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TEN-YEAR SERIES · ANSWERS AND WORKED SOLUTIONS

2021 O-Level Physics Paper 1

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ANSWER KEY

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WORKED SOLUTIONS

Q1 Answer C

Why C is correct

The boat's own velocity V (its velocity in still water) and the wind's velocity W add as vectors to give the resultant velocity R: $R = V + W$.

To add vectors, draw them tip-to-tail: draw V, then start W at the tip of V. R goes from the tail of V to the tip of W.

The boat ends up due north of where it started, so R must point due north. W points east, so V must point north-west to cancel the eastward drift.

In C, V points north-west, W starts at the tip of V and points east, and R runs from the tail of V to the tip of W, pointing due north. This is the correct triangle.

Why the rest are wrong

A — W points west, but the wind blows from west to east, so W must point east.

B — V points north-east and R joins V's tail to W's tail, so here $R + W = V$, not $V + W = R$. Also, heading north-east with an eastward wind cannot bring the boat due north.

D — R is the north-west side. The resultant must point due north, because the boat arrives due north of its start. Here the north-pointing side is labelled V.

Watch out for

D. Students who think the boat must point north pick D. The boat must point upstream into the drift (north-west) so that the resultant is north.

B. Check the arrows: the resultant must join the tail of the first vector to the tip of the last one.

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Q2 Answer **B**

Why B is correct

Time to travel between the posts: t = distance ÷ average speed = $120 \div 20 = 6.0\ \text{s}$.

Acceleration $a = (v - u)/t = (26 - 14)/6.0 = 12/6.0 = 2.0\ \text{m/s}^2$.

Why the rest are wrong

A — $1.4\ \text{m/s}^2$ is 14 ÷ 10 or similar; it does not come from $(v - u) / t$.

C — $2.6\ \text{m/s}^2$ is 26 ÷ 10; it ignores the starting speed and uses the wrong time.

D — $3.3\ \text{m/s}^2$ is 20 ÷ 6.0, which divides the average speed by the time instead of the change in speed.

Watch out for

D. Students who divide the average speed (20 m/s) by the time pick D. Acceleration uses the change in velocity, $26 - 14 = 12\ \text{m/s}$.

Q3 Answer **D**

Why D is correct

Acceleration is the rate of change of velocity, not speed. Velocity has direction, so a change in direction is also an acceleration.

Non-uniform acceleration means this rate of change is not constant: it varies with time. So the complete description is D.

Why the rest are wrong

A — Constant rate of change describes uniform acceleration, and it uses speed instead of velocity.

B — It uses speed. Acceleration is the rate of change of velocity, so B is not a complete description.

C — A rate of change of velocity that is constant with time is uniform acceleration.

Watch out for

B. Students who mix up speed and velocity pick B. The word 'complete' points to velocity, which includes direction.

Q4 Answer **A**

Why A is correct

F is the Earth's gravitational pull on the book (the book's weight): the Earth acts on the book.

In an action-reaction pair the two forces are the same type, equal in size, opposite in direction and act on different bodies, with the bodies swapped.

So the partner of 'Earth on book' (gravitational) is 'book on Earth' (gravitational).

Why the rest are wrong

B — The book pushing on the table is a contact force; its partner is the table pushing on the book.

C — This involves the Earth and the table, not the book, so it cannot pair with F.

D — The table's upward push balances F, but both forces act on the book and are different types. Balanced forces on one body are not an action-reaction pair.

Watch out for

D. Students who confuse balanced forces with action-reaction pairs pick D. The two forces of a pair always act on different bodies.

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Q5 Answer **A**

Why A is correct

Three forces act on the child: weight, the contact (normal) force from the slide and friction.

Weight acts vertically downwards. The normal contact force acts perpendicular to the surface of the slide. Friction acts along the slide and opposes the motion, so it points up the slope.

Only diagram A shows all three in these directions.

Why the rest are wrong

B — Friction is drawn down the slope, in the direction of motion. Friction opposes the motion, so it points up the slope.

C — Weight is drawn along the slope. Weight always acts vertically downwards.

D — The contact force is drawn vertically upwards. The normal contact force is perpendicular to the slide's surface, so it is tilted.

Watch out for

D. Students who think the contact force always points straight up pick D. It is perpendicular to the surface the child touches.

Q6 Answer **B**

Why B is correct

Acceleration $a = (v - u)/t = (6.0 - 0)/2.0 = 3.0\ \text{m/s}^2$.

Resultant force = applied force − friction = $18 - 6.0 = 12\ \text{N}$.

