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TEN-YEAR SERIES · ANSWERS AND WORKED SOLUTIONS

2019 O-Level Physics Paper 1

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ANSWER KEY

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WORKED SOLUTIONS

Q1 Answer A

Why A is correct

Refractive index is a ratio: n = speed of light in vacuum ÷ speed of light in the medium (or sin i ÷ sin r).

When you divide one speed by another, the units (m/s ÷ m/s) cancel. So refractive index is a pure number with no unit.

Why the rest are wrong

B — Resistance has the unit ohm (Ω).

C — Volume has a unit, for example m^3 or cm^3.

D — Wavelength is a length, so it is measured in metres (m).

Watch out for

B. Some students think resistance is 'just a ratio' (V ÷ I) and so has no unit. But volts ÷ amperes do not cancel; the result is the ohm (Ω).

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Q2 Answer **B**

Why B is correct

Find the resultant force by adding the forces in each direction.

Vertical: 6 N up and 3 N down give a resultant of $6 - 3 = 3\ \text{N}$ upwards.

Horizontal: there is only the 3 N force, so the resultant is 3 N to the left.

3 N up together with 3 N left give a resultant pointing up and to the left at 45°. The point mass accelerates in the direction of the resultant force, which is arrow B.

Why the rest are wrong

A — A ignores the 3 N force to the left. The upward forces leave 3 N upwards, but there is also 3 N to the left.

C — C ignores the vertical forces. The 6 N up is larger than the 3 N down, so there is a net upward force as well.

D — D points down and to the left. The net vertical force is upwards $(6\ \text{N} > 3\ \text{N})$, not downwards.

Watch out for

A. Students who only look at the largest force (6 N up) pick A. Every force counts: the 3 N to the left is not balanced by anything.

Q3 Answer **A**

Why A is correct

A scalar has size only. A vector has size and direction.

Mass (e.g. 2 kg) has size only, so it is a scalar.

Speed (e.g. 20 m/s) has size only, so it is a scalar. The vector version of speed is velocity, which also states the direction.

So both are scalars: row A.

Why the rest are wrong

B — Speed is a scalar. Velocity is the vector.

C — Mass has no direction, so it is not a vector.

D — Neither mass nor speed has a direction.

Watch out for

B. Students who mix up speed and velocity pick B. Speed is how fast; velocity is how fast and in which direction.

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Q4 Answer **D**

Why D is correct

Main (sleeve) scale: the upper line marks whole millimetres (0, 1, 2 ... 7) and the lower line marks the half-millimetres. The last mark visible before the edge of the thimble is the half-millimetre mark after 7, so the sleeve reading is 7.50 mm.

Thimble scale: the horizontal datum line on the sleeve lines up with division 14 on the thimble (between 10 and 15, just below 15). Each division is 0.01 mm, so this gives $14 \times 0.01 = 0.14\ \text{mm}$.

Reading = $7.50\ \text{mm} + 0.14\ \text{mm} = 7.64\ \text{mm}$.

Why the rest are wrong

A — 5.64 mm misreads the main scale. The thimble edge is well past the 7 mm mark, not near 5 mm.

B — 7.14 mm forgets the half-millimetre mark that is visible after 7 mm. The sleeve reading is 7.50 mm, not 7.00 mm.

C — 7.16 mm forgets the half-millimetre mark and also reads the thimble as 16. The datum line is just below 15 (at 14), not above it.

Watch out for

B. Students who read only the upper (whole-millimetre) scale pick B. Always check whether a half-millimetre mark on the lower side of the datum line is showing before the thimble edge.

Q5 Answer **A**

Why A is correct

Acceleration is the gradient of a velocity–time graph.

At 30 s the curve reaches its highest point (25 m/s). At a maximum, the tangent to the curve is horizontal, so its gradient is zero.

So the acceleration at 30 s is 0. The car has stopped speeding up and is about to slow down.

Why the rest are wrong

B — 25 ÷ 50 divides the velocity at 30 s by the total time. That is not the gradient at 30 s.

C — (25 − 5) ÷ 30 is the average acceleration from 0 s to 30 s, not the acceleration at the instant 30 s.

D — 25 ÷ 30 divides velocity by time at one point. That is not a gradient; a gradient needs a change in velocity over a change in time along the tangent.

Watch out for

C. Students who calculate the average acceleration over the first 30 s pick C. 'At 30 s' asks for the gradient of the tangent at that instant, and at the peak the tangent is flat.

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Q6 Answer **C**

Why C is correct

If the velocity is the same at two points, the object is moving at constant velocity, so its acceleration is zero.

Zero acceleration means the resultant force is zero $(F = ma)$.

