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TEN-YEAR SERIES · ANSWERS AND WORKED SOLUTIONS

2022 O-Level Physics Paper 1

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ANSWER KEY

1 **A**	2 **D**	3 **C**	4 **C**	5 **B**	6 **D**	7 **C**	8 **D**	9 **B**	10 **C**
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WORKED SOLUTIONS

Q1 Answer A

Why A is correct

Convert each value by dividing by the size of the prefix.

Hydrogen atom: $1\ \text{nm} = 10^{-9}\ \text{m}$, so $1.1 \times 10^{-10}\ \text{m} \div 10^{-9}\ \text{m} = 1.1 \times 10^{-1}\ \text{nm}$.

Earth: $1\ \text{Gm} = 10^{9}\ \text{m}$, so $1.3 \times 10^{7}\ \text{m} \div 10^{9}\ \text{m} = 1.3 \times 10^{-2}\ \text{Gm}$. Both match option A.

Why the rest are wrong

B — $1\ \text{Mm} = 10^{6}\ \text{m}$, so $1.3 \times 10^{7}\ \text{m} = 1.3 \times 10^{1}\ \text{Mm}$, not $1.3 \times 10^{-2}\ \text{Mm}$.

C — $1\mu m = 10^{-6}\ \text{m}$, so $1.1 \times 10^{-10}\ \text{m} = 1.1 \times 10^{-4}\mu m$, not $1.1 \times 10^{-1}\mu m$.

D — Both conversions are wrong: the atom would be $1.1 \times 10^{-4}\mu m$ and the Earth $1.3 \times 10^{1}\ \text{Mm}$.

Watch out for

B. Students who are unsure whether M (mega, 10^{6}) or G (giga, 10^{9}) is bigger pick B. Learn the prefixes in order: $n10^{-9}$, $\mu 10^{-6}$, $m10^{-3}$, $k10^{3}$, $M10^{6}$, $G10^{9}$.

Q2 Answer D

Why D is correct

Speed is the same before and after: 10 m/s. So the speed has not changed.

Velocity has a size and a direction. The direction changes from north to east, so the velocity changes.

Acceleration is the rate of change of velocity. A change in velocity, even a change of direction only, means the car accelerates.

Why the rest are wrong

A — The speed stays at 10 m/s, and the car does accelerate.

B — The speed does not change; only the direction changes.

C — A change in velocity always means there is an acceleration.

Watch out for

C. Students who think acceleration means 'speeding up' pick C. Any change in velocity, including a change in direction at constant speed, is an acceleration.

Q3 Answer **C**

Why C is correct

With no air resistance the object falls with acceleration $g = 10\ \text{m/s}^2$, so its speed increases by 10 m/s every second.

$v = u + at$

= $25 + 10 \times 2.0 = 45\ \text{m/s}$

Why the rest are wrong

A — 5.0 m/s comes from subtracting 20 m/s, as if the object were slowing down. It is moving downwards, so gravity speeds it up.

B — 25 m/s assumes the speed stays constant, but gravity still acts on the object.

D — 50 m/s doubles the starting speed; it does not use the acceleration of $10\ \text{m/s}^2$.

Watch out for

A. Students who think of the object as 'going against gravity' subtract 20 m/s. The object is moving down, the same way as the pull of gravity, so it speeds up.

Q4 Answer **C**

Why C is correct

Uniform deceleration means the velocity decreases by the same amount every second. The velocity–time graph is a straight line sloping down to zero. That is graph R.

On a displacement–time graph, the gradient is the velocity. As the train slows down, the gradient must decrease gradually until it is zero when the train stops. Graph Q is a curve whose gradient falls smoothly to zero.

So the two graphs are Q and R.

Why the rest are wrong

A — P has a constant gradient (constant velocity) and then a sudden stop. That is not uniform deceleration.

B — P shows constant velocity then a sudden stop, and S shows velocity falling faster at first and then more slowly, which is not uniform deceleration.

D — Q is correct, but S is a curve. Its gradient (the deceleration) changes, so the deceleration is not uniform.

Watch out for

A. Students who see P's straight line as 'uniform' pick P. A straight displacement–time line means constant velocity, not constant deceleration. On a displacement–time graph, slowing down shows as a curve that flattens out.

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Q5 Answer **B**

Why B is correct

While the ball falls, weight acts down and air resistance acts up. Resultant force = weight − air resistance.

As air resistance increases, the resultant downward force decreases, so the acceleration decreases. The ball is still speeding up, but by less each second.

When air resistance equals weight, the resultant force is zero. The acceleration is zero, so the ball falls at uniform velocity (terminal velocity).

Why the rest are wrong

A — When air resistance equals weight the resultant force is zero, so there is no acceleration at all.