$F = ma$, so $m = F/a = 12/3.0 = 4.0\ \text{kg}$.

Why the rest are wrong

A — 2.0 kg comes from 6.0 ÷ 3.0, using the friction instead of the resultant force.

C — 6.0 kg comes from 18 ÷ 3.0, which ignores friction.

D — 8.0 kg comes from (18 + 6.0) ÷ 3.0, adding friction instead of subtracting it.

Watch out for

C. Students who use the applied force 18 N instead of the resultant 12 N pick C.

Q7 Answer **C**

Why C is correct

The engine turns the wheel clockwise. At the bottom of the wheel, the tyre surface therefore tries to move to the left, pushing the road backwards.

Friction opposes this slipping. So the road pushes the wheel to the right — this forward friction is what accelerates the car to the right.

By Newton's third law, the wheel pushes the road with an equal and opposite friction force, to the left.

Why the rest are wrong

A — Friction on the wheel to the left would slow the car, but the car accelerates to the right.

B — Both directions are reversed: this would describe a wheel being braked, not driven.

D — The two frictional forces form an action-reaction pair, so they must point in opposite directions.

Watch out for

B. Students who think friction always opposes the motion of the car pick B. On a driven wheel, friction opposes the slipping of the tyre on the road, so it pushes the car forward.

Q8 Answer **C**

Why C is correct

Mass is the amount of matter in the spacecraft. It does not change from place to place, so the mass on Mars is the same as on Earth.

Weight $W = mg$. On Mars $g = 3.8\ \text{N/kg}$, smaller than 10 N/kg on Earth, so the weight on Mars is less than on Earth.

Why the rest are wrong

A — Mass does not change with location, and weight depends on g, which differs.

B — g on Mars is smaller, so the weight is smaller, not greater.

D — Weight = mg, and g on Mars is smaller, so the weight cannot be the same.

Watch out for

A. Students who mix up mass and weight pick A. Only weight depends on the gravitational field strength.

Q9 Answer **C**

Why C is correct

The rod is uniform, so its weight of 12 N acts at its centre. The figure shows the weight acting 50 cm from the right end, so the rod is 100 cm long and the weight is 50 cm from the hinge.

The dashed lines form a right-angled triangle. The 80 cm side lies along the line of action of F, and the 60 cm side is perpendicular to it from the hinge. So the perpendicular distance from the hinge to F is 60 cm. (Check: $\sqrt{60^2 + 80^2} = 100\ \text{cm}$, the length of the rod.)

Take moments about the hinge. Clockwise moment = anticlockwise moment: $12 \times 50 = F \times 60$

$F = 600/60 = 10\ \text{N}$.

Why the rest are wrong

A — 6.0 N is 12 × 50 ÷ 100, using the length of the rod as the distance for F. F does not act perpendicular to the rod.

B — 7.5 N is 12 × 50 ÷ 80, using the 80 cm side, which lies along F, not perpendicular to it.

D — 12 N assumes F equals the weight; the moments of the two forces have different perpendicular distances.

Watch out for

A. Students who use 100 cm (the rod length) as the distance for F pick A. The moment uses the perpendicular distance from the pivot to the line of action, which is the 60 cm side.

Q10 Answer **D**

Why D is correct

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

This is the definition in D.

Why the rest are wrong

A — Other forces on a body (for example contact forces) need not pass through the centre of gravity.

B — Forces are not 'equal' at a point; this has no meaning as a definition.

C — This is close to the idea of centre of mass; the centre of gravity is defined using weight, not mass.

Watch out for

C. Students who confuse centre of gravity with centre of mass pick C. The definition must mention weight.

Q11 Answer **D**

Why D is correct

An object is more stable if its centre of gravity is lower and/or its base is wider.

The figure shows the centre of gravity above the middle of the object's height. The top surface has the same width as the base, so turning the object upside down keeps the same base width but puts the centre of gravity nearer the bench.

A lower centre of gravity means the object must be tilted further before the line of action of its weight falls outside the base, so it is more stable.

Why the rest are wrong

A — Adding weight on top raises the centre of gravity, making the object less stable.

B — A less dense material makes the object lighter, but the centre of gravity stays at the same height and the base is unchanged, so stability does not change.

C — A larger g increases the weight, but the centre of gravity and base stay the same, so the angle it can tilt before toppling does not change.

Watch out for

C. Students who think a heavier object is always more stable pick C. Stability depends on the height of the centre of gravity and the width of the base.

