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TEN-YEAR SERIES · ANSWERS AND WORKED SOLUTIONS

2020 O-Level Physics Paper 1

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ANSWER KEY

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WORKED SOLUTIONS

Q1 Answer C

Why C is correct

1 Mm (megametre) = 10^6 m, and $1\ \text{m} = 10^3\ \text{mm}$.

So $1\ \text{Mm} = 10^6 \times 10^3\ \text{mm} = 10^9\ \text{mm}$. The conversion factor is 10^9.

Why the rest are wrong

A — 10^3 converts metres to millimetres (or Mm to km), not Mm to mm.

B — 10^6 converts Mm to metres only; it misses the further factor of 10^3 from m to mm.

D — 10^{12} would mean adding the two powers wrongly (6 + 6). Milli is 10^{-3}, not 10^{-6}.

Watch out for

B. Students who stop at metres pick B. Always go Mm → m → mm, multiplying both factors: $10^6 \times 10^3 = 10^9$.

Q2 Answer C

Why C is correct

An atom is about 10^{-10} m across. $0.5\ \text{nm} = 0.5 \times 10^{-9}\ \text{m} = 5 \times 10^{-10}\ \text{m}$, which is the right size.

The Earth's diameter is about $12\,700\ \text{km} \approx 1.2 \times 10^7\ \text{m}$. $12\ \text{Mm} = 12 \times 10^6\ \text{m} = 1.2 \times 10^7\ \text{m}$, which matches.

So the row is 0.5 nm and 12 Mm.

Why the rest are wrong

A — $0.5\mu m = 5 \times 10^{-7}$ m is about a thousand times too big for an atom (that is the size of a bacterium).

B — $0.5\mu m$ is far too big for an atom, and $12\ \text{Gm} = 1.2 \times 10^{10}$ m is about a thousand times the Earth's diameter.

D — 0.5 nm is right for the atom, but $12\ \text{Gm} = 1.2 \times 10^{10}$ m is far too big for the Earth.

Watch out for

D. Students who are unsure whether giga or mega fits the Earth pick D. Turn 12 Gm into metres ($1.2 \times 10^{10}\ \text{m} = 12$ million km) and compare with the Earth's diameter of about 12 700 km.

Q3 Answer B

Why B is correct

O is stationary, so the resultant force on it is zero. The forces must balance both vertically and horizontally.

The 5 N force points down and to the right. The only upward force is 4 N, so the downward part of the 5 N force must be 4 N. The only leftward force is X, so X must equal the rightward part of the 5 N force.

The 5 N force is the hypotenuse of a right-angled triangle with a 4 N vertical side: horizontal part = $\sqrt{5^2 - 4^2} = \sqrt{25 - 16} = \sqrt{9} = 3\ \text{N}$.

So $X = 3\ \text{N}$. (Equivalently, a 3 N, 4 N, 5 N set of forces closes into a triangle.)

Why the rest are wrong

A — 1 N is 5 − 4, found by subtracting the sizes. Forces at an angle cannot be subtracted like this.

C — 9 N is 5 + 4, adding the sizes. That is the resultant only if both forces act in the same direction.

D — 20 N is 5 × 4. Forces are never multiplied to find a resultant.

Watch out for

A. Students who just subtract 5 − 4 pick A. Split the 5 N force into a vertical part (must cancel the 4 N) and a horizontal part (must cancel X), then use Pythagoras.

The figure is not drawn to scale: the 5 N arrow looks like 45°, but balance needs it at about 53° below the horizontal ($\tan\theta = 4/3$). Do not measure the angle from the diagram.

Q4 Answer C

Why C is correct

Both balls start with the same acceleration, $g = 10\ \text{m/s}^2$, because without air resistance all objects fall with the same acceleration whatever their mass.

As each ball speeds up, the air resistance on it grows. A ball stops accelerating (reaches terminal velocity) when air resistance equals its weight.

The metal ball is much heavier, so the air resistance has to grow much larger before it balances the weight. The metal ball therefore keeps accelerating for longer and reaches a greater speed before the forces balance, so it lands first.

Why the rest are wrong

A — A gravitational field gives every object the same acceleration g; heavier objects get a bigger force but have proportionally more mass.

B — g does not depend on the mass of the object; it is the same (about $10\ \text{m/s}^2$) for all objects near the Earth's surface.

D — Air resistance depends mainly on speed and size/shape, not on mass. The large metal ball can actually have the bigger air resistance; what matters is that its weight is much larger still.

Watch out for

D. Students who think 'light things get more air resistance' pick D. Air resistance does not depend on mass; the point is how big the air resistance must get before it balances the weight.

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Q5 Answer **D**

Why D is correct

On a height–time graph, the gradient gives the speed. At terminal velocity the speed is constant, so the graph is a straight line. This happens from about $t = 1.0\ \text{s}$ onwards.

