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TEN-YEAR SERIES · ANSWERS AND WORKED SOLUTIONS

2018 O-Level Physics Paper 1

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ANSWER KEY

1 **B**	2 **D**	3 **C**	4 **C**	5 **C**	6 **B**	7 **A**	8 **C**	9 **A**	10 **A**
11 **A**	12 **B**	13 **D**	14 **C**	15 **C**	16 **D**	17 **A**	18 **A**	19 **B**	20 **D**
21 **D**	22 **B**	23 **C**	24 **B**	25 **D**	26 **B**	27 **B**	28 **D**	29 **B**	30 **C**
31 **A**	32 **A**	33 **A**	34 **A**	35 **D**	36 **C**	37 **D**	38 **B**	39 **B**	40 **C**

WORKED SOLUTIONS

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Q1 Answer B

Why B is correct

The internal diameter is about 3 cm. A rule reads only to 0.1 cm, which is too coarse for such a small length, and a rule cannot reach inside the pipe. Vernier calipers have internal jaws that fit inside the pipe and read to 0.01 cm, so they are the right choice for the internal diameter.

The length is about 60 cm. This is well within the range of a metre rule, which reads to 0.1 cm. That is accurate enough for a 60 cm length.

So the best pair is calipers (diameter) and rule (length).

Why the rest are wrong

A — A micrometer cannot measure 60 cm — its range is only about 2.5 cm. It also cannot measure an internal diameter.

C — A rule cannot measure an internal diameter accurately, and a micrometer cannot measure a 60 cm length.

D — A rule is too coarse and cannot reach inside the pipe for the diameter. A tape is less accurate than a rule for a 60 cm length.

Watch out for

A. Students who think 'more precise is always better' pick the micrometer, but its range is far too small for 60 cm and it has no jaws for measuring inside a pipe.

The word 'internal' is the key: only vernier calipers have jaws for measuring inside a tube.

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Q2 Answer **D**

Why D is correct

To add two vectors with a triangle, draw them tip-to-tail: the second vector starts where the first one ends. The resultant then goes from the tail of the first vector to the tip of the last one.

In C and D, F_2 is drawn first, then F_1 starts at the head of F_2. They are tip-to-tail. Because the angle between F_1 and F_2 is 60°, the angle inside the triangle between them is $180° - 60° = 120°$, as shown.

The resultant R must run from the start of F_2 (top left) to the end of F_1 (right). In D, R points from the top-left corner towards the right corner. This is correct.

Why the rest are wrong

A — F_1 and F_2 both start from the same point, so they are not tip-to-tail. The third side joins the two heads and gives $F_1 - F_2$ (or $F_2 - F_1$), not the sum.

B — Same problem as A: F_1 and F_2 start from the same point, so the third side is a difference of the two forces, not their resultant.

C — F_2 and F_1 are tip-to-tail, but R points the wrong way. It goes from the end of F_1 back to the start of F_2, which is $-(F_1 + F_2)$.

Watch out for

C. Students who get the triangle right but forget to check the arrow on R pick C. R must start where the first vector starts and end where the last vector ends.

A and B copy the 60° from the original diagram, which looks familiar, but a vector triangle needs the vectors joined head-to-tail.

Q3 Answer **C**

Why C is correct

One period is the time for one complete oscillation: the swing must return to its starting point, moving in the same direction as it started.

The swing starts at X. It swings through Y to Z, then back through Y to X. Only then is it back where it started, ready to repeat the same motion. So one oscillation is X → Z → X.

Why the rest are wrong

A — X to Y is only a quarter of an oscillation.

B — X to Z is only half an oscillation; the swing has not returned to X.

D — X to Z and back to Y is three-quarters of an oscillation.

Watch out for

B. Students who think one swing from one side to the other is a full oscillation pick B. That is only half a period.

D. Passing through Y again does not complete the cycle, because the swing is moving in the opposite direction from the first time it passed Y.

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Q4 Answer **C**

Why C is correct

The propeller pushes the water backwards with a force of 2000 N. By Newton's third law, the water pushes back on the propeller with a force that is equal in size and opposite in direction.

So the forward force on the propeller due to the water is 2000 N.

The 1800 N resistive force is a different force, acting on the boat. It affects the resultant force on the boat ($2000 - 1800 = 200\ \text{N}$ forwards), but it does not change the action–reaction pair.

Why the rest are wrong

A — 200 N is the resultant force on the boat (2000 − 1800), not the force of the water on the propeller.

B — 1800 N is the resistive force. It is not the reaction to the propeller's push.

D — 3800 N comes from adding the two forces, which has no physical meaning here.

Watch out for

A. Students who work out the resultant force pick 200 N. The question asks only for the reaction to the 2000 N push, which by Newton's third law is equal in size.