The answer depends on reading the figure: the centre of gravity is marked above the mid-height, and the top and bottom faces are the same width.

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Q12 Answer **B**

Why B is correct

Pressure due to a liquid $p = h\rho g$. Use SI units: $h = 120\ \text{cm} = 1.20\ \text{m}$, $\rho = 0.80\ \text{g/cm}^3 = 800\ \text{kg/m}^3$.

$p = 1.20 \times 800 \times 10 = 9600\ \text{Pa} = 9600\ \text{N/m}^2$.

$1\ \text{m}^2 = 10\,000\ \text{cm}^2$, so $p = 9600 \div 10\,000 = 0.96\ \text{N/cm}^2$.

The cross-sectional area of the tube is not needed: liquid pressure depends only on depth, density and g.

Why the rest are wrong

A — $0.096\ \text{N/cm}^2$ is ten times too small, a unit-conversion slip.

C — $96\ \text{N/cm}^2$ comes from 120 × 0.80 × 10 ÷ 10, mixing cm and g/cm^3 without proper conversion.

D — $960\ \text{N/cm}^2$ comes from 120 × 0.80 × 10 using cm and g/cm^3 directly, without converting units.

Watch out for

D. Students who multiply 120 × 0.80 × 10 straight from the given units pick D. Convert to m and kg/m^3 first, then convert Pa to N/cm^2.

Do not divide by the area $0.25\ \text{cm}^2$; it is extra information.

Q13 Answer **D**

Why D is correct

The pressure is transmitted equally through the liquid, so the pressure on both pistons is the same: $F_1/A_1 = F_2/A_2$.

Area = πr^2. The radius doubles from 10 cm to 20 cm, so the area becomes $2^2 = 4$ times larger.

$F_2 = F \times (A_2/A_1) = F \times 4 = 4F$.

Why the rest are wrong

A — F/4 has the ratio upside down; the larger piston gets the larger force.

B — F/2 uses the ratio of radii, upside down.

C — $2F$ uses the ratio of radii instead of areas. Area depends on radius squared.

Watch out for

C. Students who use the radius ratio (2) instead of the area ratio (4) pick C.

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Q14 Answer **C**

Why C is correct

The gas in the bubble is at the same pressure as the water around it.

At depth d, the pressure is P = atmospheric pressure + $\rho g d$.

At $d = 0$ (the surface), P equals atmospheric pressure, not zero. P then increases linearly with d, since ρ and g are constant.

So the graph is a straight line starting at atmospheric pressure and rising — graph C.

Why the rest are wrong

A — Pressure increases at a steady rate with depth, so the graph is a straight line, not a curve that gets steeper.

B — It starts at zero and levels off at atmospheric pressure. The pressure at the surface is atmospheric, and it keeps rising with depth.

D — It starts at zero. This ignores the atmospheric pressure acting on the surface of the ocean.

Watch out for

D. Students who use only $P = h\rho g$ and forget the atmosphere pressing on the water's surface pick D.

Q15 Answer **A**

Why A is correct

Gain in gravitational potential energy = mgh. It depends only on the mass and the vertical height gained.

The boxes are identical (same m) and rise through the same height h, so they gain equal GPE.

The force on box 2 does more work than the force on box 1, because it also does work against friction on the rough incline. That extra work becomes thermal energy, not GPE.

Why the rest are wrong

B — The GPE gains are equal, but the reason is wrong: the force on box 2 does more work, because some work is done against friction.

C — The extra work done on box 2 goes into thermal energy from friction, not into GPE.

D — GPE depends on the vertical height gained, not the distance moved along the slope.

Watch out for

B. Students who see 'equal GPE' and stop reading pick B. Check the reason too: the forces do different amounts of work because of friction.

Q16 Answer **C**

Why C is correct

Convert the speed: $90\ \text{km/h} = 90\,000\ \text{m} \div 3600\ \text{s} = 25\ \text{m/s}$. So the lorry moves 25 m every second.

Work done = force × distance moved in the direction of the force = $3600 \times 25 = 90\,000\ \text{J}$ each second.

Why the rest are wrong

A — 5400 J does not come from force × distance travelled in 1 s.

B — 40 000 J comes from 3600 ÷ 0.09, dividing instead of multiplying.

D — 324 000 J is 3600 × 90, using the speed in km/h without converting it to m/s.

Watch out for

D. Students who multiply by 90 without converting km/h to m/s pick D.

Q17 Answer **B**

Why B is correct

The smoke particles move in a random, zig-zag way.