Read two points on the straight part: at $t = 1.0\ \text{s}$, height = 3.0 m; at $t = 2.5\ \text{s}$, height = 0 m.

speed = distance fallen ÷ time = $(3.0 - 0) \div (2.5 - 1.0) = 3.0 \div 1.5 = 2.0\ \text{m/s}$.

Why the rest are wrong

A — 1.0 m/s does not match any gradient on the straight part; it would be, for example, dropping 1 m in 1 s.

B — 1.2 m/s may come from a curved early section or from misreading the grid; the straight part has a steeper gradient.

C — 1.6 m/s is the average speed over the whole fall (4.0 m ÷ 2.5 s). The average includes the slow start, so it is less than the terminal velocity.

Watch out for

C. Students who divide total height by total time (4.0 ÷ 2.5) pick C. Terminal velocity is the gradient of the straight part only.

Q6 Answer **B**

Why B is correct

The front wheels are driven. They push backwards on the road, so the road pushes forwards on the front wheels. This friction F_1 is the force that drives the car forwards.

The rear wheels are not driven; they are simply pushed along and made to roll. The friction on them opposes their motion, so F_2 acts backwards.

Diagram B shows F_1 forwards (in the direction of motion) and F_2 backwards.

Why the rest are wrong

A — A has F_1 backwards. If the friction on the driven wheels pointed backwards, nothing would push the car forwards.

C — C has F_2 forwards on the rear wheels, but these wheels are not driven by the engine, so the road gives them no forward push.

D — D has both forces the wrong way round: driving wheels backwards and free wheels forwards.

Watch out for

A. Students who think friction always opposes motion pick A. On a driven wheel, friction is what moves the car forward; only on the free-rolling wheels does it act backwards.

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Q7 Answer **A**

Why A is correct

Both spheres are made of copper. Density is a property of the material, so density is the same for both.

Q has a smaller volume than P, so Q has a smaller mass (mass = density × volume) and a smaller weight.

Why the rest are wrong

B — The same force for the same time gives a lighter object a higher speed. Q's kinetic energy turns out larger than P's, so the kinetic energy gained is not the same.

C — Q has less volume, so with the same density it has less mass.

D — Weight = mass × g. Q has less mass, so it has less weight.

Watch out for

B. Students who think 'same force, same time, so same energy' pick B. The lighter sphere moves further in that time, so the force does more work on it and it gains more kinetic energy.

Q8 Answer **D**

Why D is correct

Volume of metal actually present: $V = m \div \rho = 15 \div 3.0 = 5.0\ \text{cm}^3$.

Outside volume of the cube: $4.0 \times 4.0 \times 4.0 = 64\ \text{cm}^3$.

Empty space = $64 - 5.0 = 59\ \text{cm}^3$.

Why the rest are wrong

A — $5.0\ \text{cm}^3$ is the volume of the metal, not the empty space.

B — $11\ \text{cm}^3$ does not come from correct working; it is 16 − 5, using the area of one face ($4.0 \times 4.0 = 16\ \text{cm}^2$) instead of the cube's volume.

C — $19\ \text{cm}^3$ does not come from correct working; it is 24 − 5, using $4.0 \times 6 = 24$ instead of the cube's volume of $4.0^3 = 64\ \text{cm}^3$.

Watch out for

A. Students who stop after $m \div \rho$ pick A. That gives the metal's volume; subtract it from the cube's total volume to get the empty space.

Q9 Answer **D**

Why D is correct

Take moments about P. The stick balances, so clockwise moment = anticlockwise moment.

$24\ \text{N} \times 0.50\ \text{m} = F \times 0.30\ \text{m}$, so $F = 12 \div 0.30 = 40\ \text{N}$.

The stick is light and in equilibrium, so the total upward force equals the total downward force: shoulder force = $24 + 40 = 64\ \text{N}$.

Why the rest are wrong

A — 16 N is 40 − 24; the two downward forces act in the same direction, so they add, not subtract.

B — 24 N is just the load. The shoulder also has to support the downward push of the hand.

C — 40 N is the hand force F, not the shoulder force.

Watch out for

C. Students who stop after finding F pick C. The question asks for the force at the pivot, which must hold up both the load and the hand's downward push.

Q10 Answer **A**

Why A is correct

Each brick lies flat, 0.10 m high, with a base area of $0.20\ \text{m} \times 0.10\ \text{m} = 0.020\ \text{m}^2$.

A single layer of bricks pushes 10 N on each $0.020\ \text{m}^2$, a pressure of $10 \div 0.020 = 500\ \text{Pa}$. Stacking more bricks on the same base area adds 500 Pa per layer, however wide the pile is.

So 2000 Pa needs $2000 \div 500 = 4$ layers. Pile A is 4 bricks high.