The two forces in a Newton's third law pair act on different objects (propeller on water, water on propeller), so other forces on the boat do not affect them.

Q5 Answer **C**

Why C is correct

In the evacuated tube there is almost no air resistance. The only force is the weight, so the acceleration stays constant at about $10\ \text{m/s}^2$. The velocity–time graph is a straight line through the origin.

In air, the ball starts from rest, so at first there is no air resistance and it starts with the same acceleration (same initial gradient). As the speed increases, air resistance increases, so the resultant force and the acceleration decrease. The graph curves and becomes less steep, staying below the straight line.

Graph C shows both features: the two lines start together, the evacuated-tube line is straight, and the air line curves below it.

Why the rest are wrong

A — The air curve gets steeper and rises above the vacuum line. That would mean air resistance makes the ball accelerate more, which is wrong.

B — The air line is straight, meaning constant acceleration in air. Air resistance increases with speed, so the acceleration in air must decrease and the graph must curve.

D — The evacuated-tube line curves upwards, meaning increasing acceleration. With only the weight acting, the acceleration is constant, so this line must be straight.

Watch out for

B. Students who know air slows the ball but forget that air resistance grows with speed pick B. In air the gradient must decrease over time, so the line curves.

Both graphs should have the same gradient at the very start, because the ball is at rest and there is no air resistance yet.

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Q6 Answer **B**

Why B is correct

The acceleration is negative when the velocity is decreasing. On the graph this is from $t = 30\ \text{s}$ to $t = 60\ \text{s}$, where the velocity falls from 8 m/s to 0 m/s.

Distance = area under the velocity–time graph. This part is a triangle.

Distance = ½ × base × height = $\frac{1}{2} \times (60 - 30)\ \text{s} \times 8\ \text{m/s} = \frac{1}{2} \times 30 \times 8 = 120\ \text{m}$.

Why the rest are wrong

A — 40 m is the area of the first part (0 to 10 s), when the acceleration is positive.

C — 240 m is 30 s × 8 m/s — the area of a rectangle, not a triangle. The ½ has been left out.

D — 480 m is 60 s × 8 m/s, which treats the whole graph as one rectangle. It is not the area of the decelerating section.

Watch out for

C. Students who forget the ½ in the triangle area pick 240 m.

A. 40 m is the area of the other triangle, from 0 to 10 s. Check which section has a negative gradient: it is the one sloping down.

Q7 Answer **A**

Why A is correct

Take north as positive. The train starts $at + 25\ \text{m/s}$. The acceleration of $-2.0\ \text{m/s}^2$ means its velocity decreases by 2.0 m/s every second.

From $t = 5.0\ \text{s}$ to $t = 15.0\ \text{s}$ is 10.0 s.

$v = u + at = 25 + (-2.0)(10.0) = 25 - 20 = +5.0\ \text{m/s}$.

The velocity is still positive, so the train is still moving north, and its speed is still falling. It will not stop until $v = 0$, which is at $25 \div 2.0 = 12.5\ \text{s}$ after the braking starts $(t = 17.5\ \text{s})$.

Why the rest are wrong

B — The acceleration is opposite to the velocity, so the speed decreases, not increases.

C — At $t = 15.0\ \text{s}$ the velocity is +5.0 m/s, so the train has not yet stopped and reversed. It is still moving north.

D — The train is still moving north, and its speed is decreasing, not increasing.

Watch out for

D. Students who read the minus sign as 'moving south' pick D or C. A negative acceleration only means the velocity is decreasing; the direction of motion is given by the sign of the velocity.

Use the time since the change started $(15.0 - 5.0 = 10.0\ \text{s})$, not the full 15.0 s. Using 15.0 s gives $25 - 30 = -5\ \text{m/s}$ and the wrong answer.

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Q8 Answer **C**

Why C is correct

Weight = mass × gravitational field strength. Neither the mass of the ball nor g changes as it falls, so the weight stays the same.

As the ball speeds up, the drag (viscous) force from the oil increases. Resultant force = weight − upthrust − drag, so the resultant force decreases.

At terminal velocity the upward forces balance the weight and the resultant force becomes zero.

Why the rest are wrong

A — The weight does not increase; mass and g are unchanged.

B — The weight does not increase, and the resultant force falls rather than rises.

D — The resultant force decreases towards zero, because the drag force grows as the ball speeds up.

Watch out for

D. Students who think 'the ball is speeding up, so the force must be increasing' pick D. The ball does speed up, but by less and less each second because the resultant force is falling.

The weight of an object does not depend on how fast it moves or whether it is in a fluid.

Q9 Answer **A**

Why A is correct

Weight is the gravitational force on an object. Between the Earth and the Moon, the Earth pulls the spacecraft towards the Earth and the Moon pulls it towards the Moon — in opposite directions.

At one point on the journey the two pulls are equal in size. They cancel, so the resultant gravitational force, and hence the weight, is zero.