C — The velocity does not decrease while air resistance is increasing; there is still a downward resultant force, so the ball keeps speeding up. And zero resultant force gives zero acceleration.

D — The velocity keeps increasing (more slowly) while air resistance is still less than the weight.

Watch out for

D. Students who think rising air resistance slows the ball down pick D. While air resistance is less than the weight, the resultant force is still downward, so the ball still speeds up; only its acceleration gets smaller.

Q6 Answer **D**

Why D is correct

A wall pushes on the water. A push from a surface acts at right angles to the surface and into the object being pushed.

So the side walls push sideways, inwards towards the water, and the base pushes upwards on the water.

Diagram D shows both side arrows pointing inwards and the base arrow pointing up.

Why the rest are wrong

A — A shows the side forces pointing outwards. Those are the forces the water exerts on the walls, not the walls on the water.

B — Forces from the walls act at right angles to the walls, not along them, and the base pushes the water up, not down.

C — C shows the forces the water exerts on the container (outwards on the sides, down on the base).

Watch out for

C. Students who draw the water pressure pushing outwards and downwards pick C. That is the force of the water on the walls. The question asks for the force of the walls on the water, which is the opposite direction.

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Q7 Answer **C**

Why C is correct

Air resistance always opposes the motion. The object moves down, so air resistance acts upward.

Weight $W = mg = 20 \times 10 = 200\ \text{N}$, downwards.

Resultant force = $200 - 80 = 120\ \text{N}$, downwards.

$a = F/m = 120/20 = 6.0\ \text{m/s}^2$

Why the rest are wrong

A — Air resistance acts against the motion, so it acts upward, not downward.

B — Air resistance does not act downward, and $14\ \text{m/s}^2$ comes from adding the forces $(200 + 80 = 280\ \text{N})$.

D — The direction is right, but $14\ \text{m/s}^2$ comes from adding 80 N to the weight instead of subtracting it.

Watch out for

D. Students who add the two forces pick D. Air resistance acts upward, against the weight, so subtract it to get the resultant force.

Q8 Answer **D**

Why D is correct

A gravitational field is a region in which a mass experiences a force because of gravitational attraction.

Option D says exactly this.

Why the rest are wrong

A — A force cannot 'experience' a force. It is a mass that experiences the force.

B — A force does not produce mass.

C — Gravitational attraction does not produce mass.

Watch out for

A. Option A uses the same words as the definition in a muddled order. Learn the definition word for word: a region where a mass experiences a force.

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Q9 Answer **B**

Why B is correct

Y is the weight of the uniform rule, acting at its centre. X and Z are the upward forces from the supports.

Up forces = down forces, so $Y = X + Z$. Y is the largest force.

Take moments about Z. From the figure, X is further from Z than Y is (X is at the left end; Y is at the centre, much closer to Z). X × (distance of X from Z) $= Y$ × (distance of Y from Z). Since X has the larger distance, X must be smaller than Y.

In the same way, the support closer to the centre of gravity carries more of the weight. Z is closer to the centre than X, so $Z > X$. So $Y > Z > X$.

Why the rest are wrong

A — X is not bigger than Z. X is further from the centre of gravity, so it carries less of the weight.

C — Y is the total weight, which equals X + Z, so it must be bigger than either support force.

D — $Y = X + Z$, so Z cannot be larger than Y.

Watch out for

A. Students who guess that the support at the end of the rule carries more load pick A. The support nearer the centre of gravity always carries the larger share of the weight.

Q10 Answer **C**

Why C is correct

Pressure in a liquid depends on depth: $p = h\rho g$. Points at the same level in the same liquid are at the same pressure.

In the figure the bottoms of piston 1 and piston 2 are at the same level, so $P_1 = P_2$.

Point X is lower down in the oil, at a greater depth below the pistons. So the pressure at X is greater: $P > P_2$.

Why the rest are wrong

A — $P_1 = P_2$ is right, but X is deeper than the pistons, so P is greater than P_2, not less.

B — The pistons are at the same level, so P_1 equals P_2. The different piston areas change the forces, not the pressures.

D — The pistons are at the same level, so $P_1 = P_2$; also P is greater than both because X is deeper.

Watch out for

A. Students who think the pressure at the bottom of a liquid is less pick A. Pressure increases with depth, so the extra oil above X adds $h\rho g$ to the pressure there, making P greater than P_2.

B. Students who think the larger piston has the larger pressure pick B. A larger piston gets a larger force, not a larger pressure.

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Q11 Answer **B**

Why B is correct

The principle of conservation of energy: energy cannot be created or destroyed, only transferred from one store to another.

So during any energy transfer in a system, the total energy before and after the transfer is always equal. That is option B.

Why the rest are wrong

A — Energy can be transferred between stores within the same object (for example, a falling ball changes gravitational potential energy to kinetic energy). It does not always go from one object to another.