Check using A in full: 2 × 3 bricks per layer × 4 layers = 24 bricks, weight 240 N; base $0.40\ \text{m} \times 0.30\ \text{m} = 0.12\ \text{m}^2$; $p = F \div A = 240 \div 0.12 = 2000\ \text{Pa}$.

Why the rest are wrong

B — B is 5 layers high: $5 \times 500 = 2500\ \text{Pa}$.

C — C is 3 layers high: $3 \times 500 = 1500\ \text{Pa}$.

D — D is 6 layers high: $6 \times 500 = 3000\ \text{Pa}$.

Watch out for

C. Students who think a wider pile gives more pressure, or who count total bricks instead of layers, can be misled. For identical bricks laid the same way, pressure depends only on the number of layers.

Q11 Answer **A**

Why A is correct

The space above the liquid is a vacuum, so the only thing holding the liquid up the tube is the pressure of the air on the liquid surface outside.

The pressure of a liquid column depends on its vertical height, not the length along the tube: $p = h\rho g$. Here the vertical height is l and the liquid's density is d.

So air pressure = ldg.

Why the rest are wrong

B — ρ is the density of the air. The column that balances the air pressure is liquid, so the liquid's density d must be used.

C — x is the length of liquid measured along the sloping tube. Pressure depends on vertical height, so x gives too large a value.

D — This uses both the wrong length (x along the slope) and the wrong density (air instead of liquid).

Watch out for

C. Students who take the length of liquid in the tube pick C. Tilting the tube makes the column longer but not taller; only the vertical height l counts.

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Q12 Answer **D**

Why D is correct

As the stone falls, air resistance acts against its motion. Work is done against air resistance, so some of the lost gravitational potential energy becomes thermal energy (and sound) in the stone and the air.

So only part of P becomes kinetic energy: $P > K$.

Energy is still conserved: $P = K$ + energy transferred to other forms. No energy is created or destroyed.

Why the rest are wrong

A — $P = K$ would only be true with no air resistance. The question says the stone experiences air resistance.

B — P and K are not equal, but conservation of energy is still obeyed; the missing energy has gone into the surroundings as thermal energy.

C — K cannot be more than P: the stone starts from rest, so all its kinetic energy came from the lost potential energy.

Watch out for

B. Students who think '$P \neq K$ means energy is not conserved' pick B. Energy is conserved when you count all forms, including the thermal energy produced by air resistance.

Q13 Answer **D**

Why D is correct

Work done = force × distance moved in the direction of the force.

$W = F \times d = 3600 \times 100 = 360\,000\ \text{J}$.

The speed of 90 km/h is not needed: work depends only on force and distance.

Why the rest are wrong

A — 360 J is 3600 × 0.1, as if 100 m were 0.1 m (or 0.1 km left unconverted).

B — 14 400 J does not come from $F \times d$; it may come from mixing in the speed, e.g. 3600 × 4.

C — 21 600 J may come from 3600 × 6 or other working that uses the speed. The speed is not part of work done.

Watch out for

A. Students who convert 100 m to 0.1 km and multiply pick A. Keep force in N and distance in m to get joules.

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Q14 Answer **A**

Why A is correct

The slope is smooth, so all the work done by F goes into gravitational potential energy.

Length of slope (hypotenuse of a 3.0 m by 4.0 m triangle) = $\sqrt{3.0^2 + 4.0^2} = 5.0\ \text{m}$.

Work done by F = gain in GPE: $F \times 5.0 = 20 \times 3.0 = 60\ \text{J}$, so $F = 60 \div 5.0 = 12\ \text{N}$.

Why the rest are wrong

B — 15 N comes from 60 ÷ 4.0, using the horizontal distance instead of the distance along the slope, which F actually moves through.

C — 16 N is 20 × 4/5, the component of weight perpendicular to the slope (pressing into it), not along it.

D — 20 N is the force needed to lift the box straight up. The slope lets a smaller force do the same work over a longer distance.

Watch out for

B. Students who use the 4.0 m horizontal distance pick B. F acts along the slope, so the distance it moves is the slope length, 5.0 m.

Q15 Answer **C**

Why C is correct

The temperature is constant, so the average speed of the gas particles does not change.

The volume is larger, so the particles are more spread out and travel further between collisions with the walls and piston. They hit each unit area of the piston less frequently.

Fewer collisions per second on each unit area means a smaller average force per unit area, so the pressure decreases.

Why the rest are wrong

A — The particles do not move faster: their speed depends on temperature, which stays constant. And a larger volume gives less frequent collisions, not more.

B — Particles move more slowly only if the gas cools. The temperature here is constant.

D — With a larger volume the particles hit the piston less often, not more, so the pressure falls.