Why the rest are wrong

B — Leaving the atmosphere does not remove gravity. The Earth's gravitational field extends far beyond the atmosphere (it keeps the Moon in orbit).

C — Weight does not depend on whether an object is moving. A spacecraft at rest still has weight if there is a gravitational field.

D — Air resistance is a separate force from weight. Having no air resistance does not change the gravitational pull.

Watch out for

B. Students who think gravity stops where the air stops pick B. Gravity acts through a vacuum and does not need air.

Weight is a force caused by a gravitational field, so the only way to make it zero is for the field (here, the combined field) to be zero.

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Q10 Answer **A**

Why A is correct

Moment of a force = force × perpendicular distance from the pivot to the line of action of the force.

The force F acts along the chain. The distance d is drawn from P to the chain, meeting it at a right angle (the right-angle mark is on the figure).

So the moment of F about $P = F \times d$.

Why the rest are wrong

B — h is the vertical distance from P to where the chain meets the wall. It is not perpendicular to the chain.

C — l is the length of the pole. It is the distance from P to the point where F acts, but it is not perpendicular to the line of action of F, because the chain is at an angle.

D — s is the length of the chain. It runs along the line of action of F, so it is not a distance from P at all.

Watch out for

C. Students who use 'the distance to where the force is applied' pick l. The distance must be measured at right angles to the line of the force, and the chain is not perpendicular to the pole.

Look for the right-angle symbol on the figure: it marks the perpendicular distance d.

Q11 Answer **A**

Why A is correct

The plank is level and balanced, so take moments about the support X. Sum of clockwise moments = sum of anticlockwise moments.

Distances from X: the 400 N weight acts 1.0 m from X; the plank's 100 N weight acts at its centre, $1.0 + 1.0 = 2.0\ \text{m}$ from X; F acts 2.0 m beyond the centre, so $2.0 + 2.0 = 4.0\ \text{m}$ from X.

Clockwise moments (the weights, to the right of X): $400 \times 1.0 + 100 \times 2.0 = 400 + 200 = 600\ \text{N m}$.

Anticlockwise moment: F × 4.0. So $F \times 4.0 = 600$, giving $F = 600 \div 4.0 = 150\ \text{N}$.

Why the rest are wrong

B — 200 N comes from using a wrong distance, e.g. 600 ÷ 3.0 (taking F as 3.0 m from X) — check the distances add up to $1.0 + 1.0 + 2.0 = 4.0\ \text{m}$.

C — 250 N is half of the total weight (500 N ÷ 2), which would only be right if the force were the same distance from X as the combined load.

D — 500 N is the total weight. This assumes F alone holds up the whole load, ignoring the upward force at the support X.

Watch out for

D. Students who balance forces instead of moments pick 500 N. The support at X also pushes up, so F does not have to equal the total weight.

Measure every distance from the pivot X, not from the centre of the plank: F is 4.0 m from X, not 2.0 m.

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Q12 Answer **B**

Why B is correct

Hands: the man pushes the box to the right. By Newton's third law, the box pushes back on the man's hands with an equal force to the left.

Feet: to push forwards, the man pushes his feet backwards (to the left) against the floor. The floor pushes forward on his feet with a friction force to the right.

This forward force from the floor is what lets the man push the box without sliding backwards.

Why the rest are wrong

A — The force on the feet is not to the left. The man's feet push the floor to the left, so the floor pushes the man to the right.

C — Both directions are reversed. The man pushes the box to the right, so the box pushes his hands to the left.

D — The force on the hands is not to the right; that is the force of the man on the box, not the force on the man.

Watch out for

C. Students who give the forces the man exerts (on the box and on the floor) instead of the forces on the man pick C. Read 'on the man' carefully and flip each one using Newton's third law.

The friction from the floor on the man's feet points the way he is trying to move — forwards, to the right.

Q13 Answer **D**

Why D is correct

Pressure in a liquid at depth h is $p = h\rho g$. It depends only on the depth and the density of the liquid, not on the shape or base area of the container.

Both beakers contain water filled to the same level, so h and ρ are the same. The pressure on the two bases is therefore the same.

The force on the base is $F = p \times A$. Since S has a smaller base area, the force on its base is smaller than on T. This rules out A and B.

Why the rest are wrong

A — Force = pressure × area. The pressure is the same, and S has the smaller area, so the force on S's base is smaller, not greater.

B — The forces are not equal, because the base areas are different while the pressure is the same.

C — The pressure does not depend on base area. Same depth and same liquid give the same pressure.

Watch out for

C. Students who think a wider container holds more water and so gives more pressure pick C. Pressure depends only on depth and density.

Keep force and pressure separate: same pressure, but bigger area means bigger force.

