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TEN-YEAR SERIES · ANSWERS AND WORKED SOLUTIONS

2024 O-Level Physics Paper 1

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ANSWER KEY

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WORKED SOLUTIONS

Q1 Answer B

Why B is correct

The seven SI base units include the kilogram (kg), metre (m), second (s) and ampere (A). Every other unit, such as the coulomb, joule and newton, is a derived unit.

Option B, $\mathrm{kg\ m^2/(s^3\ A)}$, is built only from kg, m, s and A, so it contains only base units.

It is in fact the base-unit form of the volt: $V = W \div A = (J \div s) \div A = (\mathrm{kg\ m^2\ s^{-2}}) \div (sA) = \mathrm{kg\ m^2\ s^{-3}\ A^{-1}}$.

Why the rest are wrong

A — The coulomb (C) is a derived unit: $1\ \mathrm{C} = 1\ \mathrm{A\ s}$. So this expression is not made of base units only.

C — The joule (J) is a derived unit: $1\ \mathrm{J} = 1\ \mathrm{kg\ m^2\ s^{-2}}$. So J / (A s) contains a derived unit.

D — The newton (N) is a derived unit: $1\ \mathrm{N} = 1\ \mathrm{kg\ m\ s^{-2}}$. So N m / (A s) contains a derived unit.

Watch out for

A. It looks very close to B, and the coulomb feels like a basic electrical unit.

The base electrical unit is the ampere, not the coulomb. Charge is defined from current: $Q = It$, so $C = As$.

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Q2 Answer A

Why A is correct

The resultant of two forces depends on the angle between them. It is largest when they point the same way and becomes smaller as the angle between them opens up.

At $\theta = 0°$, the forces act along the same line: resultant = $3.0\ \text{N} + 4.0\ \text{N} = 7.0\ \text{N}$.

At $\theta = 90°$, the forces are perpendicular: resultant = $\sqrt{3.0^2 + 4.0^2} = \sqrt{25} = 5.0\ \text{N}$.

As θ goes from 0° to 90°, the resultant falls steadily from 7.0 N to 5.0 N. So only values from 5.0 N to 7.0 N are possible. 1.0 N is outside this range.

A resultant of 1.0 N would need the forces to point in opposite directions ($\theta = 180°$), which is not allowed here.

Why the rest are wrong

B — 5.0 N is the resultant when $\theta = 90°$, so it is possible.

C — 6.0 N lies between 5.0 N and 7.0 N, so it occurs at some angle between 0° and 90°.

D — 7.0 N is the resultant when $\theta = 0°$, so it is possible.

Watch out for

B or D. Students may think the end values are not allowed, but 0° and 90° are both included in the range.

Always work out the resultant at both limits of the angle and check which options fall between them.

Q3 Answer C

Why C is correct

First find the average time: $t = (0.56 + 0.62 + 0.64 + 0.58)\ \text{ms} \div 4 = 2.40\ \text{ms} \div 4 = 0.60\ \text{ms}$.

Convert to seconds: $0.60\ \text{ms} = 0.60 \times 10^{-3}\ \text{s}$.

Speed = distance ÷ time: $v = d \div t = 3.0\ \text{m} \div (0.60 \times 10^{-3}\ \text{s}) = 5000\ \text{m/s}$.

Why the rest are wrong

A — 1250 m/s comes from dividing by 2.40 ms (the total of the four times) instead of the average.

B — 2500 m/s is half the correct value; it would need a time of 1.2 ms, twice the average.

D — 10 000 m/s is twice the correct value; it would need a time of 0.30 ms, half the average.

Watch out for

A. Forgetting to divide the total time by 4 gives 1250 m/s.

Find the mean time first, then convert ms to s before using $v = d \div t$.

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Q4 Answer **B**

Why B is correct

Gravitational field strength g is the gravitational force per unit mass acting on a mass in the field.

So g = gravitational force ÷ mass, measured in N/kg. On Earth, $g \approx 10\ \mathrm{N/kg}$.

Why the rest are wrong

A — Force × mass has units N kg, not N/kg. It does not describe force per unit mass.

C — Weight is the gravitational force, so force ÷ weight is always 1 with no units.

D — Weight ÷ gravitational force is also always 1, for the same reason.

Watch out for

A. Students who remember $W = mg$ may rearrange it wrongly.

From $W = mg$, divide both sides by m: $g = W \div m$. Field strength is force per unit mass.

Q5 Answer **D**

Why D is correct

Weight is the gravitational force that the Earth exerts on a body. It always acts vertically downwards.

The metal hangs at rest, so the downward weight is balanced by the upward pull of the spring.

Why the rest are wrong

A — Friction acts between surfaces that slide or try to slide over each other. There is no such surface here.