C — A motor wastes some energy as thermal energy and sound, so the useful output is less than the total input.

D — The useful output can never be more than the input; that would mean energy is created.

Watch out for

C. Students who apply 'energy is conserved' to the useful output only pick C. The total input equals the useful output plus the wasted energy, so the useful output is always less than the input.

Q12 Answer **B**

Why B is correct

Energy lost as gravitational potential energy goes partly to kinetic energy and partly to work done against F.

Work done against $F = 100\,000 - 20\,000 = 80\,000\ \text{J}$

Work done = $F \times d$, so $F = W/d$

= $80\,000/50 = 1600\ \text{N}$

Why the rest are wrong

A — $400\ \text{N} = 20\,000/50$ uses the kinetic energy gained instead of the energy lost to F.

C — $2000\ \text{N} = 100\,000/50$ uses the full loss of gravitational potential energy and ignores the kinetic energy gained.

D — $2400\ \text{N} = 120\,000/50$ adds the kinetic energy gained instead of subtracting it.

Watch out for

C. Students who divide the whole 100 000 J by 50 m pick C. Only the energy that does not become kinetic energy is used against the backward force.

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Q13 Answer **D**

Why D is correct

Attraction is not proof of magnetism: a magnet attracts both magnets and unmagnetised magnetic materials such as iron.

Repulsion only happens between two magnets (like poles repel). So if the block is repelled by one pole of a magnet, it must be a magnet.

Why the rest are wrong

A — The two blocks attract if either one of them is a magnet. So attraction does not show that this block is the magnet; the other block could be the magnet.

B — Aluminium is non-magnetic, so neither a magnet nor an unmagnetised piece of iron is attracted to it. This tells you nothing.

C — A magnet attracts an unmagnetised magnetic material, so the block could just be iron.

Watch out for

C. Students who think 'attracted by a magnet' means 'is a magnet' pick C. Repulsion is the only sure test.

Q14 Answer **D**

Why D is correct

The vapour is at the boiling point, the same temperature as the boiling water. Temperature is linked to the average kinetic energy of the molecules, so the average kinetic energy is the same.

In the vapour, the molecules are much further apart than in the liquid, so the forces of attraction between them are much smaller.

The thermal energy supplied during boiling (latent heat) is used to pull the molecules apart against these forces, not to raise their kinetic energy.

Why the rest are wrong

A — The vapour and the liquid are at the same temperature, so the average kinetic energy is the same, not greater.

B — The average kinetic energy is the same, and the forces between molecules in a gas are much smaller than in a liquid.

C — The molecules in the vapour are much further apart, so the forces between them are smaller.

Watch out for

A. Students who think the molecules escape because they gain kinetic energy pick A. During boiling the temperature stays constant, so the average kinetic energy stays the same; the energy supplied goes into separating the molecules.

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Q15 Answer **D**

Why D is correct

Increasing the mass of gas in the same volume puts more molecules in the cylinder. There are more collisions with the walls per second, so the pressure increases.

Increasing the temperature makes the molecules move faster. They hit the walls more often and harder, so the pressure increases.

So both changes must be increases: option D.

Why the rest are wrong

A — Fewer molecules and slower molecules both reduce the pressure.

B — Removing gas reduces the number of collisions, so it lowers the pressure.

C — Cooling the gas makes the molecules move slower, so it lowers the pressure.

Watch out for

B. Students who mix up 'more mass' with 'more crowded so less room to move' may pick B. More molecules in the same volume means more collisions per second on the walls, so the pressure rises.

Q16 Answer **C**

Why C is correct

The chain of cause and effect is:

1. The water at the bottom becomes warmer → 4. the water expands → 2. its density decreases (same mass, larger volume) → 3. the less dense water rises and colder, denser water moves in to replace it.

So the order is 1 → 4 → 2 → 3.

Why the rest are wrong

A — The density decreases because the water expands, so expansion (4) must come before the density decrease (2), not at the end.

B — The water cannot rise (3) before it has expanded and become less dense.

D — The water rises because it is less dense, so the density decrease (2) must come before rising (3).

Watch out for

A. Students who skip the expansion step pick A. Density falls because the volume increases while the mass stays the same, so expansion comes first.

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Q17 Answer **D**

Why D is correct

Shiny, white surfaces are poor absorbers and poor emitters of infrared radiation, and good reflectors.

The sheet reflects the infrared radiation emitted by the athlete back towards the athlete, and it emits little radiation itself. So less thermal energy is lost and the athlete cools down more slowly.

This keeps the athlete from getting cold too quickly after the race.

Why the rest are wrong

A — A shiny white surface reflects more radiation, not less, and this keeps the athlete warmer.

B — Shiny white surfaces reflect more radiation than dull black ones, not less.