The two forces on the falling object are its weight (down) and air resistance (up). For the resultant to be zero, air resistance = weight. The object has reached terminal velocity.

Why the rest are wrong

A — Objects do not always fall at constant velocity. At first they speed up because the weight is larger than the air resistance.

B — Air resistance is a force (in N) and g is an acceleration (in m/s^2 or N/kg). A force cannot be equal to an acceleration.

D — If air resistance were larger than the weight, the resultant force would be upwards and the object would slow down, so the two velocities would not be the same.

Watch out for

B. Students who link 'falling' with g pick B. Compare forces with forces: air resistance balances the weight $W = mg$, not g itself.

Q7 Answer **D**

Why D is correct

The Earth's diameter is about $13\,000\ \text{km} = 1.3 \times 10^7\ \text{m}$. To the nearest power of ten this is $10^7\ \text{m} = 10 \times 10^6\ \text{m} = 10\ \text{Mm}$.

An atom's diameter is about $10^{-10}\ \text{m} = 0.1 \times 10^{-9}\ \text{m} = 0.1\ \text{nm}$.

So the row is 10 Mm and 0.1 nm: D.

Why the rest are wrong

A — $10\ \text{Gm} = 10^{10}\ \text{m}$ is about a thousand times too big for the Earth, and $0.1\mu m = 10^{-7}\ \text{m}$ is about a thousand times too big for an atom.

B — The atom is right, but $10\ \text{Gm} = 10^{10}\ \text{m}$ is about a thousand times larger than the Earth.

C — The Earth is right, but $0.1\mu m = 10^{-7}\ \text{m}$ is about a thousand times larger than an atom.

Watch out for

B. Students who are unsure of the prefixes may pick B. Remember $M = 10^6$ and $G = 10^9$, so $10\ \text{Mm} = 10^7\ \text{m}$ and $10\ \text{Gm} = 10^{10}\ \text{m}$.

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Q8 Answer **A**

Why A is correct

Resultant force needed: $F = ma = 800 \times 2.0 = 1600\ \text{N}$.

The resultant force is the driving force minus the resistive force: $2500 - R = 1600$.

$R = 2500 - 1600 = 900\ \text{N}$.

Why the rest are wrong

B — 1600 N is the resultant force, not the resistive force.

C — 2100 N does not follow from the data. The resistive force must be the driving force minus m a: $2500 - 1600 = 900\ \text{N}$.

D — 4100 N adds the resultant force to the driving force. The resistive force opposes the motion, so it must be subtracted.

Watch out for

B. Students who stop after $F = ma$ pick B. That 1600 N is what is left after the resistance has been taken away from the 2500 N.

Q9 Answer **C**

Why C is correct

The question asks for the statement that is not correct.

Mass is the amount of matter in a body. It does not depend on where the body is. Moving a body to a place with a different gravitational field strength changes its weight ($W = mg$), but its mass stays the same.

So statement C is wrong.

Why the rest are wrong

A — This is correct. A body in a gravitational field has weight $W = mg$ because it has mass.

B — This is correct. Mass is a measure of the amount of matter in a body.

D — This is correct. Mass is a measure of inertia: it resists a change in the body's state of rest or motion.

Watch out for

A. Students who forget the 'not' may hunt for a true statement. Read negative questions twice: here you want the false statement, and C confuses mass with weight.

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Q10 Answer **C**

Why C is correct

Pressure = force ÷ area. The force is the weight: $W = mg = 8.0 \times 10 = 80\ \text{N}$.

The pressure is smallest when the area in contact is largest. The largest face is $20\ \text{cm} \times 10\ \text{cm} = 200\ \text{cm}^2$.

Convert: $200\ \text{cm}^2 = 200 \times 10^{-4}\ \text{m}^2 = 0.020\ \text{m}^2$.

$p = F \div A = 80 \div 0.020 = 4000\ \text{Pa}$.

Why the rest are wrong

A — 0.40 Pa uses $200\ \text{cm}^2$ without converting to $m^2 (80 \div 200 = 0.40)$.

B — 400 Pa comes from a unit slip: taking $200\ \text{cm}^2$ as $0.2\ \text{m}^2 (80 \div 0.2 = 400)$. $200\ \text{cm}^2$ is $0.020\ \text{m}^2$.

D — 40 000 Pa uses the smallest face, $10\ \text{cm} \times 2\ \text{cm} = 0.0020\ \text{m}^2 (80 \div 0.0020 = 40\,000\ \text{Pa})$. That is the maximum pressure, not the minimum.

Watch out for

D. Students who use the smallest face (10 cm × 2 cm) get 40 000 Pa, which is the maximum pressure. Minimum pressure needs the largest contact area.