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Q14 Answer **C**

Why C is correct

The excess pressure of the gas equals the pressure due to the extra column of liquid of height h: $\Delta p = h\rho g$.

h is measured and g is known (10 N/kg), so the only other quantity needed is ρ, the density of the liquid in the manometer.

Why the rest are wrong

A — Liquid pressure does not depend on the cross-sectional area of the tube.

B — The gas density does not appear in $h\rho g$; the pressure difference is set by the liquid column.

D — The length l is not the difference in levels. The excess pressure depends only on the height difference h.

Watch out for

B. Students who think 'it is a gas pressure, so we need the gas density' pick B. The manometer measures pressure by the height of the liquid column, so it is the liquid's density that matters.

D. Use the difference in levels h, not the length of the tube or of the liquid.

Q15 Answer **C**

Why C is correct

As the stone moves down, its height falls, so its gravitational potential energy decreases.

The stone also slows down, so its kinetic energy decreases.

Both forms of energy are lost and are converted to thermal energy by the work done against the resistance of the water. So: kinetic energy + gravitational potential energy → thermal energy.

Why the rest are wrong

A — The stone is slowing down, so kinetic energy is not being gained.

B — Again, kinetic energy is not being gained; it is being lost along with the potential energy.

D — The stone is moving downwards, so gravitational potential energy decreases. It cannot be gained.

Watch out for

A. Students who think 'falling objects always gain kinetic energy' pick A or B. Here the question says the stone slows down, so its kinetic energy is decreasing.

Check each energy store separately: is the height falling? Is the speed falling? Whatever decreases goes on the left of the arrow.

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Q16 Answer **D**

Why D is correct

Efficiency = useful energy output ÷ total energy input.

The total energy input is E. The energy wasted is W, so the useful energy output = $E - W$.

Efficiency = $(E - W) \div E$.

Why the rest are wrong

A — E/W is the input divided by the wasted energy. It is greater than 1 and is not an efficiency.

B — W/E is the fraction of energy that is wasted, not the fraction that is useful.

C — $(E - W)/W$ divides the useful energy by the wasted energy. Efficiency must divide by the total input E.

Watch out for

B. Students who mix up 'wasted' and 'useful' pick W/E. That gives the fraction wasted, which is 1 – efficiency.

C. The denominator of an efficiency is always the total energy input.

Q17 Answer **A**

Why A is correct

When mercury freezes, it changes from liquid to solid. Its molecules lose energy and settle into fixed positions, closer together, in a regular arrangement.

In a solid the molecules are held in place by strong attractive forces. So when mercury freezes, the molecules attract each other more strongly than in the liquid.

Why the rest are wrong

B — The molecules themselves do not change size when a substance changes state. Only the spacing and arrangement change.

C — Molecules do not get smaller either. The size of each molecule stays the same.

D — Molecules in a solid do not stop moving. They keep vibrating about fixed positions.

Watch out for

D. Students who think particles in a solid are completely still pick D. Particles in a solid still vibrate; they only stop moving about from place to place.

B and C. Changes of state change the arrangement and spacing of molecules, never the size of the molecules themselves.

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Q18 Answer **A**

Why A is correct

The temperature is constant, so the average speed of the molecules does not change. Any option saying the molecules move faster is wrong.

When the volume decreases, the same number of molecules are in a smaller space, so they are closer together. Each molecule hits the walls more often, so there are more collisions per second on each unit area of the wall.

More frequent collisions mean a larger force per unit area, so the pressure increases.

Why the rest are wrong

B — The temperature is constant, so the molecules do not move faster.

C — The molecules do not move more quickly at constant temperature. The extra collisions come from them being closer together.

D — At constant temperature the speed and so the force of each impact stay the same.

Watch out for

C. Students who link 'more collisions' with 'faster molecules' pick C. Here the speed is fixed by the temperature; the extra collisions happen because there is less space.

Always check what is held constant: constant temperature means constant average molecular speed.

Q19 Answer **B**

Why B is correct

A thermometer needs a physical property that changes steadily with temperature, so that the reading can be linked to temperature.

The mass of a liquid does not change when the liquid is heated or cooled. So it cannot be used to measure temperature.

Length of a metal, electrical resistance of a metal and volume of a liquid all change with temperature, and are used in real thermometers.

Why the rest are wrong

A — The expansion of a metal changes with temperature, so it can be used (for example in a bimetallic strip thermometer).

C — The resistance of a metal increases as temperature rises, so it can be used in a resistance thermometer.

D — The volume of a liquid changes with temperature, which is how a liquid-in-glass thermometer works.

Watch out for

D. Students who mix up mass and volume may pick D. The volume of a liquid changes when it is heated; its mass stays the same.

The question asks which is NOT suitable — look for the property that does not change with temperature.