C — Reflecting radiation back to the athlete reduces the heat loss, so the athlete cools more slowly, not more quickly.

Watch out for

C. Students who think the sheet reflects heat 'away from' the athlete pick C. The radiation comes from the athlete, so it is reflected back towards the athlete, cutting the heat loss.

Q18 Answer **A**

Why A is correct

The cold junction is at 0 °C (melting ice). Assume the e.m.f. is proportional to the temperature difference between the junctions.

e.m.f. per $^\circ\mathrm{C} = 9.6\mu V \div 80^\circ\mathrm{C} = 0.12\mu V$ per °C

Temperature difference = $-1.8\mu V \div 0.12\mu V$ per $^\circ\mathrm{C} = -15^\circ\mathrm{C}$

The negative e.m.f. means the second junction is colder than the ice junction: $\theta = 0 - 15 = -15^\circ\mathrm{C}$.

Why the rest are wrong

B — −10 °C would need an e.m.f. of $-1.2\mu V$.

C — A positive temperature gives a positive e.m.f. (like the 80 °C reading). A reading of $-1.8\mu V$ means the junction is below 0 °C.

D — 15 °C has the right size but the wrong sign. It would give $+1.8\mu V$.

Watch out for

D. Students who ignore the minus sign pick D. The reading is negative, so the second junction is colder than the 0 °C junction in the ice.

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Q19 Answer **C**

Why C is correct

Total internal energy depends on the amount of water as well as its temperature. The pool contains a vastly larger mass of water than the kettle, so the pool has the greater total internal energy.

Temperature is a measure of the average kinetic energy of the molecules. The kettle water is hotter (80 °C compared with 28 °C), so its molecules have the greater average kinetic energy.

Why the rest are wrong

A — The kettle has the higher temperature, but far less water, so its total internal energy is smaller.

B — The kettle has less total internal energy, and its molecules have a higher (not lower) average kinetic energy.

D — The pool is at the lower temperature, so its molecules have the lower average kinetic energy.

Watch out for

A. Students who link 'hotter' with 'more internal energy' pick A. Internal energy is the total over all the molecules, so a huge amount of warm water has more than a small amount of hot water.

Q20 Answer **D**

Why D is correct

Energy supplied: $E = Pt$

= $500 \times (10 \times 60) = 300\,000\ \text{J}$

Specific latent heat: $l = E/m$

= $300\,000/0.360 = 8.3 \times 10^5\ \text{J/kg}$

So $l = 8.3 \times 10^5\ \text{J/kg}$.

Why the rest are wrong

A — $1.4 \times 10^1\ \text{J/kg}$ uses $t = 10\ \text{s}$ and $m = 360\ \text{g}(500 \times 10 \div 360)$: neither unit is converted.

B — $8.3 \times 10^2\ \text{J/kg}$ uses the mass in grams (300 000 ÷ 360) instead of kilograms.

C — $1.4 \times 10^4\ \text{J/kg}$ uses $t = 10\ \text{s}$ instead of 600 s (500 × 10 ÷ 0.360).

Watch out for

B. Students who forget to change 360 g into 0.360 kg pick B. Convert minutes to seconds and grams to kilograms before substituting.

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Q21 Answer **B**

Why B is correct

Period and frequency are linked by $T = 1/f$.

So if the frequency doubles, the period halves. The period is inversely proportional to the frequency.

An inverse relationship gives a curve that falls steeply at first and then levels off, getting closer and closer to the frequency axis without touching it. Graph B has this shape.

Why the rest are wrong

A — A straight line through the origin means the period is directly proportional to the frequency, so a higher frequency would give a longer period. That is the wrong way round.

C — C shows the period increasing faster and faster as frequency increases. Period must decrease as frequency increases.

D — D shows a straight-line decrease that reaches zero period at a finite frequency. $T = 1/f$ never reaches zero, and the line is a curve, not straight.

Watch out for

D. Students who know that period goes down when frequency goes up pick D. 'Goes down' is not enough: $T = 1/f$ is an inverse relationship, which is a curve, not a straight line.

Q22 Answer **A**

Why A is correct

A wavefront is a line joining points on a wave that are in the same position in their oscillation (in phase), for example all the points along one crest.

So a line drawn along the crest of a wave is a wavefront.

Why the rest are wrong

B — The distance between two consecutive crests is the wavelength, not a wavefront.

C — A wavefront is not 'the first wave'. Every crest of a wave has its own wavefront.

D — The transfer of energy by oscillations describes what a wave is, not what a wavefront is.

Watch out for

C. The word 'front' makes some students think of the leading wave. A wavefront is any line joining points in phase, such as any crest, not just the first one.

Q23 Answer **C**

Why C is correct

Ultraviolet is part of the electromagnetic spectrum. All electromagnetic waves are transverse.