Q11 Answer **B**

Why B is correct

Pressure in a liquid depends only on the depth below the surface ($p = h\rho g$), not on the shape or width of the container.

Both vessels are open and connected, so the water surface is at the same level in both. Q and R are at the same level, so they are at the same depth: pressure at R is the same as at Q.

P is higher up than R, so P is at a smaller depth: pressure at R is greater than at P.

Why the rest are wrong

A — R and Q are at the same depth in the same connected liquid, so R's pressure is not lower than Q's.

C — R is deeper than P, so R's pressure is greater, not the same.

D — R is deeper than P, so R's pressure is greater than at P.

Watch out for

A. Students who think the wide left vessel holds more water, so pushes harder, pick A. Pressure depends on depth only, not on the amount of water above the point.

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Q12 Answer **B**

Why B is correct

The mercury thread is at rest, so the forces (pressures) on it balance.

From below, the atmosphere pushes up on the mercury through the open end: 1.0×10^5 Pa.

From above, the trapped air pushes down, and the mercury's own weight adds 0.18×10^5 Pa downwards.

p(air) + $0.18 \times 10^5 = 1.0 \times 10^5$, so p(air) = 0.82×10^5 Pa.

Why the rest are wrong

A — 0.18×10^5 Pa is the pressure due to the mercury alone, not the trapped air.

C — The trapped air is not at atmospheric pressure: the mercury's weight also acts, so the air needs less pressure to hold it up.

D — 1.18×10^5 Pa would be correct if the open end faced upwards, so the mercury pressed down on the air. Here the open end is at the bottom.

Watch out for

D. Students who always add the mercury pressure pick D. Check which way the open end faces: here the atmosphere pushes the mercury up, and the mercury's weight pulls it down, so the air pressure is smaller than atmospheric.

Q13 Answer **D**

Why D is correct

When the motor works as a generator, the moving car turns it, so the input is the car's kinetic energy.

The generator converts this kinetic energy into electrical energy.

Charging the battery stores the electrical energy as chemical potential energy.

So the chain is kinetic → electrical → chemical.

Why the rest are wrong

A — There is no thermal energy input. Thermal energy is wasted, not the source.

B — The energy does not start as thermal energy; it starts as the kinetic energy of the moving car.

C — Thermal energy is not a stage between kinetic and electrical. The generator changes kinetic energy straight into electrical energy.

Watch out for

B. Students who think of the combustion engine (fuel burning) pick an option starting with thermal. Here the motor is acting as a generator, so energy enters as motion.

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Q14 Answer **C**

Why C is correct

With no air resistance, total energy is conserved. Take m as the mass.

At 10 m: $PE = mgh = m \times 10 \times 10 = 100m$.

The object has fallen $50 - 10 = 40$ m, so the PE lost and the KE gained is $m \times 10 \times 40 = 400m$.

KE : $PE = 400m : 100m = 4 : 1$.

Why the rest are wrong

A — 5 : 4 compares the total energy (from 50 m) with the KE (from 40 m), not KE with PE.

B — 2 : 1 has no basis; the drop is 40 m and the height is 10 m.

D — 5 : 1 compares the total energy (50 m) with the PE at 10 m. The KE is only the energy lost from falling 40 m.

Watch out for

D. Students who use 50 m instead of the distance fallen (40 m) for the KE pick D. KE equals the PE lost, which depends on how far it has dropped.

Q15 Answer **B**

Why B is correct

Power = work done ÷ time, so in one minute (60 s) the work done is $W = Pt = 90\,000 \times 60 = 5\,400\,000$ J.

Work done = force × distance, so $d = W \div F = 5\,400\,000 \div 3600 = 1500$ m.

(Or: $P = Fv$, so $v = 90\,000 \div 3600 = 25$ m/s, and $d = 25 \times 60 = 1500$ m.)

Why the rest are wrong

A — 1.5 m is a power-of-ten slip: 1500 m is 1.5 km, not 1.5 m.

C — 90 km treats the 90 000 in J/s as if it were metres. Power must be divided by force to get the speed (25 m/s).

D — 5400 km comes from $90\,000 \times 60 = 5\,400\,000$ J and treating joules as metres. You still need to divide by the force.

Watch out for

A. Students who mix up m and km pick A. Work in SI units throughout: J/s ÷ N gives m/s, and time must be in seconds (60 s).

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Q16 Answer **B**

Why B is correct

In a smoke cell, the smoke particles are seen to move in a random, jerky (zig-zag) way.

They move like this because they are hit unevenly by the invisible air molecules around them.

So Brownian motion is evidence that air molecules are moving randomly.

Why the rest are wrong

A — Brownian motion says nothing about how well air conducts heat.