This is because the smoke particles are bombarded unevenly from all sides by the air molecules, which are too small to see and move fast and randomly. The unequal collisions push each smoke particle in a changing direction.

Why the rest are wrong

A — The movement is random, but it is the invisible air molecules that hit the smoke particles, not the other way round.

C — The smoke particles do not vibrate about fixed positions; they wander randomly. The explanation is also reversed.

D — The explanation is correct, but the smoke particles move randomly from place to place; they do not just vibrate.

Watch out for

A. Students who reverse the cause pick A. The motion we see is of the smoke particles, so they are the ones being hit.

Q18 Answer **C**

Why C is correct

When air is cooled, its molecules move more slowly and are closer together, so the same mass occupies a smaller volume. The cool air is denser than the warm air.

Denser air sinks below less dense air, so the cold air from the unit sinks and sets up a convection current in the room.

Density is a property of the air as a whole, not of a single molecule.

Why the rest are wrong

A — Density does not apply to a single molecule. A cool air molecule is the same as a warm one; only the spacing between molecules changes.

B — Density does not apply to a single molecule, and the direction is wrong too.

D — If the cool air were less dense it would rise, not sink.

Watch out for

A. Students who pick A think individual molecules get denser. The molecules themselves do not change; they are closer together, so the air is denser.

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Q19 Answer **B**

Why B is correct

The temperature is constant, so the average kinetic energy of the molecules is constant. The average speed remains the same.

The gas expands, so the molecules have more space. They hit the walls less often per unit area, so the pressure decreases (pV = constant for a fixed mass at constant temperature).

Why the rest are wrong

A — Average speed depends on temperature, which is constant, so the speed does not decrease.

C — Increasing the volume at constant temperature lowers the pressure.

D — The pressure falls, not rises, and the speed stays the same.

Watch out for

A. Students who think expansion slows the molecules pick A. The average speed depends only on temperature.

Q20 Answer **D**

Why D is correct

During boiling, thermal energy must be supplied to keep the liquid boiling.

This energy (latent heat) is used to break the attractive forces between molecules and push them apart to form gas. It does not increase the kinetic energy of the molecules, so the temperature stays constant at the boiling point.

Why the rest are wrong

A — Boiling needs thermal energy supplied, and the temperature does not fall.

B — Without a supply of thermal energy the liquid stops boiling.

C — While the liquid boils, the temperature stays at the boiling point; the energy goes into changing state.

Watch out for

C. Students who think supplying heat always raises the temperature pick C. During a change of state the energy breaks bonds instead.

Q21 Answer **B**

Why B is correct

The two fixed points of the Celsius scale are the ice point (0 °C, pure melting ice) and the steam point (100 °C, pure water boiling at standard atmospheric pressure).

Difference = $100^\circ\mathrm{C} - 0^\circ\mathrm{C} = 100^\circ\mathrm{C}$. The −10 °C and 110 °C marks are just the ends of this thermometer's range; they are not fixed points.

Why the rest are wrong

A — 10 °C is the gap from −10 °C to 0 °C, or from 100 °C to 110 °C. Neither pair are the two fixed points.

C — 110 °C is the gap from 0 °C to 110 °C. 110 °C is only the top of the scale, not a fixed point.

D — 120 °C is the full range of the thermometer (−10 °C to 110 °C), not the gap between the fixed points.

Watch out for

D. Students who read 'difference' as the whole range of the scale pick D. The question asks about the fixed points, which are always the ice point and the steam point.

Q22 Answer **C**

Why C is correct

Condensation of steam at 100 °C happens at constant temperature. Temperature measures the average kinetic energy of the molecules, so while the steam is turning into water at 100 °C the kinetic energy stays the same.

As the gas becomes a liquid, the molecules move much closer together and attract each other more strongly. Energy is released as latent heat, so the potential energy decreases.

So kinetic energy stays the same and potential energy decreases.

Why the rest are wrong

A — Kinetic energy does not decrease during the change of state, because the temperature stays at 100 °C while condensation takes place.

B — This has the two energies the wrong way round. The temperature is constant, so kinetic energy is unchanged; it is the potential energy that falls as latent heat is given out.

D — If neither energy changed, no energy would be released. Condensation gives out latent heat, so the internal energy must fall, and that comes from the potential energy.

Watch out for

A. Students who think 'the mirror is cold, so everything cools' pick A. Focus on the change of state itself: it happens at a fixed temperature, so only the potential energy changes.