Ultrasound is sound with a frequency above 20 kHz. All sound waves are longitudinal: the air particles vibrate back and forth along the direction the wave travels.

So ultraviolet is transverse and ultrasound is longitudinal.

Why the rest are wrong

A — Ultraviolet is an electromagnetic wave, so it is transverse, not longitudinal.

B — Both are the wrong way round: ultraviolet is transverse and ultrasound is longitudinal.

D — Ultrasound is a sound wave, so it is longitudinal, not transverse.

Watch out for

B. 'Ultraviolet' and 'ultrasound' both start with 'ultra', and students mix them up. Ultraviolet is light-like (electromagnetic, transverse); ultrasound is sound (longitudinal).

Q24 Answer **A**

Why A is correct

Refractive index $n = \sin i / \sin r$, where i is the angle in air and r is the angle in glass, both measured from the normal.

At the curved surface the light goes from air into glass. P is the angle between the incident ray (in air) and the surface, so the angle of incidence is $i = 90° - P$. Q is the angle between the ray in the glass and the surface, so the angle of refraction is $r = 90° - Q$.

$n = \sin i / \sin r = \sin(90° - P) / \sin(90° - Q)$. This is option A.

(At the flat surface the same idea gives $n = \sin(90° - S) / \sin(90° - R)$, because S is the angle in air and R is the angle in glass. That expression is not one of the options.)

Why the rest are wrong

B — This puts the glass angle (90° − R) on top and the air angle (90° − S) underneath, so it gives 1 / n, not n.

C — P and Q are measured from the surface, not from the normal. sin P / sin Q uses the wrong angles.

D — R and S are measured from the surface, not from the normal, and the ratio is also upside down (glass angle on top).

Watch out for

C. Students who see angles marked at the point of entry plug them straight into sin i / sin r. Always check whether an angle is measured from the normal or from the surface; here they are all measured from the surface, so you need 90° minus each.

B. At the exit surface the angle in air (S) must go on top. Putting the glass angle on top gives 1 / n.

Q25 Answer **D**

Why D is correct

A diverging (concave) lens is thinner in the middle than at the edges. It bends parallel rays away from the principal axis as they pass through.

After the lens, the rays spread out as if they came from a point (the focal point) on the same side as the incoming light.

In D, both rays pass through the lens and then spread apart, away from the axis. This is what a diverging lens does.

Why the rest are wrong

A — The rays converge to a point after the lens. That is what a converging (convex) lens does, not a diverging lens.

B — The rays are shown bouncing back and crossing in front of the lens. A lens refracts light through it; it does not reflect it back.

C — The rays are shown turning back towards the source. Light passes through a lens; it is not reflected back.

Watch out for

A. Some students remember that rays cross the axis at a focal point and pick A. Crossing at a real focus after the lens is converging behaviour; a diverging lens spreads the rays out.

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Q26 Answer **C**

Why C is correct

The echo travels to the wall and back, so the distance is $2 \times 85 = 170\ \text{m}$.

Time for the echo: t = distance / speed = $170/340 = 0.50\ \text{s}$.

He claps just as he hears the echo of the previous clap, so the time between claps (the period) is 0.50 s.

$f = 1/T = 1/0.50 = 2.0\ \text{Hz}$.

Why the rest are wrong

A — 0.25 Hz corresponds to a period of 4.0 s. It comes from inverting the speed-to-distance ratio wrongly $(85/340 = 0.25)$ and treating it as a frequency.

B — 0.50 Hz is the echo time 0.50 s written as a frequency. You must take 1 / T.

D — 4.0 Hz uses the one-way distance only: $t = 85/340 = 0.25\ \text{s}$, $f = 1/0.25 = 4.0\ \text{Hz}$. The sound has to go to the wall and back.

Watch out for

D. Forgetting that an echo travels there and back. Use $2 \times 85\ \text{m} = 170\ \text{m}$.

B. Stopping at the time 0.50 s and choosing the option with the same number. The question asks for frequency = 1 / period.

Q27 Answer **A**

Why A is correct

The long plate of a cell is the positive terminal. In every diagram both cells have the long plate on the right, so the right-hand terminal of the battery (right cell's long plate) is positive and the left-hand end is negative.

Conventional current I flows out of the positive terminal, round the circuit, to the negative terminal. It leaves the right-hand side, goes down the right wire and along the bottom wire from right to left. So I points to the left on the bottom wire.

Electrons flow the opposite way, from negative to positive, so e points to the right on the bottom wire.

Diagram A shows I to the left and e to the right.

Why the rest are wrong

B — B shows e and I in the same direction. Electron flow is always opposite to conventional current.

C — C has both directions reversed: I to the right and e to the left. That would need the positive terminal on the left.