C — Air molecules are much lighter (and much smaller) than smoke particles. That is why many molecule hits are needed to move a smoke particle a little.

D — The motion is random in all directions. Convection would carry the particles together in a steady current, not make each one jiggle.

Watch out for

D. Students who think of air movement inside the cell pick D. Convection is a bulk flow; Brownian motion is a random jiggling of each particle.

Q17 Answer **C**

Why C is correct

As air is pumped in, the pressure in the bell jar rises, so the air outside the balloon pushes harder on it.

The balloon is squashed until the gas inside is at the same pressure as the air around it. So the pressure of the gas in the balloon increases.

For a fixed mass of gas at constant temperature, pV is constant. Since p increases, the volume decreases.

Why the rest are wrong

A — The balloon gas pressure cannot fall while the pressure outside it rises; the balloon is compressed, not allowed to expand.

B — This is what happens when air is pumped out of the jar, not in.

D — Pressure and volume of a fixed mass of gas at constant temperature cannot both increase; when one goes up the other goes down.

Watch out for

B. Students who remember the classic demonstration where air is pumped out (the balloon grows) pick B. Read the question: here air is pumped in.

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Q18 Answer **D**

Why D is correct

The temperature of a gas is linked to the average kinetic energy of its molecules. A higher temperature means faster molecules.

Internal energy includes the kinetic energy of the molecules, so if the temperature rises, the internal energy must increase.

Volume, pressure and density can each stay the same or even fall, depending on what else happens to the gas.

Why the rest are wrong

A — The volume need not increase. If the gas is in a sealed rigid container, its volume stays the same.

B — The pressure need not increase. If the gas is free to expand (e.g. a syringe with a free piston), its pressure stays the same.

C — Density need not increase. A gas that expands when heated becomes less dense; a gas in a sealed container keeps the same density.

Watch out for

B. Students who think of a gas in a closed container pick B. The question says 'must', so the property has to rise in every case; only internal energy does.

Q19 Answer **A**

Why A is correct

Internal energy is the total kinetic and potential energy of all the particles. A smaller block at the same temperature has fewer particles, so its internal energy is less.

Heat capacity $C = mc$ is the energy needed to raise the whole block by 1 °C. A smaller mass means a smaller heat capacity.

Specific heat capacity c is a property of the material (copper), per kilogram. It is the same for any size of copper block.

Why the rest are wrong

B — Heat capacity depends on mass, so it is not the same; and specific heat capacity depends only on the material, so it does not get less.

C — Internal energy depends on the number of particles as well as temperature, so the smaller block has less.

D — Only the specific heat capacity stays the same; internal energy and heat capacity both depend on the amount of copper.

Watch out for

C. Students who think 'same temperature means same internal energy' pick C. Temperature tells you the average energy per particle; internal energy is the total over all particles.

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Q20 Answer **B**

Why B is correct

The heater warms the air next to it. The air expands, so the same mass takes up more volume: its density decreases.

Less dense air is pushed up by the denser cooler air around it, so the warm air rises. Cooler, denser air sinks to take its place, setting up a convection current.

Why the rest are wrong

A — Less dense air rises, not sinks.

C — Heating makes air expand, so it becomes less dense, not more dense.

D — Heated air becomes less dense, and more dense air would sink, not rise.

Watch out for

C. Students who think heated air 'gets heavier' pick C. Heating does not change the mass of the air; it spreads it out, so density falls.

Q21 Answer **A**

Why A is correct

The ice point is 0 °C and the steam point is 100 °C. Over these 100 °C the resistance rises from 15.0Ω to 20.0Ω, so it changes by 5.0Ω for every 100 °C.

Change in resistance per degree = $5.0\Omega \div 100^\circ\text{C} = 0.050\Omega$ per °C.

At the unknown temperature the resistance is 14.0Ω, which is 1.0Ω below the ice-point value.
Temperature = $0^\circ\text{C} - (1.0\Omega \div 0.050\Omega \text{ per } ^\circ\text{C}) = 0^\circ\text{C} - 20^\circ\text{C} = -20^\circ\text{C}$.

Equivalently, $\theta = (R - R_0) \div (R_{100} - R_0) \times 100^\circ\text{C} = (14.0 - 15.0) \div (20.0 - 15.0) \times 100^\circ\text{C} = -20^\circ\text{C}$.

Why the rest are wrong

B — −17 °C comes from a wrong ratio, such as dividing 1.0Ω by 6.0Ω (or by the 14.0–20.0 range) instead of by the 5.0Ω fixed-point interval.

C — 17 °C is wrong in both size and sign: 14.0Ω is below the ice-point resistance, so the temperature must be below 0 °C.

D — +20 °C has the right size but the wrong sign. A resistance lower than at the ice point means a temperature below 0 °C.