Watch out for

B. Students who link 'pressure falls' with 'particles slow down' pick B. At constant temperature the speed stays the same; only the frequency of collisions changes.

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Q16 Answer **D**

Why D is correct

Glass is a solid non-metal, so thermal energy passes through it by conduction.

The molecules at the hot bottom surface gain energy and vibrate more vigorously about their fixed positions. They pass kinetic energy to the neighbouring molecules, which in turn vibrate more, so the energy is passed upwards through the glass.

Why the rest are wrong

A — Molecules do not expand when heated; the spacing between them increases slightly, but a molecule itself does not get bigger.

B — Molecules in a solid stay in fixed positions; they cannot move up through the glass. Particles moving from place to place is convection, which happens in fluids.

C — Thermal radiation is infrared, not microwaves, and conduction through a solid is not by radiation.

Watch out for

B. Students who mix up conduction and convection pick B. In a solid the particles only vibrate; they never travel through the material.

Q17 Answer **A**

Why A is correct

A temperature scale needs a property that changes steadily and measurably with temperature.

The mass of a column of liquid does not change when it is heated: the liquid expands, so its length changes, but the amount of matter is the same. So mass cannot be used.

Gas volume at constant pressure, thermocouple e.m.f. and the resistance of a metal wire all change with temperature, and each is used in a real thermometer.

Why the rest are wrong

B — The volume of a gas at constant pressure increases with temperature; this is the basis of a gas thermometer.

C — A thermocouple produces an e.m.f. that changes with the temperature difference between its junctions.

D — The resistance of a metal wire increases with temperature; this is used in a resistance thermometer.

Watch out for

C. Students who have not met the thermocouple may pick C because it sounds unusual. It is a standard thermometer; the property that never changes with temperature is mass.

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Q18 Answer **B**

Why B is correct

Volume of water = $12 \times 8.0 \times 1.2 = 115.2\ \text{m}^3$. Mass = $\rho V = 1000 \times 115.2 = 115\,200\ \text{kg} = 1.152 \times 10^8\ \text{g}$.

Energy needed: $Q = mc\Delta\theta = 1.152 \times 10^8 \times 4.2 \times (29 - 20) = 4.35 \times 10^9\ \text{J}$. (c is in J/(g °C), so the mass must be in grams.)

Time = $24 \times 3600 = 86\,400\ \text{s}$. $P = Q \div t = 4.35 \times 10^9 \div 86\,400 = 5.04 \times 10^4\ \text{W} \approx 50\ \text{kW}$.

Why the rest are wrong

A — 42 kW does not come from correct working; it may come from dropping the temperature rise or other factors.

C — 1200 kW is 24 times too large: it uses 24 hours as 3600 s (one hour) instead of 86 400 s.

D — 3000 kW is 60 times too large: it converts 24 hours into minutes (1440 min) instead of seconds.

Watch out for

C. Students who use $t = 3600\ \text{s}$ pick C. 24 hours is $24 \times 3600 = 86\,400\ \text{s}$.

Watch the units of c: 4.2 J/(g °C) needs mass in grams ($1.152 \times 10^8\ \text{g}$), not kilograms.

Q19 Answer **D**

Why D is correct

The flat part of the graph (constant temperature at 50 °C) is where the liquid freezes. It lasts from 50 s to 150 s, a time of 100 s.

Energy removed while freezing: $E = Pt = 200 \times 100 = 20\,000\ \text{J}$.

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

Why the rest are wrong

A — 0.040 J/g is far too small; it comes from dividing the wrong way round (for example 8.0 ÷ 200). Latent heat is energy ÷ mass.

B — 8.0 J/g is 400 ÷ 50, dividing by the mass twice. Divide the energy (20 000 J) by the mass once.

C — 60 J/g does not come from the freezing section; the energy must be the power times the 100 s the temperature stays at 50 °C.

Watch out for

B. Students who divide by the mass twice pick B. Find the energy first ($E = Pt = 20\,000\ \text{J}$), then divide once by the mass.

Only the flat 100 s section (50 s to 150 s) is freezing time; do not use times from the start of the graph.

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Q20 Answer C

Why C is correct

Heat capacity of the block: $C = Q \div \Delta\theta = 36 \div (10 - (-10)) = 36 \div 20 = 1.8\ \text{J/°C}$.

Specific heat capacity: $c = C \div m = 1.8 \div 2.0 = 0.90\ \text{J/(g°C)}$.

Ratio $c \div C = 0.90 \div 1.8 = 1/2$. (In general $c \div C = 1/m$, and $m = 2.0\ \text{g}$.)

Why the rest are wrong

A — 1/30 does not follow from the data; c ÷ C depends only on the mass.

B — 1/10 might come from using a temperature change of 10 °C instead of 20 °C, but the ratio c ÷ C does not depend on the temperature change at all.