The question says 'during the process of condensation'. Any further cooling of the water drops on the mirror afterwards is a separate step and is not asked about.

Q23 Answer **B**

Why B is correct

Specific heat capacity: $Q = mc\Delta T$, so $c = Q \div (m\Delta T)$

$c = 3800 \div (2.0 \times 5.0) = 380\ \text{J/(kg°C)}$

Heat capacity of the whole pan: $C = Q \div \Delta T = 3800 \div 5.0 = 760\ \text{J/°C}$. (Check: $C = mc = 2.0 \times 380 = 760\ \text{J/°C}$.)

Why the rest are wrong

A — 190 J/°C comes from dividing 380 by 2.0. Heat capacity is m × c, so you multiply by the mass, which gives 760 J/°C.

C — 9500 comes from (3800 × 5.0) ÷ 2.0, which multiplies by the temperature rise instead of dividing. 4800 does not match any correct working.

D — 9500 J/(kg °C) multiplies by ΔT instead of dividing by it, and $19\,000\ \text{J/°C} = 3800 \times 5.0$ makes the same mistake.

Watch out for

A. Students who mix up the two quantities divide by the mass again to get heat capacity. Remember: heat capacity is for the whole object (J/°C), so $C = mc$, which is bigger than c when $m > 1\ \text{kg}$.

Q24 Answer **B**

Why B is correct

The back surface heats up only if energy from the flash is conducted through the block quickly, and the energy that arrives raises the temperature by a lot.

A poor thermal conductor lets very little energy reach the back surface in the short time before T is measured.

A large heat capacity means a given amount of energy causes only a small temperature rise.

Both effects keep T small, so the block with a large heat capacity made from a poor conductor has the smallest T.

Why the rest are wrong

A — A good conductor carries energy to the back surface quickly, so T rises more than for a poor conductor.

C — A good conductor with a small heat capacity gives the largest T: energy arrives quickly and each joule raises the temperature a lot.

D — A small heat capacity means the little energy that does get through causes a bigger temperature rise than in B.

Watch out for

D. Students who look only at conduction pick D because both B and D are poor conductors. Then use heat capacity to decide: a larger heat capacity gives a smaller temperature rise for the same energy.

Q25 Answer **A**

Why A is correct

Refractive index $n = \sin i \div \sin r$, where i and r are both measured from the normal (the dashed line).

In the figure, P is the angle between the incident ray in air and the normal, so P is the angle of incidence. R is the angle between the refracted ray in glass and the normal, so R is the angle of refraction.

So $\sin P \div \sin R = n$ for glass, which stays constant as the angle of incidence changes.

Why the rest are wrong

B — Q and S are measured from the glass surface, not from the normal. $Q = 90° - P$ and $S = 90° - R$, so $\sin Q \div \sin S = \cos P \div \cos R$, which changes as P changes.

C — P is from the normal but S is from the surface. Mixing the two does not give Snell's law, so the ratio is not constant.

D — Q is from the surface but R is from the normal. Again the two angles are measured from different lines, so the ratio changes.

Watch out for

B. Students who measure angles from the surface pick B. In refraction (and reflection) the angles are always measured from the normal.

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Q26 Answer **A**

Why A is correct

Light travels down the vertical tube and has to turn through 90° to travel to the left, towards the person.

For total internal reflection the ray must enter the prism through one of the two short faces at right angles, hit the long face (the hypotenuse) at 45°, and leave through the other short face. Inside glass the critical angle is about 42°, so 45° is larger and the ray is totally internally reflected.

To send a downward ray to the left, the hypotenuse must slope like the mirror at the top, from bottom-left to top-right. The ray enters through the top face, reflects off the hypotenuse, and leaves through the left face. This is the prism in A, with its right angle at the top left.

Why the rest are wrong

B — The hypotenuse slopes the right way, but it faces the incoming ray. The light enters through the hypotenuse and then strikes the bottom face and the right face, so it is not sent out to the left.

C — The hypotenuse slopes from top-left to bottom-right. A downward ray reflecting off it is sent to the right, away from the person.

D — The ray enters through the sloping hypotenuse, which faces the wrong way, so the light is not turned out through the left opening towards the person.

Watch out for

C. Students who pick C have the hypotenuse sloping the wrong way. Check with the top mirror: the bottom reflector must be parallel to it, sloping from bottom-left to top-right.

B. B has the right slope but the wrong position. The light must enter and leave through the two short faces and reflect off the long face.

Q27 Answer **D**

Why D is correct

Microwaves are on the long-wavelength side of the electromagnetic spectrum, between radio waves and infrared. So they have a lower frequency than visible light.