Watch out for

D. Students who work out $1.0 \div 0.050 = 20$ and forget that the resistance has gone down from the ice-point value pick +20 °C. Check the sign: less than 15.0Ω means colder than 0 °C.

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Q22 Answer **D**

Why D is correct

The masses are equal and both start at 90 °C. Neither liquid changes state while cooling from 90 °C, so only the heat lost by a temperature change matters: $Q = mc\Delta\theta$.

For the same mass and the same rate of heat loss, a liquid with a lower specific heat capacity must drop by more degrees for each joule it loses ($\Delta\theta = Q \div mc$). So oil, with a lower c than water, cools faster.

Why the rest are wrong

A — The boiling point is not involved: the liquids are cooling down from 90 °C, not boiling.

B — The melting point is not involved: neither liquid reaches its freezing point in this process.

C — Specific latent heat matters only during a change of state. No melting, freezing or boiling happens here.

Watch out for

C. Students mix up latent heat and specific heat capacity. Latent heat is only for changes of state; a temperature change at constant state depends on specific heat capacity.

Q23 Answer **B**

Why B is correct

The graph is displacement against time for one point (the boat). From it you can read the amplitude and the period, but not the wavelength.

Amplitude = maximum displacement from equilibrium = 2.0 m.

One full cycle takes from $t = 0$ s to $t = 20$ s, so the period $T = 20$ s.

Frequency $f = 1/T = 1/20\ \text{s} = 0.050\ \text{Hz}$.

Why the rest are wrong

A — The amplitude is right, but the speed cannot be found: $v = f\lambda$ needs the wavelength, and a displacement–time graph does not give it.

C — A wavelength cannot be read from a displacement–time graph. The 20 on the time axis is the period in seconds, not a length in metres.

D — The frequency is right, but '20 m' wrongly treats the 20 s period as a wavelength.

Watch out for

D. Students who read the 20 off the horizontal axis as a wavelength pick D. Always check the axis label: here it is time / s, so 20 is the period.

A. 0.40 m/s comes from 2.0 m ÷ 5 s and has no meaning for this wave.

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Q24 Answer **D**

Why D is correct

Going from the bottom position to the top position is only half an oscillation. So half a period = 4.0 ms, and the period $T = 8.0\ \text{ms} = 8.0 \times 10^{-3}\ \text{s}$.

Frequency $f = 1/T = 1/(8.0 \times 10^{-3}\ \text{s}) = 125\ \text{Hz}$.

Wavelength $\lambda = v/f = 340/125 = 2.72\ \text{m} \approx 2.7\ \text{m}$.

Why the rest are wrong

A — 0.37 m comes from using $\lambda = v \times T$ with T taken wrongly, or from a v/f error; it does not match $T = 8.0\ \text{ms}$.

B — 0.74 m is not consistent with any correct use of $\lambda = vT$ with $T = 8.0\ \text{ms}$.

C — 1.4 m comes from taking 4.0 ms as the full period: $f = 250\ \text{Hz}$, $\lambda = 340/250 = 1.36\ \text{m}$. But bottom to top is only half a cycle.

Watch out for

C. Students who treat the 4.0 ms as the whole period get 1.4 m. A full oscillation is bottom → top → bottom, so $T = 2 \times 4.0\ \text{ms} = 8.0\ \text{ms}$.

Q25 Answer **D**

Why D is correct

At first the ray hits the mirror along the normal, so the angle of incidence is 0° and the light goes straight back.

When the mirror tilts through 10°, its normal also tilts through 10°. The incoming ray has not moved, so it now makes an angle of incidence of 10° with the new normal.

By the law of reflection, the angle of reflection is also 10°. The angle between the incident ray and the reflected ray = angle i + angle $r = 10^\circ + 10^\circ = 20^\circ$.

Why the rest are wrong

A — 5° halves the tilt instead of doubling it.

B — 10° is the angle of incidence (or of reflection) alone, not the angle between the incident and reflected rays.

C — 15° has no basis: the angle between the rays is $i + r = 2 \times 10^\circ$.

Watch out for

B. Students who give the angle of incidence, 10°, as the answer pick B. The question asks for the angle between the incident ray and the reflected ray, which is $i + r = 20^\circ$.

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Q26 Answer **C**

Why C is correct

The critical angle is the angle of incidence in the denser medium for which the angle of refraction is 90°, so the refracted ray travels along the boundary.

Angles of incidence are measured between the ray and the normal, on the side where the light arrives. Here the light arrives from below (the denser medium), so the critical angle is the angle between the incident ray and the normal below the boundary. That is angle C.

Why the rest are wrong

A — A is in the less dense medium, between the normal and the refracted ray. That is the angle of refraction, which is 90° at the critical angle.