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Q20 Answer **D**

Why D is correct

Heat crosses the vacuum only by radiation. Surface R is the inner face of the outer wall, facing the vacuum. If R is silver, it reflects the infrared radiation from the inner wall back towards the liquid instead of absorbing it.

Surface S is the outer face, touching the air outside. Whatever heat reaches the outer wall is lost from S by radiation (and convection). A silver surface is a poor emitter of infrared radiation, so S being silver reduces the loss.

So both R and S should be silver.

Why the rest are wrong

A — Black surfaces are good absorbers and good emitters. A black R would absorb radiation from the inner wall, and a black S would radiate it away to the surroundings.

B — A black R absorbs the radiation crossing the vacuum, so more heat reaches the outer wall.

C — A black S is a good emitter, so it would radiate heat from the outer wall to the air outside.

Watch out for

C. Students who think 'black absorbs, so make the outside black to keep the heat' pick C. On the outside surface, black would mainly emit heat away, because the flask is hotter than its surroundings.

Silver surfaces are poor absorbers and poor emitters, so silver reduces radiation in both directions.

Q21 Answer **D**

Why D is correct

The warm air is above the ice. Heat reaches the ice in two ways.

Conduction: air particles touching the top of the ice collide with the ice particles and pass on kinetic energy. Radiation: the warm surroundings emit infrared radiation, which travels straight down and is absorbed by the ice. Radiation needs no medium and works in any direction.

Convection cannot carry heat down to the ice. Air next to the ice is cooled, becomes denser and stays at the bottom. The warmer, less dense air stays on top. No convection current forms, so convection does not move heat from the air into the ice. The answer is radiation and conduction only.

Why the rest are wrong

A — Leaves out radiation, which reaches the ice from the warm surroundings, and wrongly includes convection.

B — Includes convection. Warm air sitting above cold ice does not set up a convection current, because the cooled air near the ice is denser and stays down.

C — Leaves out conduction, which happens wherever the air touches the ice, and wrongly includes convection.

Watch out for

B. Students who tick all three processes because 'air is a fluid' pick B. Convection only carries heat when warmer fluid can rise; here the warm air is already on top, so the cold, dense air stays at the ice surface.

The decider is the position of the heat source: warm fluid above a cold surface gives no convection current.

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Q22 Answer **B**

Why B is correct

The wavelength is the distance between two neighbouring points on a wave that are in phase, for example from one point to the next point doing exactly the same thing. It is a distance, so it must be read from a graph of height against distance.

In graph B the axis is distance, and L runs from the start of the wave (height 0, going up) to the end of one full wave (height 0, going up again). That is one complete wave, so L is the wavelength.

Why the rest are wrong

A — L here is measured vertically from crest to trough. That is twice the amplitude, not the wavelength.

C — The axis is time, and L is measured vertically from 0 to the crest. That is the amplitude.

D — The axis is time, so a horizontal length is a time, not a distance. Also L covers only half a wave; it is half the period.

Watch out for

D. Students who see a horizontal arrow and pick D miss that the axis is time. On a time graph a horizontal length is part of the period, never the wavelength.

A. Crest-to-trough is twice the amplitude; it is a height, not a wavelength.

Q23 Answer **C**

Why C is correct

The frequency of a wave is set by the source. The dipper vibrates at a constant frequency, so the same number of waves pass every point each second. The frequency remains the same over the glass block.

The diagram shows the waves bunched closer together over the glass block: the wavelength is shorter there. The water is shallower over the block, and water waves travel more slowly in shallow water.

Using $v = f\lambda$: f stays the same and λ decreases, so $v = f\lambda$ decreases.

Why the rest are wrong

A — Frequency cannot change, because it is fixed by the dipper. Speed decreases, not increases, since λ gets shorter.

B — Frequency cannot change, and the speed does change because λ changes while f stays the same.

D — The frequency part is right, but a shorter wavelength at the same frequency means a lower speed, not a higher one.

Watch out for

B. Students who think a shorter wavelength means a lower frequency pick B. When a wave crosses a boundary, the frequency stays the same; it is the speed and wavelength that change together.

D. Read the figure: the waves are closer together over the block, so λ is smaller and v is smaller.

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Q24 Answer **B**

Why B is correct

The ducks only move up and down; the wave shape moves to the right. To see what a duck does next, look at the part of the wave just to its left — that part will arrive at the duck next.

Duck P is at zero displacement. Just to its left the water is below the dashed line (heading into a trough). So P moves down first. Over half a cycle P goes from zero down to the trough and back up to zero: P falls then rises.

Duck Q is at a crest (maximum displacement). In half a cycle a crest becomes a trough. So Q moves all the way down from the top to the bottom: Q only falls.

Why the rest are wrong

A — P does not only fall. It reaches the trough after a quarter cycle and then rises back to zero in the next quarter cycle.