D — D shows e and I in the same direction. Electron flow is always opposite to conventional current.

Watch out for

C. Students who know e and I are opposite but misread the cell symbol pick C. The long plate is positive; current leaves the long plate.

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Q28 Answer **C**

Why C is correct

Current in the lamp: $I = P/V = 24/12 = 2.0\ \text{A}$.

Time: $t = 25 \times 60 \times 60 = 90\,000\ \text{s}$.

Charge: $Q = It = 2.0 \times 90\,000 = 180\,000\ \text{C}$.

Why the rest are wrong

A — $3000\ \text{C} = 2.0 \times 1500$, which uses 25 hours converted to minutes (1500 min) instead of seconds.

B — $45\,000\ \text{C} = 0.50 \times 90\,000$ uses $I = V/P = 12/24 = 0.50\ \text{A}$, which is upside down.

D — $1\,100\,000\ \text{C} \approx 12 \times 90\,000$ or similar: using the voltage instead of the current in $Q = It$.

Watch out for

A. Converting hours to minutes instead of seconds. Charge in coulombs needs time in seconds.

B. Writing $I = V/P$. Power $P = VI$, so $I = P/V$.

Q29 Answer **A**

Why A is correct

Charge that flows: $Q = It = 300\,000 \times 0.0050 = 1500\ \text{C}$.

Energy and p.d. are linked by $E = QV$, so $V = E/Q$.

$V = 450\,000\,000/1500 = 300\,000\ \text{V} = 0.30\ \text{MV}$.

(Or: power $P = E/t = 450 \times 10^6/0.0050 = 9.0 \times 10^{10}\ \text{W}$, then $V = P/I = 9.0 \times 10^{10}/300\,000 = 3.0 \times 10^5\ \text{V}$.)

Why the rest are wrong

B — 7.5 MV does not follow from $E = QV$ with the given data; it comes from mixing up the powers of ten in kA, ms and MJ.

C — 300 MV comes from dividing 450 MJ by 1.5 C, i.e. using 5.0 ms as $5.0 \times 10^{-6}\ \text{s}$ or forgetting the 'k' in $kA (Q = 1.5\ \text{C})$.

D — 680 MV does not follow from the data; it comes from a mistaken combination of the numbers.

Watch out for

C. Dropping one prefix: 300 kA is $3.0 \times 10^5\ \text{A}$ and 5.0 ms is $5.0 \times 10^{-3}\ \text{s}$. Convert every prefix before calculating, or the answer is out by 1000.

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Q30 Answer **B**

Why B is correct

A filament lamp gets hotter as the current increases. Its resistance increases as it heats up, so equal increases in voltage give smaller and smaller increases in current.

Check each set using $R = V/I$ at 1.0 V, 2.0 V and 3.0 V. For B: $1.0/0.025 = 40\Omega$, $2.0/0.045 = 44\Omega$, $3.0/0.060 = 50\Omega$. The resistance rises, and the lamp takes $60\ \text{mA} = 0.060\ \text{A}$ at 3.0 V as rated.

So B is the filament lamp.

Why the rest are wrong

A — The current stays at 60 mA while the voltage rises from 1.0 V to 3.0 V. A real lamp's current increases with voltage; this is not a filament lamp.

C — Current is directly proportional to voltage ($R = 50\Omega$ every time). That is an ohmic conductor such as a fixed resistor at constant temperature.

D — $R = 100\Omega$, 100Ω, then 50Ω: the resistance falls at higher current. A filament's resistance rises as it heats up.

Watch out for

C. All four sets end at 3.0 V, 60 mA, so students pick the neat proportional one. A filament lamp is non-ohmic: its I–V graph bends towards the voltage axis because resistance rises with temperature.

Q31 Answer **B**

Why B is correct

The current is largest when the wire's resistance is smallest, since the battery's e.m.f. is the same each time.

For wires of the same material, resistance is proportional to length and inversely proportional to cross-sectional area: $R = \rho L/A$.

So the smallest resistance is the shortest and thickest wire: length 10 cm and diameter 0.8 mm. That is wire B.

Why the rest are wrong

A — Same length as B but half the diameter, so a quarter of the cross-sectional area and four times the resistance of B.

C — Twice the length and a quarter of the area of B, so eight times the resistance of B. This gives the smallest current, not the largest.

D — Same thickness as B but twice the length, so twice the resistance of B.

Watch out for

C. Students who think a longer, thinner wire lets more current through pick C. A longer wire has more resistance, and a thinner wire has more resistance.

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Q32 Answer **B**

Why B is correct

A_1 and A_4 are both in the main (series) part of the circuit with the battery and the top resistor. Current is the same everywhere in a series path, so A_4 reads the same as A_1: 4.0 A.