B — B is measured from the normal below the boundary round to the refracted ray along the boundary; it is not the angle between the incident ray and the normal.

D — D is between the incident ray and the boundary itself, not the normal. It equals 90° minus the critical angle.

Watch out for

D. Students who measure from the surface instead of from the normal pick D. Angles of incidence, reflection and refraction are always measured from the normal.

Q27 Answer **B**

Why B is correct

Position X is further from the lens than F (more than one focal length away; from the figure it lies between F and $2F$). For an object outside F, a converging lens forms a real, inverted image on the other side of the lens.

Position Y is between F and the lens (less than one focal length away). The rays leaving the lens diverge, so no real image forms. The image is virtual, upright and magnified, on the same side as the object (the magnifying-glass case).

So: X ✓ inverted, Y ✓ upright.

Why the rest are wrong

A — At Y the object is inside the focal length, so the image is virtual and upright, not inverted.

C — At X the object is outside the focal length, so the image is real and inverted, not upright.

D — This has the two cases swapped: outside F gives inverted, inside F gives upright.

Watch out for

A. Students who remember 'a converging lens makes inverted images' and forget the magnifying-glass case pick A. Check whether the object is inside or outside F.

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Q28 Answer **A**

Why A is correct

A ray inside the glass meets a face at an angle of incidence bigger than 42° only if it hits that face at 45° (from the prism angles). Since $45^\circ > 42^\circ$, every 45° hit gives total internal reflection.

In A, the beam meets the long sloping face (the hypotenuse) at 90°, so it enters without bending. Travelling down and to the left, it hits the vertical face at 45° → total internal reflection → now travels down and to the right, hits the bottom face at 45° → total internal reflection again → travels up and to the right and leaves through the hypotenuse at 90°.

So arrangement A gives two total internal reflections before any light leaves.

Why the rest are wrong

B — The vertical beam meets the sloping face at 45° from outside, so it refracts as it enters and is bent towards the normal. Inside, it no longer meets the other faces at 45°, and it does not undergo two total internal reflections.

C — The beam enters the vertical face at 90°, hits the hypotenuse at 45° and is totally internally reflected once. It then travels straight down and meets the bottom face at 90°, where it leaves. Only one total internal reflection.

D — The beam enters the vertical face at an angle and is refracted, so it does not then strike the other faces at 45°; it does not give two total internal reflections.

Watch out for

C. Students pick C because it is the familiar 90° periscope-prism set-up. That gives only one total internal reflection; two reflections need the beam to enter through the hypotenuse, as in A (the 'reversing' prism).

Q29 Answer **C**

Why C is correct

When a pen is rubbed with a cloth, electrons are transferred between them, so the pen and the cloth gain opposite charges.

Both pens are identical and were rubbed with identical cloths, so the two pens have the same charge.

Opposite charges attract and like charges repel. So the cloth attracts the balanced pen and the second pen repels it.

Why the rest are wrong

A — The second pen has the same charge as the balanced pen, so it repels it, not attracts.

B — The cloth has the opposite charge to the pen, so it attracts it, not repels.

D — This swaps the two: the cloth (opposite charge) attracts, the second pen (same charge) repels.

Watch out for

A. Students who think 'any charged object attracts' pick A. A charged object attracts an uncharged one, but two objects with the same charge always repel.

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Q30 Answer **D**

Why D is correct

The copper sphere is a conductor on an insulating mat, so its total charge cannot change. In the first figure it carries a net charge of three negative signs.

The negative rod repels the free electrons in the copper, so electrons move to the side of the sphere away from the rod. The near side is left with a shortage of electrons and shows positive charge.

Diagram D shows three + on the side near the rod and six − on the far side. Net charge = $6 - 3 = 3$ negative, the same as before. D is the only diagram that is both correctly separated and keeps the total charge.

Why the rest are wrong

A — A shows six negative charges and no positive charges: a net charge of −6. The sphere cannot gain charge while standing on an insulating mat, so the total is wrong.

B — B shows three + and three −, a net charge of zero. The sphere started negatively charged and nothing has removed that charge.

C — C shows positive charge on the far side. The negative rod pushes electrons away, so the far side must be negative, not positive.

Watch out for

A. Students who only think 'electrons move away from the rod' pick A. Count the signs: A has a net charge of −6, but the sphere started with −3 and is insulated, so its net charge must still be −3.

The answer turns on counting the charge signs in each diagram (D: 3 +, 6 −; original: 3 −). Charge conservation decides between A and D.

Q31 Answer **A**

Why A is correct

Electric current is the rate of flow of charge: $I = Q/t$.