C — Q is at the top. Half a cycle takes it from the crest to the trough, so it only falls; it would need a full cycle to rise back up.

D — P moves down first, not up, because the trough to its left is coming towards it. Q only falls in half a cycle.

Watch out for

D. Students who think P 'climbs up the slope' towards the crest pick D. The crest at Q is moving away from P to the right; the trough on P's left is arriving, so P goes down.

C. Half a cycle is only crest to trough. 'Falls then rises' for Q would need a full cycle.

Q25 Answer **D**

Why D is correct

Both angles are measured from the normal, the line at 90° to the surface where the ray meets it.

At X the ray crosses the vertical side of the tank, so the normal at X is horizontal. The angle of refraction r is between the ray in the water and this horizontal dashed line. That is shown in B and D.

At Y the ray meets the horizontal water surface, so the normal at Y is vertical. The critical angle c is the angle of incidence in the water, measured between the incoming ray and the vertical dashed line, for which the refracted ray runs along the surface. That is shown in A and D.

Only diagram D has both angles measured from the correct normals.

Why the rest are wrong

A — c is correct, but r is measured from the glass surface (vertical), not from the horizontal normal at X.

B — r is correct, but c is drawn between the reflected ray and the water surface. The critical angle is between the incident ray and the normal.

C — Both angles are measured from surfaces instead of normals.

Watch out for

B. Students who measure c from the water surface pick B. The critical angle, like every angle of incidence or refraction, is measured from the normal, and for the incident ray in the denser medium.

At X the normal is horizontal because the glass wall is vertical — check which dashed line is the normal at each point.

Q26 Answer **B**

Why B is correct

At the top surface light goes from air into water. $n = \sin i / \sin r$.

$\sin x = \sin 40^\circ / 1.34 = 0.643 / 1.34 = 0.480$, so $x = 29^\circ$.

The mirror is horizontal, so the ray leaves the mirror at the same angle to the vertical and reaches the surface again at 29° to the normal. Leaving the water, the light bends back to 40° from the normal (the path is reversible).

The angle y is marked between the emerging ray and the water surface, not the normal. $y = 90^\circ - 40^\circ = 50^\circ$.

Why the rest are wrong

A — $x = 29^\circ$ is right, but 40° is the angle to the normal. y is measured from the water surface, so $y = 50^\circ$.

C — $x = 30^\circ$ comes from rounding badly or guessing; $\sin^{-1}(0.480) = 28.7^\circ \approx 29^\circ$. And y should be 50°, not 40°.

D — $y = 50^\circ$ is right, but $x = 28.7^\circ$ rounds to 29°, not 30°.

Watch out for

A. Students who see that the ray leaves at 40° to the normal and stop there pick A. Look at the figure: y is drawn between the ray and the horizontal water surface, so $y = 90^\circ - 40^\circ = 50^\circ$.

Check the calculator is in degree mode: $\sin^{-1}(\sin 40^\circ \div 1.34) = 28.7^\circ$.

Q27 Answer **B**

Why B is correct

The first pulse is the clap. The second, smaller pulse is the echo. On the screen the two pulses start 8 divisions apart.

Time between clap and echo: $t = 8 \times 10\ \text{ms} = 80\ \text{ms} = 0.080\ \text{s}$.

In this time the sound travels to the wall and back. Total distance = speed × time = $300 \times 0.080 = 24\ \text{m}$.

Distance to the wall = $24 \div 2 = 12\ \text{m}$.

Why the rest are wrong

A — 6.0 m comes from halving twice, or reading only 4 divisions. The echo time already covers the trip there and back, so halve only once.

C — 24 m is the total distance there and back. The man is half of this from the wall.

D — 1200 m is far too large. It comes from a powers-of-ten slip, for example using 8 s instead of 0.080 s, or multiplying 300 by the number of divisions and by 0.5 without converting ms to s. An echo heard after 0.08 s cannot come from a wall over a kilometre away.

Watch out for

C. Students who forget the sound goes to the wall and back pick C. Always halve the echo distance.

Count divisions from the start of one pulse to the start of the other (8 divisions), and convert ms to s.

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Q28 Answer **D**

Why D is correct

Loudness depends on amplitude. X has an amplitude of about 4 divisions; Y has an amplitude of about 2 divisions. Y has the smaller amplitude, so Y is quieter.

Pitch depends on frequency. One full wave of X takes about 3.5 divisions; one full wave of Y takes about 7 divisions. Y has the longer period, so it has the lower frequency (half that of X). Y has a lower pitch.

Why the rest are wrong

A — Y's waves are shorter in height (quieter) and more spread out (lower frequency) — both parts are wrong.

B — Y has a smaller amplitude than X, so it is quieter, not louder.

C — Y's waves are more spread out on the screen, so its period is longer and its frequency lower, not higher.