B — Mass is the amount of matter in a body, measured in kg. It is not a force.

C — Tension is the pull of the spring on the metal. It acts upwards, not downwards.

Watch out for

C. The spring is stretched, so tension comes to mind first.

Tension in the spring pulls the metal up towards the spring. The force pulling it down is its weight.

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Q6 Answer **A**

Why A is correct

Air resistance on a ball increases with its speed. At terminal velocity, air resistance equals weight and the resultant force is zero.

Here the ball moves faster than its terminal velocity, so the air resistance on it is greater than its weight.

The resultant force is therefore upwards, opposite to the motion. The ball decelerates, so it begins to slow down.

As it slows, air resistance decreases until it equals the weight. The ball then falls at its terminal velocity.

Why the rest are wrong

B — A constant velocity needs zero resultant force, but here air resistance exceeds weight.

C — Terminal velocity depends on the ball's weight, shape and size and on the air. Starting faster does not change it.

D — Acceleration of free fall happens only when weight is the only force. Here there is a large air resistance, so the ball is not in free fall.

Watch out for

B. Students may think a moving object keeps its speed.

Compare the forces: if air resistance > weight, the resultant force opposes motion and the object slows down.

Q7 Answer **B**

Why B is correct

The engine turns the front wheels. Each front tyre pushes backwards on the road. By Newton's third law, the road pushes forwards on the tyre. So F_1 acts forwards, in the direction of motion.

The rear wheels are not driven. They are pushed along by the car, and friction at the road opposes their motion, so F_2 acts backwards.

Diagram B shows F_1 forwards (to the right) and F_2 backwards (to the left).

Why the rest are wrong

A — It shows F_1 backwards. The driven front wheels push back on the road, so the road pushes them forwards.

C — It shows F_2 forwards. The rear wheels are not driven, so friction on them opposes motion.

D — It has both forces the wrong way round: F_1 backwards and F_2 forwards.

Watch out for

A. Many students think friction always opposes motion.

Friction opposes sliding between surfaces. A driven tyre tries to slide backwards on the road, so friction on it points forwards.

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Q8 Answer **A**

Why A is correct

When the support just leaves the ground, the wheelbarrow turns about the axle of the wheel. The ground no longer pushes on the support.

Principle of moments about the axle: clockwise moment = anticlockwise moment.

Distance of F from the axle = $0.80\ \text{m} + 0.80\ \text{m} = 1.60\ \text{m}$. Distance of the weight from the axle = 0.80 m.

$F \times 1.60\ \text{m} = 400\ \text{N} \times 0.80\ \text{m}$, so $F = 320\ \text{N m} \div 1.60\ \text{m} = 200\ \text{N}$.

Why the rest are wrong

B — 320 N m is the value of the moment of the weight, not the force F.

C — 400 N would be needed only if F acted at the same distance from the axle as the weight.

D — 800 N comes from using 0.80 m for F and 1.60 m for the weight, which swaps the distances.

Watch out for

D. Using the wrong distance for each force gives 800 N.

Measure every distance from the pivot (the axle). F is 1.60 m away and the weight is 0.80 m away.

Q9 Answer **C**

Why C is correct

Density = mass ÷ volume of the glass. The glass volume is the block volume minus the volume of the hole.

Block volume = $10\ \text{cm} \times 9.0\ \text{cm} \times 5.0\ \text{cm} = 450\ \text{cm}^3$.

Hole volume = $\pi r^2 h = \pi \times (1.5\ \text{cm})^2 \times 7.0\ \text{cm} \approx 49.5\ \text{cm}^3$. The radius is half the diameter: $3.0\ \text{cm} \div 2 = 1.5\ \text{cm}$.

Glass volume = $450\ \text{cm}^3 - 49.5\ \text{cm}^3 \approx 400\ \text{cm}^3$.

Mass = $1.0\ \text{kg} = 1000\ \text{g}$. Density = $1000\ \text{g} \div 400\ \text{cm}^3 = 2.5\ \text{g/cm}^3$.

Why the rest are wrong

A — $2.2\ \text{g/cm}^3$ is the mass divided by the full block volume ($1000\ \text{g} \div 450\ \text{cm}^3$), ignoring the hole.

B — $2.3\ \text{g/cm}^3$ would need a glass volume of about $435\ \text{cm}^3$, meaning a hole of only about $15\ \text{cm}^3$. The real hole is about $49.5\ \text{cm}^3$.

D — $2.6\ \text{g/cm}^3$ comes from making the hole too big, for example running it through the full 10 cm height: $450 - \pi \times 1.5^2 \times 10 \approx 379\ \text{cm}^3$, and $1000 \div 379 \approx 2.6\ \text{g/cm}^3$. The hole is only 7.0 cm deep.