Microwaves are absorbed by water molecules in food and in the body, and this makes them vibrate more, which raises the temperature. This is how a microwave oven cooks food, and it is why too much exposure to microwaves can cause internal heating of body tissue.

Why the rest are wrong

A — Microwaves have a lower frequency than visible light, and they can heat body tissue. Both parts are wrong.

B — The frequency is right, but microwaves can heat body tissue; that is their main hazard.

C — Microwaves can heat body tissue, but their frequency is lower than that of visible light, not higher.

Watch out for

B. Students who think only high-frequency waves (UV, X-rays, gamma) are harmful pick B. Microwaves do not ionise, but they still cause internal heating of body tissue.

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Q28 Answer **D**

Why D is correct

The ultrasound pulse travels from the scanner to the crack and back again at a known speed v in the metal.

The scanner measures the time t between sending the pulse and detecting the echo. The distance to the crack is then $d = v \times t \div 2$ (divide by 2 because the pulse travels there and back).

Why the rest are wrong

A — The wavelength of the pulse is the same after reflection, so it says nothing about how far away the crack is.

B — Reflection does not change the frequency, so the frequency gives no information about the depth of the crack.

C — The speed is a property of the metal and is already known. It is used in the calculation but it does not depend on where the crack is.

Watch out for

C. Students who remember the formula 'distance = speed × time' pick C because speed appears in it. The speed is fixed for the metal; the quantity that changes with the depth of the crack, and so must be measured, is the echo time.

Q29 Answer **D**

Why D is correct

An electric field is a region in which an electric charge experiences a force. This is the definition of an electric field, so a charge always feels a force there.

Uncharged objects such as a neutral coil, a magnet or a neutral piece of plastic need not feel any force.

Why the rest are wrong

A — A coil of wire with no charge on it feels no force in an electric field. A coil carrying a current feels a force in a magnetic field, which is a different thing.

B — A magnet feels a force in a magnetic field, not an electric field.

C — A piece of plastic feels a force only if it is charged. A neutral piece of plastic does not always experience a force.

Watch out for

B. Students who mix up electric and magnetic fields pick B. A magnetic field acts on magnets and currents; an electric field acts on charges.

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Q30 Answer **A**

Why A is correct

The positive rod attracts free electrons. Because the sphere is earthed, electrons flow up from the earth through the wire on to the sphere.

The sphere now has more electrons than protons, so it has a negative charge, held there by the attraction of the rod.

Why the rest are wrong

B — Protons are fixed in the nuclei of the atoms and cannot move. Only electrons move in charging.

C — Protons cannot move. Also, the sphere does not stay neutral, because electrons flow on to it from the earth.

D — Earthing does not make the sphere neutral while the rod is nearby. The earth wire lets electrons flow on to the sphere, so the sphere becomes negative.

Watch out for

D. Students who think 'earthed means neutral' pick D. With a charged rod nearby, the earth wire lets electrons flow on to the sphere, so the sphere becomes negative.

B. Protons never move in electrostatic charging; only electrons do.

Q31 Answer **C**

Why C is correct

The plate starts positively charged everywhere. First, light from the white parts of the document falls on the plate and the charge leaks away there (R). Only the dark parts of the image are left positive.

Next, the negatively charged black toner is attracted to the remaining positive areas (P).

Finally, paper is placed over the plate, the toner is transferred to it and heated so that it sticks (Q). So the order is R → P → Q.

Why the rest are wrong

A — Toner cannot be attracted to 'the remaining positive areas' before light has removed the charge from the other areas; at that point the whole plate is positive.

B — Paper cannot pick up toner before any toner has been put on the plate.

D — The toner must be on the plate before the paper is placed over it, so P must come before Q.

Watch out for

A. Students who pick A put toner on first. Step P says 'remaining positive areas', which only makes sense after light has removed charge in step R.

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Q32 Answer **B**

Why B is correct

$Q = It$

$I = 300\ \text{mA} = 0.300\ \text{A}$ and $t = 20\ \text{min} = 20 \times 60 = 1200\ \text{s}$

$Q = 0.300 \times 1200 = 360\ \text{C}$

Why the rest are wrong

A — 6.0 C comes from 0.300 × 20, using the time in minutes instead of seconds.

C — 6000 C comes from 300 × 20, leaving the current in mA and the time in minutes.

D — 360 000 C comes from 300 × 1200, leaving the current in mA instead of converting it to amperes.