Its SI unit is the ampere (A), where $1\ \mathrm{A} = 1\ \mathrm{C/s}$. The coulomb is the unit of charge, not of current.

Why the rest are wrong

B — The coulomb is the unit of charge. Current is charge per second, measured in amperes.

C — Current is defined as the rate of flow of charge, not specifically of electrons. In some conductors (for example, solutions) the moving charges are ions, and conventional current is defined in terms of positive charge flow.

D — Wrong on both counts: current is the rate of flow of charge, and its unit is the ampere, not the coulomb.

Watch out for

C. Students who think of current only as moving electrons pick C. The definition is the rate of flow of charge, whatever carries it.

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Q32 Answer **A**

Why A is correct

Resistance $R = V/I$.

Between P and Q there is a p.d. across the diode but the current is zero (the graph lies along the axis). With $I = 0$, $R = V/I$ is very large: the diode is not conducting yet.

After Q, the current rises more and more steeply as the p.d. increases. Each increase in V gives a bigger and bigger increase in I, so V / I gets smaller: the resistance decreases.

Why the rest are wrong

B — After Q the current rises faster than the p.d., so V / I falls; the resistance decreases, not increases.

C — Zero current with a p.d. across it means very large resistance, not zero resistance. Zero resistance would mean a large current for almost no p.d.

D — Wrong on both counts: the resistance between P and Q is very large, and after Q it decreases.

Watch out for

C. Students who see 'zero' on the current axis and write 'zero resistance' pick C. No current with a p.d. present means the resistance is very large.

Q33 Answer **B**

Why B is correct

A torch lamp has a metal filament. As the current increases, the filament gets hotter and its resistance increases. So $R = V/I$ should rise as V rises, while still reaching 60 mA at 3 V.

Check B: $R = 1/0.025 = 40\Omega$, $2/0.045 \approx 44\Omega$, $3/0.060 = 50\Omega$. The resistance increases steadily, which matches a filament lamp.

Why the rest are wrong

A — The current stays at 60 mA from 1 V to 3 V, so the resistance would be 17Ω, 33Ω, 50Ω — a sudden jump then a constant current. A filament's current keeps rising with p.d.

C — The current is directly proportional to the p.d. ($R = 50\Omega$ throughout). That is an ohmic resistor, not a filament lamp.

D — $R = 100\Omega$, 100Ω, then 50Ω: the resistance falls at higher p.d., the opposite of a heating filament (more like a diode or thermistor).

Watch out for

C. Students who assume all components obey Ohm's law pick C. A filament lamp's resistance rises as it heats up, so its current rises less than in proportion to the p.d.

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Q34 Answer **B**

Why B is correct

From the figure, the blue neutral wire goes to the neutral terminal correctly. But both the brown live wire and the green-and-yellow earth wire are connected to the live terminal (the one next to the fuse). The earth terminal at the top has no wire.

The earth wire runs to the metal case. Because it is now joined to the live terminal, the metal case is connected to the live supply: the metal case becomes live. Anyone touching it could get a severe electric shock.

The fuse does not blow, because no extra current flows: the case stands on plastic wheels, so there is no path from the case to earth until someone touches it. The live and neutral are still connected to the motor, so the cleaner still works.

Why the rest are wrong

A — The fuse only blows if a large current flows. Here the case is on plastic wheels, so there is no low-resistance path to earth and no large current.

C — Nothing in this wiring causes overheating; the motor receives its normal supply and draws its normal current.

D — The live and neutral wires still reach the motor, so the cleaner works normally — which is what makes this fault dangerous.

Watch out for

A. Students who expect 'live connected to earth' always to blow the fuse pick A. A fuse blows only when a large current actually flows to earth; with the case on plastic wheels, there is no such path.

The answer depends on reading from the figure that the earth wire goes to the live (fused) terminal, not the top earth terminal.

Q35 Answer **D**

Why D is correct

The ammeter reading I_1 sits in the same single loop as I_2: the cells, ammeter I_1, ammeter I_2, the single lamp and the parallel pair are all in series. The current in a series circuit is the same everywhere, so $I_1 = I_2 = 4.0\ \text{A}$.

$V_1 = 12\ \text{V}$ is the e.m.f. across the cells. This is shared between the single lamp (V_2) and the parallel pair of lamps $(V_3 = 4.0\ \text{V})$.

$V_2 = V_1 - V_3 = 12\ \text{V} - 4.0\ \text{V} = 8.0\ \text{V}$.

Why the rest are wrong

A — I_1 is not zero: the ammeter is in series with the cells, so it carries the full 4.0 A. And V_2 is 8.0 V, not 4.0 V.

B — V_2 is right, but I_1 is not zero; the same 4.0 A flows through every part of the series loop.