Watch out for

A. Forgetting to subtract the hole gives $2.2\ \text{g/cm}^3$.

The hole contains no glass. Subtract its volume, and use the radius (1.5 cm), not the diameter, in $\pi r^2 h$.

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Q10 Answer **A**

Why A is correct

Pressure in a liquid depends on depth, density and g: $p = h\rho g$. It does not depend on the shape of the container or the amount of liquid.

All three vessels hold water, so ρ is the same. The water surface is at the same level and the bottoms are on the same table, so the depth h is the same.

Therefore $PX = PY = PZ$.

Why the rest are wrong

B — This ranks by the width of the water surface. Pressure does not depend on the surface area or on how much water is above the base.

C — Z has the widest base, but a wider base does not reduce the pressure at a given depth.

D — Z does not have the greatest pressure. The weight of water is larger in Z, but so is its base area, and the pressure $h\rho g$ is the same.

Watch out for

D or B. Students often think more water above the base, or a narrower base, changes the pressure.

Use $p = h\rho g$. Same liquid and same depth means same pressure, whatever the shape.

Q11 Answer **B**

Why B is correct

In a manometer, the side with the higher pressure pushes its water surface further down.

In the diagram, the water level on the gas-supply side is lower than the level on the side open to the atmosphere.

So the gas supply pushes harder than the atmosphere: gas pressure = atmospheric pressure + $h\rho g$, where h is the difference in levels. The gas pressure is greater than atmospheric pressure.

Why the rest are wrong

A — Equal pressures would give equal water levels in both arms.

C — If the gas pressure were less than atmospheric, the water would be pushed up on the gas side, not down.

D — Zero pressure is far below atmospheric; the water would rise high up the gas side.

Watch out for

C. Students may think the higher column belongs to the side with the higher pressure.

The side with the higher pressure pushes its liquid down. The liquid rises on the side with the lower pressure.

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Q12 Answer **D**

Why D is correct

A potential energy store holds energy because of position, arrangement or chemical bonds. Chemical, elastic and gravitational stores are all of this kind.

The kinetic store holds energy because an object is moving. It is not a potential energy store.

Why the rest are wrong

A — Chemical potential energy is stored in the bonds between particles, for example in fuel or food.

B — Elastic potential energy is stored in a stretched or compressed object, such as a spring.

C — Gravitational potential energy is stored because of an object's height in a gravitational field.

Watch out for

A. Chemical energy is sometimes not thought of as potential energy.

Energy due to motion is kinetic. Energy stored due to position, shape or bonds is potential.

Q13 Answer **D**

Why D is correct

Energy = power × time: $E = Pt$.

$P = 5.0\ \text{kW} = 5000\ \text{W}$. $t = 2$ hours = $2 \times 3600\ \text{s} = 7200\ \text{s}$.

$E = 5000\ \text{W} \times 7200\ \text{s} = 3.6 \times 10^7\ \text{J}$.

Why the rest are wrong

A — $1.0 \times 10^4\ \text{J}$ is 5000 × 2, using hours instead of seconds.

B — $3.6 \times 10^4\ \text{J}$ is 5 × 7200, using kW instead of W.

C — $6.0 \times 10^5\ \text{J}$ is 5000 × 120, using minutes instead of seconds.

Watch out for

B or A. These come from not converting kW to W or hours to seconds.

For joules, power must be in W and time in s. $1\ \text{kW} = 1000\ \text{W}$ and $1\ \text{h} = 3600\ \text{s}$.

Q14 Answer **D**

Why D is correct

Temperature is linked to the average kinetic energy of the gas particles. When the gas is heated, the particles gain kinetic energy and move faster.

The volume is constant, so the particles stay the same average distance apart. Because they move faster, they hit the walls more often and harder, and the pressure rises.

Why the rest are wrong

A — Faster particles hit the walls more often, not less often.

B — Particles do not change size when heated. The particles themselves never expand.

C — The container's volume is fixed, so the average spacing between particles does not change.

Watch out for

B. Students picture the gas expanding and give the particles that property.

A substance can expand because its particles move further apart, but the particles themselves keep the same size. Here even the spacing is fixed.

Q15 Answer **B**

Why B is correct

Energy is always transferred by conduction from a region of higher temperature to a region of lower temperature.

Rubber is an electrical insulator, so it has no free electrons to carry energy.

In rubber, conduction happens by vibration of the particles: hotter particles vibrate more and pass energy to their neighbours through the bonds between them.

Why the rest are wrong

A — The direction is correct, but rubber has no free electrons, so energy is not carried by electron movement.

C — Energy does not flow from cold to hot by conduction, and rubber has no free electrons.

D — Molecular vibration is correct, but the direction is wrong.

Watch out for

A. Students recall that electrons carry energy in conduction.

Free-electron transfer happens only in metals. In non-metals such as rubber, conduction is by particle vibrations only, which is why it is slow.

