7 \ \text{m s}^{-1}$$
$$P = Fv = (3.0 \times 10^3)(16.7) = 5.0 \times 10^4 \ \text{W} = 50 \ \text{kW}$$

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**Q16** Answer **D**

The velocities at P and Q have the same magnitude $v$, and the direction turns through 30° (the same angle as the radius).

The change in velocity is $\Delta\mathbf{v} = \mathbf{v}_\text{Q} - \mathbf{v}_\text{P}$. Drawn tail to tail, the two velocity vectors form an isosceles triangle with angle 30° between the equal sides of length $v$. The third side is

$$|\Delta v| = 2v \sin\left(\frac{30^\circ}{2}\right) = 2v \sin 15^\circ$$

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**Q17** Answer **C**

$$\omega = \frac{2\pi}{T} = \frac{2\pi}{3.70} = 1.698 \ \text{rad s}^{-1}$$

The resultant force needed for circular motion is

$$F_\text{c} = m\omega^2 r = (77.0)(1.698)^2(4.00) = 888 \ \text{N}$$

The weight is $W = (77.0)(9.81) = 755$ N.

At the top, the centre is below the passenger. With $N$ the force from the ride, taking downwards as positive:

$$N + W = F_\text{c} \quad \Rightarrow \quad N = 888 - 755 = 133 \ \text{N(downwards)}$$

At the bottom, the centre is above the passenger. Taking upwards as positive:

$$N - W = F_\text{c} \quad \Rightarrow \quad N = 888 + 755 = 1640 \ \text{N(upwards)}$$

**Q18** Answer **D**

A, B and C are all true of a geostationary orbit.

D is not correct. The satellite has the same angular velocity as an object on the Equator, but its orbital radius (about $4.2 \times 10^7$ m) is far larger than the Earth's radius. Since $v = r\omega$, the satellite moves much faster than an object on the Equator.

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**Q19** Answer **A**

The cell has negligible internal resistance, so each of the two parallel branches has the full e.m.f. across it, and the branches do not affect each other.

- Ammeter: its branch (fixed resistor and ammeter) is unchanged, so its reading does not change.
- Voltmeter: as the thermistor is heated, its resistance decreases. In its branch the e.m.f. is shared between the fixed resistor and the thermistor in the ratio of their resistances, so the thermistor takes a smaller share. The voltmeter reading decreases.

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**Q20** Answer **A**

$$R = \frac{\rho l}{A} = \frac{4\rho l}{\pi d^2} \quad \Rightarrow \quad R \propto \frac{l}{d^2}$$

For wire X: $l/d^2 = 0.800/2.0^2 = 0.200$.

- A: $0.200/1.0^2 = 0.200$
- B: $0.400/1.0^2 = 0.400$
- C: $0.400/4.0^2 = 0.025$
- D: $0.640/4.0^2 = 0.040$

Only A matches.

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**Q21** Answer **B**

With P (no internal resistance), the full 12 V is across the heater:

$$P = \frac{V^2}{R} \quad \Rightarrow \quad R = \frac{12^2}{24.0} = 6.0\ \Omega$$

With Q, the heater has the same resistance:

$$I^2 R = 13.5 \quad \Rightarrow \quad I = \sqrt{\frac{13.5}{6.0}} = 1.5\ \text{A}$$

$$R + r = \frac{12}{1.5} = 8.0\ \Omega \quad \Rightarrow \quad r = 2.0\ \Omega$$

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**Q22** Answer **A**

- P is a diode. It conducts in one direction only, so reversing its connections changes it from conducting to not conducting (or the reverse). The readings change.
- Q (an LDR) and R (a filament lamp) behave in the same way whichever way round the current flows. Reversing them makes no difference to the readings.

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**Q23** Answer **C**

The force on a negative charge is opposite to the direction of the electric field. The force is upwards, so the field at X points downwards.

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**Q24** Answer **B**

The field lines are curved and come closer together towards the left, all pointing towards P. This is the pattern near the end of a solenoid (or the pole of a magnet), where the field lines converge into the end of the solenoid at P.

- A long straight wire along PQ would give circles around the line PQ, not lines converging on P.
- A flat circular coil with a diameter along PQ would have its field along the axis of the coil, perpendicular to PQ.
- A south pole at Q would make the lines point towards Q, not towards P.

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**Q25** Answer **C**

Parallel wires with currents in opposite directions repel each other.

By Newton's third law, the force exerted by Q on P is equal in magnitude (and opposite in direction) to the force exerted by P on Q, even though the currents are different.

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**Q26** Answer **C**

The electric field is downwards, so the electric force on the positive particles is downwards. For the beam to be undeviated, the magnetic force must be upwards, with the same magnitude.

The particles move to the right, so the conventional current is to the right. By Fleming's left-hand rule, an upward force on a current to the right needs a magnetic field into the plane of the paper.

(A field in the plane of the paper, along the electric field, would give a force into or out of the paper, so it could not balance the electric force.)

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**Q27** Answer **C**

The positive particles experience a constant downward force (in the direction of the field) while their horizontal velocity is unchanged. The path is a parabola curving downwards, starting horizontally.

A and B are straight lines, and D curves upwards, which would need an upward force.

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**Q28** Answer **B**

α-decay reduces the nucleon number by 4 and the proton number by 2:

$$^{238}_{92}\mathrm{U} \rightarrow ^{234}_{90}Th + ^{4}_{2}He$$

β⁻-decay keeps the nucleon number and increases the proton number by 1:

$$^{234}_{90}Th \rightarrow ^{234}_{91}Pa + ^{0}_{-1}\mathrm{e}$$

Nucleon number 234, proton number 91.

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**Q29** Answer **A**

Nucleon number and proton number must balance. Each neutron has nucleon number 1 and proton number 0.

$$239 = 112 + A + 3(1) \quad \Rightarrow \quad A = 124$$
$$94 = 46 + Z + 3(0) \quad \Rightarrow \quad Z = 48$$

So X is $^{124}_{48}\mathrm{X}$.

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**Q30** Answer **B**

Ionising radiation damages cells by ionising molecules in them, including DNA. This can cause mutations, which can lead to cancers such as lung cancer and skin cancer.

High blood pressure is not an effect of ionising radiation.