D — 2/1 is the ratio upside down: heat capacity ÷ specific heat capacity = $m = 2$.

Watch out for

D. Students who mix up which quantity is per gram pick D. Specific heat capacity is per unit mass, so it is the smaller number: $c = C \div m$.

The mass is taken in grams, as given. Using 0.0020 kg would give 500, which is not an option.

Q21 Answer D

Why D is correct

In a longitudinal wave the particles vibrate parallel to the direction the wave travels. All sound waves, including ultrasound, are longitudinal.

In a transverse wave the vibrations are at right angles to the direction of travel. All electromagnetic waves (radio waves, microwaves, light) are transverse.

So ultrasound is longitudinal and light is transverse: row D.

Why the rest are wrong

A — The two are the wrong way round: light is transverse and ultrasound is longitudinal.

B — Microwaves are electromagnetic waves, so they are transverse, not longitudinal.

C — Radio waves are electromagnetic waves, so they are transverse, not longitudinal.

Watch out for

A. Students who know the right pair but rush pick A, which has the columns swapped. Check which column is which before choosing.

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Q22 Answer **A**

Why A is correct

The point moves between two positions 1.0 cm apart. The amplitude is the distance from the rest position to one extreme, which is half of this.

= amplitude = $1.0\ \text{cm} \div 2 = 0.50\ \text{cm}$

The 12 cm in the diagram is measured from the centre of one compression to the centre of the next compression. That is one complete wave, so the wavelength is 12 cm.

Row A: amplitude 0.50 cm, wavelength 12 cm.

Why the rest are wrong

B — 24 cm would be the distance across two complete waves. The 12 cm is already from one compression to the next one.

C — 1.0 cm is the total distance moved from one extreme to the other. The amplitude is only half of this.

D — Both values are doubled: the amplitude is half the 1.0 cm, and the wavelength is the 12 cm shown.

Watch out for

C. Students who take the full back-and-forth distance as the amplitude pick C. Amplitude is measured from the rest position to one extreme only.

B. Some students think the distance between two compressions is half a wavelength. It is a full wavelength, just as crest to crest is for a transverse wave.

Q23 Answer **D**

Why D is correct

Convert to SI units first: $v = 1.4\ \text{km/s} = 1400\ \text{m/s}$ and $\lambda = 0.70\ \text{mm} = 0.70 \times 10^{-3}\ \text{m}$.

= $f = v/\lambda$

= = $1400/(0.70 \times 10^{-3})$

= = $2.0 \times 10^{6}\ \text{Hz}$

Why the rest are wrong

A — 0.98 comes from multiplying 1.4 × 0.70 instead of dividing speed by wavelength.

B — 2.0 Hz comes from dividing 1.4 by 0.70 without converting km to m or mm to m.

C — $2.0 \times 10^{3}\ \text{Hz}$ comes from converting only one of the two units (for example km/s to m/s but leaving the wavelength in mm).

Watch out for

C. Students who convert only one of the units pick C. Change both quantities to metres before dividing.

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Q24 Answer **B**

Why B is correct

In the diagram the object is beyond F (between F and $2F$) and a real, inverted image forms on the other side of the lens.

As the object moves closer to F, the rays leaving the lens become less steeply converging, so they meet further from the lens.

At the same time the image grows. The closer the object gets to F, the further away and the larger the image becomes. When the object reaches F, the rays leave the lens parallel and the image is at infinity.

So the image moves further away from the lens and increases in size.

Why the rest are wrong

A — The image does move further away, but it gets larger, not smaller.

C — This is what happens when the object moves away from the lens (away from F), not towards F.

D — The image does get larger, but it moves away from the lens, not towards it.

Watch out for

D. Students who think 'object closer to lens, so image closer too' pick D. For a converging lens, as the object approaches F the image moves outwards to infinity. Draw two quick ray diagrams to check.

Q25 Answer **C**

Why C is correct

Angles in ray optics are always measured from the normal, not from the surface.

At X the normal is the horizontal dashed line (the left face is vertical). The angle of refraction r is between the refracted ray inside the block and this horizontal normal. Only C and D show this.

At Y the normal is the vertical dashed line. The critical angle c is the angle of incidence inside the block, between the incident ray (coming from X) and the normal, when the refracted ray just grazes the surface. Diagram C marks c between the ray arriving from X and the vertical normal.

So diagram C shows both angles correctly.

Why the rest are wrong

A — The angle r is marked between the ray and the vertical left face of the block, not between the ray and the normal at X.

B — Both angles are wrong: r is measured from the face, not the normal, and c is marked between the reflected ray and the top surface.

D — r is correct, but c is marked between the reflected ray and the top surface. The critical angle is between the incident ray and the normal.

Watch out for

D. Students who correctly find r but then mark the angle next to the surface at Y pick D. The critical angle is an angle of incidence, so it is measured from the normal on the side of the ray arriving at Y.