C — I_1 is right, but $V_2 = 12 - 4.0 = 8.0\ \text{V}$. The single lamp carries the whole 4.0 A, while each lamp in the parallel pair carries only part of it, so the single lamp takes the larger share of the p.d.

Watch out for

B. Students who think the ammeter between the cells is 'short-circuited' by the voltmeter V_1 pick B. A voltmeter has very high resistance and carries almost no current, so all the current flows through the cells and ammeter I_1.

Q36 Answer **D**

Why D is correct

Follow the current from the + terminal: up the left wire, across the top to P, then down through the card from P to Q, and back to the − terminal.

Viewed from above, the current is flowing away from you (into the card). By the right-hand grip rule — thumb pointing along the current (downwards) — the fingers curl clockwise when viewed from above.

The field strength depends on the current. A smaller current gives a weaker field, which is shown by field lines that are further apart.

Why the rest are wrong

A — Anticlockwise would need the current to flow upwards from Q to P. Also, a weaker field has lines further apart, not closer.

B — The spacing is right, but the direction is wrong: with current flowing down from P to Q, the field is clockwise viewed from above.

C — The direction is right, but reducing the current weakens the field, so the lines spread further apart.

Watch out for

B. Students who apply the grip rule with the current going the wrong way pick B. Trace the current from the + terminal first: it goes down from P to Q.

Q37 Answer **B**

Why B is correct

The induced current always flows so as to oppose the change that causes it (Lenz's law).

Magnet moved in: the N-pole approaches X. To oppose the approach, the end X becomes a N-pole, which repels the incoming N-pole.

Magnet moved out: the N-pole moves away from X. To oppose it leaving, X becomes a S-pole, which attracts the N-pole back.

Why the rest are wrong

A — X is N when the magnet moves in, but when it moves out X must be S to oppose the motion by attracting.

C — This is the wrong way round. An S-pole at X would attract the approaching magnet, helping the motion and creating energy from nothing.

D — An S-pole at X on the way in would attract the magnet, helping the change instead of opposing it.

Watch out for

C. Students who think the coil 'copies' the attraction of opposite poles pick C. The induced pole always opposes the motion: like pole when approaching, unlike pole when leaving.

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Q38 Answer **A**

Why A is correct

Each turn of the generator coil produces one cycle of a.c. Doubling the speed of rotation doubles the frequency, so twice as many cycles fit across the screen in the same time: the number of peaks doubles (with the time-base unchanged).

The induced e.m.f. depends on the rate at which the coil cuts the magnetic field lines. At double the speed the field is cut twice as fast, so the peak e.m.f. doubles: the amplitude doubles.

Why the rest are wrong

B — The number of peaks does double, but the amplitude also doubles because the rate of cutting field lines doubles.

C — The amplitude does double, but the frequency also doubles, so more peaks appear on the screen.

D — Both the frequency and the size of the induced e.m.f. depend on the speed of rotation, so neither stays the same.

Watch out for

B. Students who link the speed only to the frequency pick B. A faster coil cuts field lines faster, so the induced e.m.f. is larger as well.

Q39 Answer **D**

Why D is correct

A transformer core is made of soft iron.

The current in the primary coil is alternating, so the core's magnetism must reverse many times each second. Soft iron is easy to magnetise and demagnetise, so it follows these changes quickly with little energy wasted, and it links the changing field into the secondary coil.

Why the rest are wrong

A — Copper is not magnetic, so it cannot carry the changing magnetic field. Being a good conductor is a reason to use copper for the coils, not the core.

B — Copper cannot be magnetised at all, so it would be useless as a core.

C — Iron is the right material, but not because it conducts electricity; the core's job is magnetic. Its conductivity actually causes wasted energy as heat, which is why cores are laminated.

Watch out for

C. Students who know the core is iron but give an electrical reason pick C. The core carries a magnetic field, so the reason must be magnetic.

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Q40 Answer **D**

Why D is correct

For a given power $P = VI$, transmitting at a high voltage means a small current in the cables. The power wasted as heat in the cables is $P = I^2R$, so a small current means less energy is wasted.

Transformers only work with alternating current, because they need a changing magnetic field. Using a.c. means the voltage can be stepped up for transmission and stepped down again for safe use in homes.

Why the rest are wrong

A — A high voltage gives a low current, not a high current, and a.c. does not change the resistance of the cables.

B — The a.c. reason is right, but a high voltage gives a low current in the cables, not a high one.

C — The high-voltage reason is right, but the type of current does not change the cables' resistance; resistance depends on the material, length and thickness of the cable.

Watch out for

B. Students who think 'high voltage means high current' pick B. For the same power, $P = VI$, so raising V lowers I.

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