Q16 Answer **D**

Why D is correct

The cubes are identical in size and material, and start at the same temperature. The main difference is how well their surfaces emit infrared radiation.

Dull, black surfaces are the best emitters of infrared radiation. Shiny, white surfaces are the poorest emitters.

The white, shiny cube loses energy by radiation most slowly, so its temperature falls at the smallest rate.

Why the rest are wrong

A — A dull black surface is the best emitter, so this cube cools fastest.

B — Black is a good emitter, so this cube cools faster than a white shiny one.

C — Dull surfaces emit better than shiny ones, so this cube cools faster than a white shiny one.

Watch out for

A. Students may pick the extreme case without reading that the question asks for the smallest rate.

Good absorbers are good emitters. Pick the poorest emitter (white, shiny) for the slowest cooling.

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Q17 Answer **B**

Why B is correct

Mass of water = $0.50\ \text{kg} - 0.30\ \text{kg} = 0.20\ \text{kg}$.

Energy for the cup: $Q = C\Delta\theta = 200\ \text{J/°C} \times 60\text{°C} = 12\,000\ \text{J}$.

Energy for the water: $Q = mc\Delta\theta = 0.20\ \text{kg} \times 4200\ \text{J/(kg°C)} \times 60\text{°C} = 50\,400\ \text{J}$.

Total = $12\,000\ \text{J} + 50\,400\ \text{J} = 62\,400\ \text{J} \approx 62\,000\ \text{J}$.

Why the rest are wrong

A — 54 000 J comes from multiplying the cup's heat capacity by its mass ($0.30\ \text{kg} \times 200 \times 60 = 3600\ \text{J}$). Heat capacity is already per whole cup, in J/°C, so no mass is used.

C — 130 000 J is about $0.50\ \text{kg} \times 4200\ \text{J/(kg°C)} \times 60\text{°C} = 126\,000\ \text{J}$. It treats the whole 0.50 kg as water and leaves out the cup.

D — 140 000 J is about $126\,000\ \text{J} + 12\,000\ \text{J} = 138\,000\ \text{J}$. It includes the cup but still uses 0.50 kg as the water mass.

Watch out for

D. The 0.50 kg is the mass of cup plus water, not the water alone.

Subtract the empty-cup mass to get the water mass (0.20 kg). The cup's heat capacity is already given in J/°C, so it is multiplied only by the temperature rise.

Q18 Answer **D**

Why D is correct

The flat part of the graph, at 50 °C, is where the liquid solidifies. The temperature stays constant while latent heat of fusion is released.

This lasts from 50 s to 150 s, so $t = 100\ \text{s}$.

Energy released: $E = Pt = 200\ \text{W} \times 100\ \text{s} = 20\,000\ \text{J}$.

Specific latent heat of fusion: $l = E \div m = 20\,000\ \text{J} \div 50\ \text{g} = 400\ \text{J/g}$.

Why the rest are wrong

A — 0.040 J/g is $P \div (mt) = 200 \div (50 \times 100)$. It divides by the time instead of multiplying by it.

B — 8.0 J/g is 20 000 J ÷ (50 g × 50 °C). It divides by a temperature as if finding a specific heat capacity. Latent heat involves no temperature change.

C — 60 J/g corresponds to only 3000 J, or 15 s of extraction. The flat section lasts 100 s.

Watch out for

B. Students mix up latent heat with specific heat capacity and bring in the temperature.

During a change of state the temperature is constant. Use $l = E \div m$ with $E = Pt$ for the flat section only ($150\ \text{s} - 50\ \text{s} = 100\ \text{s}$).

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Q19 Answer **C**

Why C is correct

A stretched spring (a slinky) can show both kinds of wave. Moving one end side to side makes a transverse wave. Pushing and pulling one end along the spring's length makes a longitudinal wave, with compressions and rarefactions.

Waves on the surface of water in a ripple tank are used as the model of a transverse wave: the surface moves up and down while the wave travels across the tank.

So springs show transverse and longitudinal waves, and the ripple tank shows transverse waves only.

Why the rest are wrong

A — Springs can also carry transverse waves when one end is moved sideways.

B — Springs can carry transverse waves too, and ripple tank surface waves are treated as transverse only.

D — The ripple tank shows transverse waves only; it is not used to show longitudinal waves.

Watch out for

A. Students often link the slinky only with longitudinal waves because that is its best-known demonstration.

The direction you move the end of the spring decides the wave type: sideways gives transverse, along the axis gives longitudinal.

Q20 Answer **B**

Why B is correct

The frequency of a wave is set by its source. It does not change when the wave crosses a boundary into a new medium.

When light refracts, its speed changes. Since $v = f\lambda$ and f is fixed, the wavelength changes in proportion to the speed.