Reading the figure decided this: in C the arc for c sits between the ray from X and the vertical dashed normal.

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Q26 Answer **B**

Why B is correct

Ultrasound is a sound wave, so it needs a medium (air, water, body tissue) to travel through. It cannot travel through the vacuum of space.

Bats, fishing boats (echo-sounding the sea bed) and doctors (ultrasound scans) all send out ultrasound and detect the echo.

Satellites in space cannot use ultrasound at all, so detecting objects in space does not use an ultrasound echo. Answer B.

Why the rest are wrong

A — Bats emit ultrasound and use the echoes from obstacles to find them (echolocation).

C — Ships send ultrasound pulses down and time the echo from the sea bed to find the depth.

D — An ultrasound scan builds an image from echoes reflected at boundaries between tissues.

Watch out for

D. Some students think medical imaging uses X-rays and pick D. A scan of an unborn baby uses ultrasound echoes because X-rays would harm the baby.

Q27 Answer **C**

Why C is correct

Louder means a larger amplitude: the wave must be taller than the original.

Lower pitch means a lower frequency: fewer waves on the same time axis, so each wave is more spread out.

Diagram C has a larger amplitude and fewer waves across the screen than the original. Answer C.

Why the rest are wrong

A — A has a larger amplitude (louder) but the same number of waves, so the pitch is unchanged.

B — B has a lower frequency (lower pitch) but about the same amplitude as the original, so it is not louder.

D — D has a smaller amplitude (quieter) and the same frequency, so it is neither louder nor lower.

Watch out for

B. Students who only check the pitch pick B. You must check both the height (loudness) and the spacing (pitch).

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Q28 Answer **A**

Why A is correct

The negative rod repels free electrons in the metal sphere. Because the sphere is earthed, these electrons are pushed away down the earth wire to earth.

This leaves the sphere with a shortage of electrons, so it has a net positive charge. The positive charge is attracted to the negative rod, so it gathers on the side nearest the rod.

No negative charge is left on the far side, because it has all gone to earth. Diagram A shows this.

Why the rest are wrong

B — B shows the charge separation for a sphere that is NOT earthed. With the earth connection, the repelled electrons flow to earth.

C — The near side cannot be left uncharged with negative charge on the far side: the electrons on the far side would escape to earth, and the near side becomes positive.

D — The charges are the wrong way round: negative charge would not gather next to a negative rod.

Watch out for

B. Students who ignore the earth wire pick B. Earthing removes the charge that is repelled, leaving only the induced charge of opposite sign to the rod.

Q29 Answer **B**

Why B is correct

Current = rate of flow of charge. Each electron carries 1.6×10^{-19} C, so the number of electrons passing per second is:

= number per second = $I/e = 0.32/(1.6 \times 10^{-19})$

= = 2.0×10^{18} per second

The arrow shows the conventional current from left to right. Electrons are negative, so they flow in the opposite direction: right to left.

Why the rest are wrong

A — The number is correct, but electrons move opposite to the conventional current, so they go right to left.

C — 5.0×10^{-19} comes from dividing e by I the wrong way round. A number of electrons per second cannot be this tiny. The direction is also wrong.

D — The direction is correct, but 5.0×10^{-19} comes from dividing the wrong way round.

Watch out for

A. Students who forget that the arrow shows conventional current pick A. Electrons always flow from the negative terminal, opposite to the conventional current arrow.

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Q30 Answer **C**

Why C is correct

Each cell symbol has a long line (positive terminal) and a short line (negative terminal). Cells joined + to − add their e.m.f.s. A cell turned the other way round subtracts its e.m.f.

To get 6.0 V from 1.5 V cells, the net number of cells must be 6.0 ÷ 1.5 = 4. With six cells, this means 5 cells one way and 1 cell reversed: $5 - 1 = 4$.

In C, five cells point the same way and one (the third from the left) is reversed.

= e.m.f. = $(5 - 1) \times 1.5 = 6.0\ \text{V}$

Why the rest are wrong

A — Two cells (the third and the sixth) are reversed, so the e.m.f. is $(4 - 2) \times 1.5 = 3.0\ \text{V}$.

B — Four cells point one way and two the other way, so the e.m.f. is $(4 - 2) \times 1.5 = 3.0\ \text{V}$.

D — The cells alternate in direction: three each way, so the e.m.f. is $(3 - 3) \times 1.5 = 0\ \text{V}$.

Watch out for

A. Students who only spot one reversed cell in A pick it. Check every cell, one at a time, by looking at which side the long line is on.

Q31 Answer **B**

Why B is correct

= $I = Q/t = 15/10 = 1.5\ \text{A}$

Potential difference is the work done per unit charge:

= $V = W/Q = 60/15 = 4.0\ \text{V}$

Row B.