At the junction the 4.0 A splits between the two parallel branches. A_2 is in the top branch and reads 3.0 A.

A_3 is in the bottom branch: $I_3 = 4.0 - 3.0 = 1.0\ \text{A}$.

Why the rest are wrong

A — A_4 is in the main circuit, so it carries the full 4.0 A, not 2.0 A.

C — The branch currents must add up to the main current: $3.0 + 3.0 = 6.0\ \text{A}$ is more than the 4.0 A supplied.

D — A_3 cannot be 3.0 A: the branches must add to 4.0 A, so $A_3 = 4.0 - 3.0 = 1.0\ \text{A}$.

Watch out for

C. Assuming the two parallel branches carry equal current. Only identical branches share current equally; use $I_3 = I_1 - I_2$.

Q33 Answer **C**

Why C is correct

In circuit 1 the two resistors are in series with the battery. The e.m.f. is shared between them, so $V = V_1 + V_2$.

In circuit 2 the two resistors are each connected directly across the battery terminals, so they are in parallel. Each has the full battery p.d. across it, so $V = V_3 = V_4$.

So the correct row is C.

Why the rest are wrong

A — In circuit 1 the resistors are in series, so the p.d.s add up: $V = V_1 + V_2$, not $V_1 = V_2 = V$.

B — Both circuits are the wrong way round: series p.d.s add (circuit 1), parallel p.d.s are equal (circuit 2).

D — In circuit 2 the resistors are in parallel, so each has the full p.d. V across it, not a share.

Watch out for

D. Circuit 2 is drawn with the resistors one above the other but the wires make it easy to miss that both connect straight across the battery. Trace each resistor's two ends back to the battery terminals.

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Q34 Answer **A**

Why A is correct

The LDR and the thermistor are in series, so the battery's p.d. is shared between them in the ratio of their resistances. The thermistor gets the largest share when its resistance is large and the LDR's resistance is small.

An LDR has a low resistance in bright light.

A thermistor has a high resistance when it is cold.

So bright (small LDR resistance) and cold (large thermistor resistance) gives the largest p.d. across the thermistor.

Why the rest are wrong

B — When hot, the thermistor's resistance is low, so it takes a smaller share of the p.d.

C — In the dark the LDR's resistance is high, so the LDR takes most of the p.d., leaving less for the thermistor.

D — Dark makes the LDR's resistance high and hot makes the thermistor's resistance low: this gives the smallest p.d. across the thermistor.

Watch out for

C. Students who remember 'dark ▮ high resistance' apply it to the wrong component. The LDR needs to be low (bright) so it takes a small share; only the thermistor needs to be high (cold).

Q35 Answer **A**

Why A is correct

The switch must be in the live wire, so that turning the heater off disconnects it from the high voltage. Terminal X goes through the switch to the heater, so X is live.

The earth wire is connected to the metal case, so that if a fault makes the case live, a large current flows to earth and blows the fuse. Terminal Y is joined to the case, so Y is earth.

Terminal Z completes the circuit from the other end of the heater, so Z is neutral.

Why the rest are wrong

B — Y is joined to the metal case, which must be earth, not neutral; Z is not connected to the case so it cannot be earth.

C — The switch is on X, and the switch must be in the live wire, so X cannot be neutral.

D — X has the switch so it must be live, and the case (Y) must be earth, not live.

Watch out for

D. Picking the row with the case connection wrong. The wire joined to the metal case is always earth; the wire with the switch is always live.

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Q36 Answer **B**

Why B is correct

The beam enters moving to the left and bends towards the bottom of the page. So at the start the force on the particles is towards the bottom of the page, at right angles to their motion.

A magnetic force is at right angles to both the motion and the field. The motion is left and the force is down, both in the plane of the page, so the field must be into or out of the page. This rules out A and D.

Try a field out of the page with Fleming's left-hand rule: First finger (field) out of the page, seCond finger (current) to the left. The thumb (force) then points towards the top of the page. So a positive charge would bend upwards.

The beam bends downwards, the opposite way, so the particles are negative. (For negative charges moving left, the conventional current is to the right.) Answer B.

Why the rest are wrong

A — A field from bottom to top of the page is in the same plane as the motion, so the force would be into or out of the page, not downwards in the page.

C — With a field out of the page, positive particles moving left are pushed towards the top of the page, which is the opposite of what is shown.

D — A field from top to bottom of the page is in the plane of the page, so the force would be into or out of the page, not downwards in the page.

Watch out for

C. Forgetting that Fleming's left-hand rule uses conventional current. For negative particles moving left, the current points right; the second finger must point right.

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Q37 Answer **D**

Why D is correct

Parallel wires carrying currents in opposite directions repel. So the left wire is pushed left and the right wire is pushed right. Only C and D show this.