Watch out for

D. Students who convert minutes to seconds but forget mA to A get 360 000 C. Convert both: $300\ \text{mA} = 0.300\ \text{A}$ and $20\ \text{min} = 1200\ \text{s}$.

Q33 Answer **A**

Why A is correct

Charge that passes: Q = number of electrons × charge on each = $2.5 \times 10^{19} \times 1.6 \times 10^{-19} = 4.0\ \text{C}$

Energy converted in 3.0 s: $E = Pt = 4.0 \times 3.0 = 12\ \text{J}$

Potential difference: $V = E \div Q = 12 \div 4.0 = 3.0\ \text{V}$

(Or: $I = Q \div t = 4.0 \div 3.0 = 1.33\ \text{A}$, and $V = P \div I = 4.0 \div 1.33 = 3.0\ \text{V}$.)

Why the rest are wrong

B — 4.0 V uses the charge (4.0 C) or the power (4.0 W) as if it were the p.d. V is energy per unit charge, so you must divide the energy (12 J) by the charge.

C — 12 V is the energy in joules (12 J), not the p.d. You still need to divide by the charge, 4.0 C.

D — 36 V comes from 12 × 3.0, multiplying by the time a second time. The time has already been used to find the energy.

Watch out for

C. Students who stop at $E = Pt = 12\ \text{J}$ pick C. The p.d. is the energy transferred per coulomb, so divide by the 4.0 C of charge.

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Q34 Answer **A**

Why A is correct

Resistance $R = V \div I$ at each point (the ratio, not the slope).

At J the p.d. is not zero but the current is zero, so the resistance is extremely large (effectively infinite).

At K the current is small compared with the p.d., so $V \div I$ is large. At L the current is much larger for a p.d. that is less than twice as big, so $V \div I$ is much smaller.

So the order from largest to smallest is J, K, L.

Why the rest are wrong

B — L has a much larger current than K for a p.d. less than twice as big, so the resistance at L is smaller than at K, not larger.

C — J has zero current, so it has the largest resistance, not the smallest.

D — This is the reverse order. The diode's resistance falls as the p.d. increases past the point where it starts to conduct.

Watch out for

D. Students who think 'more current means more resistance' get the order backwards. A larger current for a similar p.d. means a smaller resistance.

Use $V \div I$ at the point, not the steepness of the curve, to compare resistances.

Q35 Answer **C**

Why C is correct

Let each resistor have resistance R and the battery p.d. be V. All three branches are connected directly across the battery.

Left branch: $2R$, current $V \div 2R$. Middle branch (through M): $2R$, current $I_{\mathrm{M}} = V \div 2R$. Right branch: R, current $V \div R = 2 \times V \div 2R$.

Current at L (total) = $V \div 2R + V \div 2R + 2 \times V \div 2R = 4 \times V \div 2R$

Ratio $I_{\mathrm{L}} \div I_{\mathrm{M}} = (4 \times V \div 2R) \div (V \div 2R) = 4.0$

Why the rest are wrong

A — 2.5 would come from treating the circuit as if the total resistance were 2.5 times the branch resistance; it does not follow from the branch currents.

B — 3.0 comes from assuming all three branches carry equal currents. The right branch has only one resistor, so it carries twice the current of each two-resistor branch.

D — 5.0 is the number of resistors, but current does not split according to how many resistors there are.

Watch out for

B. Students who see three branches and split the current equally pick B. The single-resistor branch has half the resistance, so it takes twice the current.

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Q36 Answer **D**

Why D is correct

In each circuit the two branches are in parallel across the 6.0 V supply, so each branch has 6.0 V across it. The p.d. splits between the two resistors in a branch in the ratio of their resistances.

In A, B and C the two branches have the same ratio top : bottom (10 : 5, 5 : 10 and 10 : 10 with 5 : 5). So P and Q are at the same potential and the p.d. between them is zero.

In D, the left branch is 5.0Ω on top and 10Ω below, so the bottom resistor has $6.0 \times 10 \div 15 = 4.0\ \text{V}$ across it: P is 4.0 V above the bottom wire. The right branch is 10Ω on top and 5.0Ω below, so the bottom resistor has $6.0 \times 5.0 \div 15 = 2.0\ \text{V}$: Q is 2.0 V above the bottom wire.

P.d. between P and $Q = 4.0 - 2.0 = 2.0\ \text{V}$, which is greater than zero.

Why the rest are wrong

A — Both branches are 10Ω over 5.0Ω, so P and Q are both 2.0 V above the bottom wire. The p.d. between them is zero.