Why the rest are wrong

A — 0.25 V comes from dividing Q by W (15 ÷ 60) instead of W by Q.

C — 150 A comes from multiplying Q × t instead of dividing. 0.25 V is also upside down.

D — The p.d. is correct but 150 A comes from Q × t instead of Q ÷ t.

Watch out for

A. Students who divide the wrong way round for p.d. pick A. Use $V = W/Q$: joules per coulomb.

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Q32 Answer **C**

Why C is correct

X is connected directly across the 12 V battery, and so is the branch with the 3.0Ω resistor and Y. Each branch has 12 V across it.

The battery current is 4.0 A and the lower branch carries 2.0 A, so X carries $4.0 - 2.0 = 2.0\ \text{A}$.

= $R(X) = V/I = 12/2.0 = 6.0\Omega$

Lower branch: total resistance = $12/2.0 = 6.0\Omega$, so $R(Y) = 6.0 - 3.0 = 3.0\Omega$

Why the rest are wrong

A — $X = 3.0\Omega$ would need 4.0 A through X alone. X only carries the 2.0 A left over from the 4.0 A total.

B — X and Y are swapped. X is the single resistor across 12 V carrying 2.0 A, so it is 6.0Ω.

D — $Y = 6.0\Omega$ forgets that the 3.0Ω resistor is in series with Y; the 6.0Ω is the total for that branch.

Watch out for

D. Students who work out $12/2.0 = 6.0\Omega$ for the lower branch and give that as Y pick D. Subtract the 3.0Ω that is in series with Y.

Q33 Answer **C**

Why C is correct

First find the battery e.m.f. At room temperature the two resistances are $2.0k\Omega$ and $6.0k\Omega$ in series. The p.d. divides in proportion to resistance, so the fixed resistor gets 2.0/8.0 of the total.

= $1.8\ \text{V} = (2.0/8.0) \times E$, so $E = 1.8 \times 4 = 7.2\ \text{V}$

When the thermistor falls to $2.0k\Omega$, the two resistances are equal, so the p.d. splits equally:

= $V = (2.0/4.0) \times 7.2 = 3.6\ \text{V}$

Why the rest are wrong

A — 1.2 V would mean the fixed resistor gets a smaller share. A falling thermistor resistance gives the fixed resistor a larger share, so its p.d. rises.

B — 2.4 V would come from using the wrong supply voltage or ratio; the supply is 7.2 V and the share is one half.

D — 7.2 V is the whole battery e.m.f., not the p.d. across the fixed resistor.

Watch out for

D. Students who stop after finding the e.m.f. pick D. Read the question again: it asks for the p.d. across the fixed resistor.

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Q34 Answer **B**

Why B is correct

A fuse melts when the current is too large. This stops the wires (and the appliance) from overheating and causing a fire.

The fuse must be in the live wire, so that when it melts, the appliance is cut off from the high voltage. A fuse in the earth wire would leave the appliance connected to the live supply.

Row B.

Why the rest are wrong

A — A fuse in the earth wire would not cut off the live supply. Normally no current flows in the earth wire, so the fuse would never melt anyway.

C — The fuse protects the wiring from overheating; the earth wire is what protects the user from shock. It is also in the wrong wire.

D — It is in the correct wire, but its job is to stop the wires overheating. A fuse melts too slowly, and at too large a current, to protect a person from a shock.

Watch out for

D. Students who think a fuse is a shock-protection device pick D. The earth wire with the fuse together protect the user; the fuse on its own is there to stop excessive current overheating the wires.

Q35 Answer **C**

Why C is correct

A freely hanging magnet lines up with the Earth's magnetic field. The end that points towards the Earth's geographic north is called the north-seeking pole, or N-pole.

So statement C is correct.

Why the rest are wrong

A — Pure (soft) iron is easily magnetised but loses its magnetism easily, so it is used for temporary magnets. Permanent magnets are made of steel or other hard magnetic materials.

B — Magnetic poles always come in pairs. Cutting a magnet in half gives two smaller magnets, each with an N-pole and an S-pole.

D — Like poles repel. Two S-poles repel each other.

Watch out for

A. Students who mix up hard and soft magnetic materials pick A. Iron for temporary magnets (electromagnets), steel for permanent magnets.

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Q36 Answer **C**

Why C is correct

To demagnetise a magnet, place it inside a coil carrying alternating current. The a.c. makes the magnetic field reverse direction many times a second, which jumbles up the magnetic domains.

The magnet is then slowly pulled out of the coil (or the current is slowly reduced). The reversing field gets weaker and weaker, so the domains are left pointing in random directions and the magnet is demagnetised.

Why the rest are wrong

A — Passing current through the magnet itself does not reverse the magnetisation in a controlled way. The magnet needs to be in a changing field from a coil.