So frequency is the same for the incident and refracted rays.

Why the rest are wrong

A — Some of the light is reflected, so the refracted ray carries less energy and is less bright.

C — The ray bends because its speed changes in the new medium; the speeds are different.

D — With $v = f\lambda$ and f constant, a change in speed means a change in wavelength.

Watch out for

D. Students may think wavelength is a fixed property of a colour of light.

Colour is fixed by frequency. Wavelength changes with speed when light enters a new medium.

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Q21 Answer **D**

Why D is correct

In a longitudinal wave, the particles vibrate parallel to the direction in which the wave travels, which is the direction of energy transfer.

Sound is an example: air particles move back and forth along the direction the sound travels.

Why the rest are wrong

A — Different transverse waves travel at different speeds: light at $3.0 \times 10^8\ \mathrm{m/s}$ in vacuum, water waves at a few m/s.

B — Electromagnetic waves, such as light, travel through a vacuum.

C — Longitudinal waves need particles to vibrate, so they need a medium. None travel in a vacuum.

Watch out for

A. Students recall that all electromagnetic waves have the same speed in a vacuum and apply it to all transverse waves.

The same speed applies only to electromagnetic waves in a vacuum. Other transverse waves, such as water waves, are much slower.

Q22 Answer **B**

Why B is correct

Loudness depends on amplitude: a quieter sound has a smaller amplitude.

Pitch depends on frequency: the same pitch means the frequency stays the same.

Why the rest are wrong

A — A greater amplitude makes the sound louder, not quieter.

C — A smaller frequency lowers the pitch; the pitch here is unchanged, and the amplitude must fall.

D — A greater frequency raises the pitch; the pitch here is unchanged, and the amplitude must fall.

Watch out for

C. Students sometimes link a lower sound (quieter) with a lower frequency.

Keep the two ideas apart: loudness ⇒ amplitude, pitch ⇒ frequency.

Q23 Answer **C**

Why C is correct

X-rays are electromagnetic waves, and all electromagnetic waves are transverse.

X-rays pass through soft tissue but are absorbed more by bone, so they are used in medical radiology to form images of bones and to look inside the body.

Why the rest are wrong

A — The use is correct, but X-rays are transverse, not longitudinal.

B — X-rays are not longitudinal, and TV remote controllers use infrared.

D — X-rays are transverse, but TV remote controllers use infrared, not X-rays.

Watch out for

D. Students mix up the uses of different parts of the electromagnetic spectrum.

Learn one main use for each region: remote controllers use infrared; X-rays are used for medical imaging and security scanning.

Q24 Answer **B**

Why B is correct

The normal is the line at 90° to the surface at the point where the ray strikes. For a curved mirror, it is at 90° to the tangent at that point.

In the diagram, PQ touches the ball at the point of incidence: it is the tangent. The dashed line marked with a right angle to PQ is the normal. So 'PQ is the normal' is false.

The angle between the ray and the tangent PQ is 40°. The angle of incidence is measured from the normal: $i = 90° - 40° = 50°$. So 'the angle of incidence is 50°' is true.

Why the rest are wrong

A — The angle of incidence is 50°, because it is measured from the normal, which is at 90° to PQ.

C — PQ is the tangent to the surface, not the normal.

D — PQ is the tangent. The normal is the other dashed line, drawn at 90° to PQ.

Watch out for

A. Students may take the marked 40° as the angle of incidence.

Angles of incidence and reflection are always measured from the normal, not from the surface. Subtract from 90°.

Q25 Answer **C**

Why C is correct

Angles in the refraction formula are measured from the normal. The ray makes 50° with the boundary, so the angle of incidence in the ice is $i = 90° - 50° = 40°$.

Light goes from ice $(n = 1.3)$ into air, so it speeds up and bends away from the normal: $n = \sin r \div \sin i$, where r is the angle in air.

$\sin r = n \sin i = 1.3 \times \sin 40° = 1.3 \times 0.643 = 0.836$.

$r = \sin^{-1}(0.836) \approx 57°$.

Why the rest are wrong

A — 30° comes from dividing by n: $\sin r = \sin 40° \div 1.3 = 0.494$. That is the rule for light entering the denser medium. Light going from ice into air bends away from the normal, so r must be larger than 40°.

B — 36° comes from using 50° as the angle of incidence and dividing: $\sin r = \sin 50° \div 1.3 = 0.589$.

D — 85° comes from using 50° as the angle of incidence: $\sin r = 1.3 \times \sin 50° = 0.996$.

Watch out for

D. Using the 50° given in the diagram directly as the angle of incidence gives 85°.

Always convert to the angle with the normal first: $90° - 50° = 40°$.