Watch out for

C. Students who think 'more spread out' means higher frequency pick C. More spread out means each wave takes longer: longer period, lower frequency, lower pitch.

Q29 Answer **B**

Why B is correct

Electric field lines show the direction of the force on a small positive charge. They point away from a positive charge and towards a negative charge.

Between a positive and a negative charge, the lines start on the positive charge and end on the negative charge, joining the two. Diagram B shows this, with every arrow running from + to −.

Why the rest are wrong

A — The arrows run from − to +, which is the wrong direction.

C — The lines point away from the negative charge, and they do not link the two charges. This pattern is closer to two like charges.

D — The lines point into the positive charge, which is the wrong direction, and the charges are not linked.

Watch out for

A. Students who match the shape but not the arrows pick A. Check the direction: field lines go out of + and into −.

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Q30 Answer **C**

Why C is correct

Adding another resistor in parallel gives the current an extra path, so the combined resistance of the parallel part decreases. The lamp is unchanged, so the total resistance of the circuit decreases.

The lamp and the parallel group are in series with the cell, so they share the cell's e.m.f. in proportion to their resistances. The parallel group now has a smaller share of the total resistance, so it takes a smaller share of the p.d., and the lamp takes a larger share.

Another way: lower total resistance gives a larger current I. The p.d. across the lamp is $V = IR$ (lamp), so it increases.

Why the rest are wrong

A — Total resistance decreases is right, but the larger current makes the lamp p.d. increase, not decrease.

B — Adding a resistor in parallel reduces resistance, not increases it; and the lamp p.d. rises.

D — The lamp p.d. does increase, but adding a parallel path lowers the total resistance.

Watch out for

B. Students who think 'more resistors means more resistance' pick B. That is only true in series. In parallel, each extra resistor gives the current another path and the resistance falls.

Q31 Answer **A**

Why A is correct

Resistance $R = \rho L/A$, and the area $A = \pi d^2/4$, so R is proportional to L/d^2.

For Y: length is 2 times, diameter is 3 times so area is $3^2 = 9$ times.

$R(Y) = 9.0 \times 2 \div 9 = 2.0\Omega$.

Why the rest are wrong

B — 6.0Ω comes from dividing by 3 (the diameter) instead of by 9 (the area). Area depends on diameter squared.

C — 54Ω comes from multiplying by 2 and by 3. A thicker wire has less resistance, not more.

D — 160Ω comes from multiplying by 2 and by 9. A larger cross-section lowers resistance.

Watch out for

B. Students who forget that area goes as diameter squared pick B. Tripling the diameter makes the area 9 times larger.

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Q32 Answer **A**

Why A is correct

A voltmeter measures the p.d. between two points, so it is connected in parallel across the component. Here the cell and the resistor are connected to the same two points, so a voltmeter across the resistor also reads the p.d. across the cell.

So that it does not change the current in the circuit, the voltmeter must take almost no current. It therefore has a very high resistance.

Why the rest are wrong

B — A voltmeter with very low resistance in parallel would take a large current and change the current from the cell.

C — In series, a very high resistance would cut the current almost to zero — it would change the circuit completely.

D — Very low resistance in series is how an ammeter is connected, not a voltmeter.

Watch out for

D. Students who mix up voltmeters and ammeters pick D. Ammeter: in series, very low resistance. Voltmeter: in parallel, very high resistance.

Q33 Answer **A**

Why A is correct

A current flows through something only if there is a potential difference across it.

Both of the bird's feet are on the same wire, very close together, so they are at (almost) the same voltage. There is no p.d. across the bird, so no current passes through its body and it is not harmed.

Why the rest are wrong

B — A bird's body conducts like other living tissue. If the bird touched the line and an earthed object at the same time, a large current would flow through it.

C — Bird feet are not good insulators. The bird is safe because there is no p.d., not because its feet block current.

D — The feathers are not in the path between the feet, so they make no difference.

Watch out for

B. Students who think a high resistance protects the bird pick B. The real reason is that there is no potential difference between its feet, so no current flows however low its resistance.

Q34 Answer **A**

Why A is correct

Change the time to seconds: $t = 0.25\,\text{min} \times 60 = 15\,\text{s}$.

$I = Q/t = 60/15 = 4.0\,\text{A}$.

Why the rest are wrong

B — 15 is the time in seconds, not the current. The current is the charge divided by this time: $60 \div 15 = 4.0\,\text{A}$.

C — 240 A comes from dividing 60 C by 0.25 without changing minutes into seconds.

D — 900 A comes from multiplying 60 by 15 instead of dividing.

Watch out for

C. Students who use $t = 0.25$ directly pick C. Current is charge per second, so the time must be in seconds: $0.25\,\text{min} = 15\,\text{s}$.

Q35 Answer **D**

Why D is correct

The resistance stays the same. Power $P = V^2/R$.