Use the right-hand grip rule for the field. The diagrams show each circle in perspective, viewed from slightly above, so the left and right ends of each ellipse show the field going towards or away from you.

Left wire, current upwards: the field is anticlockwise seen from above. At the right-hand end of the circle the field goes away from you (drawn as an arrow pointing up the page), and at the left-hand end it comes towards you (arrow pointing down). Right wire, current downwards: the field is the other way round.

So the two wires must show opposite circulation. In D they do; in C both wires show the same circulation, which would need the currents in the same direction. Answer D.

Why the rest are wrong

A — The forces are towards each other (attraction), which happens for currents in the same direction. Also both field patterns circulate the same way.

B — The field patterns are correct, but the forces show attraction. Opposite currents repel.

C — The forces are correct (repulsion), but both field patterns circulate the same way, even though the currents are in opposite directions.

Watch out for

C. Choosing on the forces alone. C and D both show repulsion; the difference is that the field around each wire must circulate in opposite senses because the currents are opposite.

B. Remembering 'like attracts' from charges and applying it the wrong way. For currents: same direction attract, opposite directions repel.

Q38 Answer **A**

Why A is correct

By Lenz's law, the induced current flows in the direction that opposes the change producing it. The N pole of the magnet is moving towards the top of the solenoid, so the solenoid makes an N pole at its top to repel the approaching N pole.

Inserting the magnet more quickly makes the magnetic field through the coil change faster. By Faraday's law, the induced e.m.f. and so the induced current are larger.

A larger current in the solenoid makes its magnetic field stronger.

Why the rest are wrong

B — Moving the magnet faster increases the rate of change of field through the coil, so the induced current and the solenoid's field become stronger, not unchanged.

C — An S pole at the top would attract the incoming N pole, helping the motion. That would create energy from nothing; the induced pole must oppose the motion.

D — The pole is wrong (it must be N to oppose the approaching N pole), and the field does become stronger when the magnet moves faster.

Watch out for

C. Thinking 'opposite poles' and putting an S pole at the top. The induced pole opposes the motion, so an approaching N pole is met by an N pole.

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Q39 Answer **C**

Why C is correct

The time-base setting is the same, so each horizontal division represents the same time on both screens. Compare how many divisions one cycle takes.

Waveform P: one complete cycle takes 2 divisions (the screen is 3 divisions wide and shows 1½ cycles).

Waveform Q: the screen shows 2¼ cycles across the same 3 divisions, so one cycle takes $3 \div 2.25 = 4/3$ divisions.

Frequency is inversely proportional to period: $f_{\mathrm{Q}} = 300 \times 2 \div (4/3) = 300 \times 1.5 = 450\ \mathrm{Hz}$.

Why the rest are wrong

A — 90 Hz would mean Q has a much longer period than P. Q shows more cycles on the same screen, so its frequency is higher than 300 Hz.

B — 200 Hz is 300 × 2/3: the ratio has been inverted. Q has more cycles, so its frequency must be higher than P's.

D — 500 Hz would need 2½ cycles of Q on the screen. Q shows 2¼ cycles: it starts at zero and ends at a peak.

Watch out for

B. Using the period ratio the wrong way round. More waves on the same screen means a higher frequency.

D. Miscounting the cycles of Q. Q starts at zero going up and ends at a crest, so it shows 2¼ cycles, not 2½.

Q40 Answer **A**

Why A is correct

For an ideal transformer, power in = power out, so $V_{\mathrm{p}} I_{\mathrm{p}} = V_{\mathrm{s}} I_{\mathrm{s}}$. Combined with $V_{\mathrm{s}}/V_{\mathrm{p}} = N_{\mathrm{s}}/N_{\mathrm{p}}$, this gives $I_{\mathrm{s}}/I_{\mathrm{p}} = N_{\mathrm{p}}/N_{\mathrm{s}}$.

Ideal secondary current: $I_{\mathrm{s}} = I_{\mathrm{p}} \times N_{\mathrm{p}}/N_{\mathrm{s}} = 0.60 \times 500/1500 = 0.20\ \mathrm{A}$.

The actual current is 90% of this: $0.90 \times 0.20 = 0.18\ \mathrm{A}$.

Why the rest are wrong

B — 0.20 A is the ideal value. The question says the actual current is only 90% of this.

C — 1.6 A comes from using the turns ratio the wrong way $(0.60 \times 3 = 1.8\ \mathrm{A})$ and then taking 90% (1.62 A). A step-up transformer steps current down.

D — 1.8 A uses the turns ratio the wrong way round. A step-up transformer increases voltage and decreases current.

Watch out for

C. Multiplying the current by the turns ratio as if it were voltage. The current ratio is the inverse of the turns ratio.

B. Stopping at the ideal value and forgetting the 90%.

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