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Q26 Answer **A**

Why A is correct

A converging lens forms a real, inverted image whenever the object is further from the lens than F.

When the object is between the lens and F, the rays leaving the lens spread out. They appear to come from a point on the same side as the object. The image is virtual, upright and enlarged.

This is how a magnifying glass works.

Why the rest are wrong

B — Between F and $2F$ the image is real, inverted and enlarged, formed beyond $2F$ on the other side.

C — At $2F$ the image is real, inverted and the same size, at $2F$ on the other side.

D — Beyond $2F$ the image is real, inverted and diminished, between F and $2F$ on the other side.

Watch out for

B. This position also gives an enlarged image, so it looks right at first.

Check both words: enlarged AND virtual. Only an object inside F gives a virtual image.

Q27 Answer **D**

Why D is correct

The electric field lines point downwards, from the top plate to the bottom plate. The direction of an electric field is the direction of the force on a positive charge.

The drop moves upwards, so there is an upward electric force on it, large enough to overcome its weight.

A force opposite to the field direction means the drop carries a negative charge.

Why the rest are wrong

A — A magnetic pole is not affected by an electric field between charged plates.

B — As for A, a magnetic pole feels no force from an electric field.

C — A positive charge would be pushed downwards, in the direction of the field, together with its weight.

Watch out for

C. Students may think upward motion matches the positive plate.

Work out which plate is which from the arrows: field lines go from + to −. So the top plate is positive and attracts a negative drop.

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Q28 Answer **C**

Why C is correct

The paint particles are positively charged. The object is connected to earth.

The positive paint repels positive charge and attracts negative charge on the object. Electrons flow up from earth into the object, so the object becomes negatively charged.

Opposite charges attract, so the paint is pulled onto the object. It covers the surface evenly, even the back and edges, and less paint is wasted.

Why the rest are wrong

A — Earthing the object is about attracting paint, not protecting the operator; the operator holds the gun, not the object.

B — As paint lands, its charge is neutralised by the earth connection, but that is a side effect. The reason for earthing is to make the object attract the paint.

D — The paint droplets spread out because they all carry the same positive charge and repel each other; this does not need the object to be earthed.

Watch out for

B. It describes something that does happen, so it seems reasonable.

The question asks why the object is earthed. The purpose is to give the object an opposite charge by induction so it attracts the paint.

Q29 Answer **D**

Why D is correct

Resistors in parallel have the same p.d. across them. The p.d. across the 10Ω resistor is $V = IR = 0.20\ \text{A} \times 10\Omega = 2.0\ \text{V}$.

Current in the 5.0Ω resistor: $I = V \div R = 2.0\ \text{V} \div 5.0\Omega = 0.40\ \text{A}$.

Current through the battery = $0.20\ \text{A} + 0.40\ \text{A} = 0.60\ \text{A}$.

Charge: $Q = It = 0.60\ \text{A} \times 20\ \text{s} = 12\ \text{C}$.

Why the rest are wrong

A — 0.030 C comes from dividing the current by the time (0.60 ÷ 20) instead of multiplying.

B — 4.0 C is only the charge through the 10Ω resistor: 0.20 A × 20 s.

C — 6.0 C comes from a total current of 0.30 A, for example taking the 5.0Ω current as 0.10 A. The smaller resistor carries the larger current: 0.40 A.

Watch out for

B. Students use the given 0.20 A as the battery current.

The battery current is the sum of the branch currents. The smaller resistor takes the larger share.

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Q30 Answer **B**

Why B is correct

The e.m.f. of a source is the work done by the source in driving unit charge around a complete circuit.

So the work done per coulomb by the cell is its e.m.f., $\varepsilon = W \div Q$, measured in volts.

Why the rest are wrong

A — Current is the rate of flow of charge, measured in amperes, not work per unit charge.

C — The p.d. across each resistor is the energy transferred per unit charge in that resistor only. With two resistors, each p.d. is only part of the e.m.f.

D — Power is work done per unit time, not per unit charge.

Watch out for

C. The p.d. across a component is also energy per unit charge, so it sounds similar.

e.m.f. is energy per unit charge supplied by the source to the whole circuit. p.d. is energy per unit charge used in one component.

Q31 Answer **C**

Why C is correct

The resistance of a metal wire increases as its temperature rises.

The total resistance of the circuit is the fixed resistance plus the wire's resistance, so it increases. With constant e.m.f., the current $I = \varepsilon \div R_{\text{total}}$ decreases.

The wire and the fixed resistor share the e.m.f. in the ratio of their resistances: $V_{\text{wire}} = \varepsilon \times R_{\text{wire}} \div (R_{\text{fixed}} + R_{\text{wire}})$.

As R_{wire} increases, the wire takes a larger share of the e.m.f. So the p.d. across the wire increases.