B — Both branches are 5.0Ω over 10Ω, so P and Q are both 4.0 V above the bottom wire. The p.d. between them is zero.

C — Each branch has two equal resistors, so P and Q are both at the midpoint, 3.0 V. The p.d. between them is zero.

Watch out for

C. Students who think different resistances in the two branches must give a p.d. pick C. What matters is the ratio within each branch: equal ratios give equal potentials at P and Q.

Q37 Answer **C**

Why C is correct

Both the fuse and the switch must be in the live wire.

Then when the switch is off, or the fuse has blown, the heater is cut off from the high voltage of the live wire and is safe to touch. If they are in the neutral wire, the heater stays connected to the live wire even when switched off or after the fuse has blown.

Only circuit C has both the fuse and the switch in the live wire.

Why the rest are wrong

A — Both the fuse and the switch are in the neutral wire. With the switch off, the heater is still at the live potential and can give a shock.

B — The switch is in the live wire but the fuse is in the neutral wire. If the fuse blows, the heater is still connected to the live wire.

D — The fuse is in the live wire but the switch is in the neutral wire. With the switch off, the heater element is still connected to the live wire.

Watch out for

D. Students who remember only 'fuse in live' pick D. The switch must also be in the live wire, so that switching off really isolates the appliance.

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Q38 Answer **B**

Why B is correct

Magnetic field lines point away from a north pole and towards a south pole.

At X the arrows point away from the magnet, so X is N. At Y the lines arrive and the arrows point into the magnet, so Y is S. At Z the arrows point away from the magnet (towards Y and downwards), so Z is N.

So $X = N$, $Y = S$, $Z = N$.

Why the rest are wrong

A — Y has field lines going into it, so it is a south pole, not north. And the lines leave Z, so Z is north.

C — X has field lines leaving it, so it is a north pole, not south; and Y is a south pole, not north.

D — X has field lines leaving it, so it is a north pole, not south.

Watch out for

D. Students who read the arrows near Z as pointing into Z pick D. Look at the arrowheads beside Z: they point away from Z, towards Y and downwards, so Z is a north pole like X.

The lines from X and Z curve away from each other below the magnets, which also shows X and Z are like poles.

Q39 Answer **A**

Why A is correct

The field is horizontal, from N to S (left to right). The coil starts horizontal. Its two sides that run along the axis are at right angles to the field, so they feel forces.

From the arrows, the current in the side near N flows away from X (into the page), and the current in the side near S flows towards X. Using Fleming's left-hand rule (field to the right): the side near N is pushed down and the side near S is pushed up.

Viewed from X, the left side goes down and the right side goes up, so the coil turns anticlockwise.

The turning effect is largest when the coil is horizontal and falls to zero when the coil is vertical (plane at right angles to the field): the forces then pull along the plane of the coil, not round it. There is no commutator, so the current does not reverse. If the coil swings past vertical, the forces turn it back, so it eventually settles vertical, $\theta = 90°$.

Why the rest are wrong

B — The direction is right, but at 180° the coil would be horizontal again and the forces would turn it back. The coil settles at 90°, where the turning effect is zero and any small displacement is turned back.

C — Fleming's left-hand rule gives the side near N a downward force and the side near S an upward force, which is anticlockwise when viewed from X.

D — Both the direction and the angle are wrong; see A and C.

Watch out for

B. Students who think of an electric motor pick 180°. In a motor the split-ring commutator reverses the current every half turn so it keeps turning. Here the current is constant, so the coil stops in the vertical position, 90° from the start.

C. Check the view carefully: X is the end of the axis nearest you, so the N pole is on your left.

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Q40 Answer **C**

Why C is correct

Moving the magnet into the coil induces a current in one direction (deflection to the left). Pulling it out reverses the change in magnetic flux, so the induced current is in the opposite direction: the deflection is to the right.

The size of the induced e.m.f. depends on the rate of change of magnetic flux. Moving the magnet slowly gives a smaller rate of change, so the deflection is decreased.

Why the rest are wrong

A — Pulling the magnet out reverses the direction of the induced current, so the deflection cannot still be to the left.

B — Both are wrong: the direction reverses, and moving slowly gives a smaller deflection.

D — The direction is right, but moving slowly reduces the rate of change of flux, so the deflection is smaller, not unchanged.

Watch out for

D. Students who think the same magnet must give the same size of deflection pick D. The induced e.m.f. depends on how fast the flux changes, not just on how much it changes.

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