B — The alternating field must come from a coil around the magnet, and must die away slowly. Passing a.c. through the magnet does not do this.

D — A direct current in a coil gives a steady field in one direction. This magnetises the material rather than demagnetising it.

Watch out for

D. Students who remember the 'coil and slowly remove' method but forget the current type pick D. A d.c. coil is used to make a magnet; an a.c. coil is used to destroy it.

Q37 Answer **B**

Why B is correct

Field: magnetic field lines go from N to S, so between the poles the field points from the N-pole on the right towards the S-pole on the left (towards arrow A).

Current: the long plate (positive terminal) of the cell is the lower one, so conventional current leaves the cell downwards, goes round to Y and flows along the wire from Y to X. In the drawing, X is further back than Y, so the current flows into the page.

Fleming's left-hand rule: First finger = field (to the left), seCond finger = current (into the page). The thuMb then points upwards, towards B.

Why the rest are wrong

A — A is the direction of the magnetic field. The force is at right angles to both the field and the current.

C — C is opposite to the field. The force cannot be along the field line.

D — D is the result if either the current or the field direction is reversed, for example if the cell's terminals are read the wrong way round.

Watch out for

D. Students who take the current as flowing from X to Y pick D. Find the long plate of the cell (the positive terminal) and follow the conventional current from it.

The figure detail that decides this is the cell symbol: the longer line is the lower plate, so the current goes from Y to X.

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Q38 Answer **C**

Why C is correct

The size of the induced e.m.f. depends on how fast the coil cuts the field lines. Halving the speed of rotation halves the peak e.m.f., so the amplitude is halved.

The coil also makes half as many turns each second, so the frequency is halved and the period is doubled.

The time base of the c.r.o. is unchanged, so one cycle now takes up twice the distance on the screen: the distance x is doubled.

Why the rest are wrong

A — Slowing the generator reduces the rate of cutting field lines, so the amplitude falls, not rises. The period also changes.

B — The amplitude is halved, but a lower frequency means a longer period, so x gets longer, not shorter.

D — x does double, but the amplitude also changes because the e.m.f. depends on the speed of rotation.

Watch out for

D. Students who think only the frequency depends on speed pick D. Both the peak e.m.f. and the frequency are proportional to the speed of rotation.

B. Students who confuse frequency with the distance x pick B. Lower frequency means a longer period, which is a wider wave on the screen.

Q39 Answer **B**

Why B is correct

With light shining into the box and nothing moving, the ammeter reads zero. If there were a cell in the box (with either a coil or an LDR), there would be a steady current all the time. So there is no cell: A and C are ruled out.

When the magnet moves towards the open end the ammeter deflects, and the reading drops to zero as soon as the magnet stops. This is electromagnetic induction: a changing magnetic field through a coil induces an e.m.f. only while it is changing.

An LDR on its own has no e.m.f., so it could never make a current. The box contains a coil only.

Why the rest are wrong

A — With a cell in series, there would be a steady current and the ammeter would not read zero to begin with.

C — With a cell in series with an LDR in the light, there would be a current and the ammeter would not read zero. Blocking the light would also reduce the current, not create one that stops when the magnet stops.

D — An LDR does not produce an e.m.f., so the ammeter would read zero whatever the magnet or light did.

Watch out for

D. Students who think the magnet is a distraction and focus on the light pick D or C. The key clue is that the reading returns to zero when the magnet stops moving: that only happens with induction.

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Q40 Answer **C**

Why C is correct

Read the c.r.o. trace. The square wave goes 2 divisions above and 2 divisions below 0 V, so the p.d. is +20 V or −20 V at every moment (2 × 10 V).

One period is one division high plus one division low = 2 divisions:

= $T = 2 \times 0.25\ \text{ms} = 0.50\ \text{ms} = 5.0 \times 10^{-4}\ \text{s}$

The power depends on V^2, so it is the same for +20 V and −20 V:

= $P = V^2/R = 20^2/50 = 8.0\ \text{W}$

= $E = P \times t = 8.0 \times 5.0 \times 10^{-4} = 4.0 \times 10^{-3}\ \text{J} = 4.0\ \text{mJ}$

Why the rest are wrong

A — 0 mJ comes from thinking that the positive and negative halves cancel. Current in either direction heats the resistor, so energy is dissipated in both halves.

B — 2.0 mJ comes from counting only one half of the period (the positive half), or from using a period of 1 division.

D — 8.0 mJ comes from taking the period as 4 divisions (1.0 ms), or from using the peak-to-peak voltage of 40 V in some way.

Watch out for

A. Students who 'average' the p.d. to zero pick A. Heating depends on V^2, which is always positive.

B. Students who use only the time the trace is above 0 V pick B. The resistor is heated just as much when the p.d. is negative.

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