Another way to see it: the p.d. across the fixed resistor, IR_{fixed}, falls because I falls. The two p.d.s add up to the constant e.m.f., so the wire's p.d. must rise.

Why the rest are wrong

A — The current does decrease, but the p.d. across the wire rises because the wire takes a bigger share of the constant e.m.f.

B — The current cannot stay the same when the total resistance increases at constant e.m.f.

D — The p.d. across the wire does increase, but the current falls because the total resistance rises.

Watch out for

A. Students see the current fall and assume $V = IR$ must fall too.

In $V = IR$ for the wire, I falls but R rises. Use the p.d. across the fixed resistor instead: it falls, so the wire's p.d. rises.

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Q32 Answer **D**

Why D is correct

The two cells, the ammeter reading I_1 and the ammeter reading I_2 are all in one series loop with the lamps. The current is the same at every point of a series loop, so $I_1 = I_2 = 4.0\ \text{A}$.

$V_1 = 12\ \text{V}$ is the p.d. across the cells, which is the total p.d. across the lamps.

The single lamp (V_2) is in series with the parallel pair (V_3). The p.d.s add up: $V_2 + V_3 = 12\ \text{V}$.

$V_2 = 12\ \text{V} - 4.0\ \text{V} = 8.0\ \text{V}$.

Why the rest are wrong

A — I_1 is not zero; the ammeter is in the main loop and reads the same current as I_2. V_2 is not 4.0 V either.

B — $V_2 = 8.0\ \text{V}$ is correct, but I_1 is 4.0 A, not zero.

C — $I_1 = 4.0\ \text{A}$ is correct, but V_2 is $12\ \text{V} - 4.0\ \text{V} = 8.0\ \text{V}$, not 4.0 V.

Watch out for

C. Students may think the p.d. is shared equally between the lamps.

Series p.d.s add up to the supply p.d. Subtract V_3 from V_1 to find V_2.

Q33 Answer **A**

Why A is correct

The two resistors form a potential divider. The p.d. across the variable resistor is $V_{out} = 12\ \text{V} \times R \div (10k\Omega + R)$.

When $R = 0$: $V_{out} = 12\ \text{V} \times 0 \div 10k\Omega = 0\ \text{V}$.

When $R = 5.0k\Omega$: $V_{out} = 12\ \text{V} \times 5.0k\Omega \div 15k\Omega = 4.0\ \text{V}$.

So V_{out} ranges from 0 to 4.0 V.

Why the rest are wrong

B — 8.0 V is the p.d. across the $10k\Omega$ resistor when $R = 5.0k\Omega$, not across the variable resistor.

C — 4.0 V to 8.0 V mixes the two p.d.s at $R = 5.0k\Omega$. The lower limit is 0 V when $R = 0$.

D — This is the range across the fixed $10k\Omega$ resistor (12 V when $R = 0$, 8.0 V when $R = 5.0k\Omega$), with the wrong lower value.

Watch out for

B. Students calculate the p.d. across the wrong resistor.

V_{out} is across the variable resistor. The larger its share of the total resistance, the larger its share of the 12 V.

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Q34 Answer **B**

Why B is correct

Power saved per lamp = $60\ \text{W} - 10\ \text{W} = 50\ \text{W}$. For four lamps: $4 \times 50\ \text{W} = 200\ \text{W} = 0.20\ \text{kW}$.

Time used per week = $5.0\ \text{h} \times 7 = 35\ \text{h}$.

Energy saved: $E = Pt = 0.20\ \text{kW} \times 35\ \text{h} = 7.0\ \text{kWh}$.

Why the rest are wrong

A — 1.0 kWh is the saving for one day only: 0.20 kW × 5.0 h.

C — 10 kWh would need the 0.20 kW saving to last 50 h. The lamps are used for only $5.0\ \text{h} \times 7 = 35\ \text{h}$ each week.

D — 70 kWh is ten times the correct value. It comes from a unit slip, such as writing 200 W as 2.0 kW instead of 0.20 kW.

Watch out for

A. The question asks for a week, not a day.

Multiply by 7 for the number of days, and convert W to kW by dividing by 1000.

Q35 Answer **C**

Why C is correct

Both the fuse and the switch must be in the live wire, before the heater.

The live wire is at high voltage. With the switch in the live wire, opening it cuts the heater off from the high voltage. With the fuse in the live wire, a blown fuse also disconnects the heater from the live supply.

Circuit C has both the fuse and the switch in the live wire.

Why the rest are wrong

A — Both the fuse and switch are in the neutral wire. Even when the switch is open or the fuse blows, the heater stays connected to the live wire and can give a shock.

B — The switch is in the live wire, but the fuse is in the neutral wire. A blown fuse would leave the heater live.