If V is doubled, V^2 becomes $(2V)^2 = 4V^2$. So the new power = $4V^2/R = 4P$.

Another way: doubling V doubles the current I as well, and $P = VI$, so P becomes $2 \times 2 = 4$ times larger.

Why the rest are wrong

A — Power increases when voltage increases; it does not halve.

B — The power changes, because both V and I double.

C — $2P$ forgets that the current also doubles when the voltage doubles.

Watch out for

C. Students who use $P = VI$ and double only V pick C. With R fixed, doubling V also doubles I, so P goes up by 4.

Q36 Answer **C**

Why C is correct

Two parallel wires carrying currents in opposite directions repel each other. Currents in the same direction attract.

The forces act along the line joining the wires. One current is into the page and the other out of the page, so the force on each wire points away from the other wire: the left wire is pushed left, the right wire is pushed right. That is diagram C.

Check with the field: the out-of-page current on the right makes an anticlockwise field. At the left wire this field points down the page. Fleming's left-hand rule with current into the page and field down gives a force to the left.

Why the rest are wrong

A — The forces must act along the line joining the wires, not at right angles to it.

B — Same mistake as A: the forces are along the line between the wires, not up and down.

D — The wires are pulled together here. That happens for currents in the same direction; opposite currents repel.

Watch out for

D. Students who think 'opposites attract' (as for charges or poles) pick D. For currents it is the other way: opposite currents repel, like currents attract.

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Q37 Answer **D**

Why D is correct

The field is uniform and horizontal, and the current in P and Q stays the same, so the forces on P and Q stay the same size and stay vertical as the coil turns.

The moment depends on force × perpendicular distance from the axle to the line of action of each force. As the coil turns towards the vertical, sides P and Q move closer to the vertical line through the axle. The perpendicular distance between the two vertical forces gets smaller, so the moment decreases.

When the coil is vertical, both forces act along the same vertical line through the axle, and the moment is zero.

Why the rest are wrong

A — The current is set by the supply and does not change as the coil turns.

B — The field is uniform and the current direction in P and Q is unchanged, so the forces stay vertical.

C — The other two sides of the coil are at right angles to the axle. Any force on them acts parallel to the axle, so it has no turning effect about the axle at any position.

Watch out for

B. Students who imagine the forces turning with the coil pick B. The force is set by the field and current directions, which do not change, so it stays vertical; only its distance from the axle changes.

Q38 Answer **B**

Why B is correct

Moving the wire up and down cuts the magnetic field lines between N and S. This induces an e.m.f. in the wire, and the ammeter shows a current. This is electromagnetic induction.

A generator uses exactly this: a coil is turned in a magnetic field so its wires cut field lines, and a current is induced.

Why the rest are wrong

A — A battery produces current from chemical energy, not from a wire moving in a magnetic field.

C — A motor does the opposite: a current in a wire in a magnetic field produces a force and motion.

D — An electromagnet uses a current to make a magnetic field; nothing is moving to induce a current.

Watch out for

C. Students who see 'wire + magnets' and pick motor have the cause and effect the wrong way round. Motion in → current out is a generator; current in → motion out is a motor.

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Q39 Answer **B**

Why B is correct

The lamp needs 12 V. For a transformer, $V_s/V_p = N_s/N_p$.

$N_s = N_p \times V_s/V_p = 320 \times 12/240 = 16$ turns.

From the figure: W to X is 10 turns, X to Y is 6 turns, Y to Z is 2 turns. W to $Y = 10 + 6 = 16$ turns, so the lamp is connected between W and Y.

Why the rest are wrong

A — W to X is 10 turns, giving $240 \times 10/320 = 7.5$ V. The lamp would be dim.

C — W to Z is all 18 turns, giving $240 \times 18/320 = 13.5$ V. The lamp would be too bright.

D — X to Z is $6 + 2 = 8$ turns, giving 6.0 V.

Watch out for

C. Students who use the whole secondary coil pick C. Work out the number of turns needed first (16), then add up the sections in the figure to find which pair of terminals gives it.

The 24 W rating is not needed to find the terminals.

Q40 Answer **C**

Why C is correct

The power sent is fixed: $P = VI$. If the voltage is stepped up, the current in the cable becomes smaller.

The cable has resistance, so it loses power as heat: P(loss) = I^2R. A smaller current gives a much smaller I^2R loss.

So the voltage is increased to reduce the energy loss in the cable.

Why the rest are wrong

A — Stepping up the voltage decreases the current in the cable, because $P = VI$ is constant.

B — A transformer does not change the frequency of the a.c. supply.

D — The resistance depends on the cable's material, length and thickness. Changing the voltage does not change it.

Watch out for

A. Students who think a higher voltage pushes a bigger current pick A. For a fixed power, $P = VI$, so higher V means lower I — that is the whole point.

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