D — The fuse is in the live wire, but the switch is in the neutral wire. With the switch off, the heater is still at high voltage.

Watch out for

D. It has the fuse correctly placed, which is the part many students check first.

Check both devices. The switch and the fuse both belong in the live wire.

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Q36 Answer **A**

Why A is correct

When current flows in the coil, the bar becomes magnetised and attracts the iron nails.

When the current is switched off, the bar still holds the nails, so it has kept its magnetism.

Steel is a hard magnetic material: it is harder to magnetise but keeps its magnetism. It is used for permanent magnets.

Why the rest are wrong

B — Iron is a soft magnetic material. It loses nearly all its magnetism when the current stops, so the nails would fall.

C — Copper is not a magnetic material; it would not attract the nails even with the current on.

D — Aluminium is not a magnetic material; it would not attract the nails even with the current on.

Watch out for

B. Iron is the usual core of an electromagnet, and the nails are iron.

Iron is chosen for electromagnets because it loses its magnetism when the current stops. A bar that stays magnetised is steel.

Q37 Answer **D**

Why D is correct

Outside a bar magnet, field lines go from the N pole round to the S pole.

On the mid line, level with the centre of the magnet, the field lines run parallel to the magnet, pointing from the N end towards the S end.

In the diagram, N is on the left and S on the right, so the field at the compass points to the right.

The compass needle's north end points along the field, so the needle points to the right, as in D.

Why the rest are wrong

A — Pointing left would mean the field goes from S to N outside the magnet, which is backwards.

B — Pointing up and to the right would mean the needle is pulled towards the S pole directly. On the mid line the N and S effects combine to give a field parallel to the magnet.

C — Pointing down and to the right would mean the needle is pushed away from the magnet. On the mid line the field is parallel to the magnet.

Watch out for

A. Students may think the needle's north end points to the magnet's N pole.

Like poles repel. The compass north end is repelled by N and attracted by S, and on the mid line these combine to point it from the N end towards the S end.

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Q38 Answer **A**

Why A is correct

Fleming's left-hand rule: first finger = field (N to S), second finger = current, thumb = force.

In A, P is N and Q is S, so the field points downwards, from P to Q. The current flows from S to T, to the right.

Point the first finger down the page and the second finger to the right. The thumb points into the page, which matches the force given.

So the current flows from S to T with P as N and Q as S.

Why the rest are wrong

B — The field points upwards and the current to the right. The left-hand rule gives a force out of the page.

C — The field points downwards and the current to the left. The left-hand rule gives a force out of the page.

D — Two N poles facing each other push their fields apart. Midway between them, the upward and downward parts cancel, so there is no vertical field across the wire and no force into the page.

Watch out for

B or C. Each has only one of the two quantities reversed compared with A.

Reversing either the field or the current reverses the force. Check each row with the left hand rather than guessing.

Q39 Answer **C**

Why C is correct

Graph 1: peak e.m.f. 5 V, period 1.0 s (one full cycle in 1.0 s), so frequency 1.0 Hz.

Graph 2: peak e.m.f. 10 V, period 0.50 s (two full cycles in 1.0 s), so frequency 2.0 Hz. Measuring the figure, the peaks in graph 2 are half as far apart as in graph 1.

Both the peak e.m.f. and the frequency have doubled.

Rotating the coil faster does both. The coil completes more turns each second, so the frequency increases. The magnetic flux through the coil also changes faster, so a larger e.m.f. is induced.

Doubling the rotation speed doubles both the frequency and the peak e.m.f.

Why the rest are wrong

A — A larger coil area gives a larger peak e.m.f., but the frequency stays the same because the coil rotates at the same rate.

B — More turns give a larger peak e.m.f., but the frequency stays the same.

D — A stronger magnet gives a larger peak e.m.f., but the frequency stays the same.

Watch out for

B or D. They double the peak e.m.f. correctly, but students miss that graph 2 also has more cycles.

Always compare both amplitude and period. Only a change in rotation speed changes the frequency.

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Q40 Answer **D**

Why D is correct

Ionisation needs radiation of high frequency and high energy. Gamma rays are high-frequency electromagnetic radiation and are ionising, so they can ionise soft tissue.

Infrared radiation is absorbed by the skin and tissue and heats it, raising its temperature. It does not ionise.

So radiation 1 is gamma rays and radiation 2 is infrared.

Why the rest are wrong

A — Infrared is not ionising, so it cannot be radiation 1.

B — Infrared is not ionising, and gamma rays are known for ionising rather than for heating.

C — Microwaves have even lower frequency than infrared and are not ionising, so they cannot be radiation 1.

Watch out for

C. Microwaves are known to harm tissue, so students link them with damage.

Microwaves damage tissue by heating it. Only high-frequency radiation (ultraviolet, X-rays, gamma rays) ionises.

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