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TEN-YEAR SERIES · ANSWERS AND WORKED SOLUTIONS

2017 A-Level H1 Physics Paper 1

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ANSWER KEY

1 **A**	2 **D**	3 **C**	4 **C**	5 **A**	6 **A**	7 **B**	8 **C**	9 **D**	10 **B**
11 **A**	12 **D**	13 **C**	14 **C**	15 **D**	16 **A**	17 **A**	18 **B**	19 **C**	20 **B**
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WORKED SOLUTIONS

Q1 Answer A

Convert the power rating into watts first, using the SI prefix $\mathrm{d} = 10^{-1}$:

$$100\mathrm{dW} = 100 \times 10^{-1}\mathrm{W} = 10\mathrm{W}$$

Express the watt in base SI units. Power is energy per unit time, and energy (joules) in base units is $\mathrm{kg\,m^2\,s^{-2}}$ (from $E = \frac{1}{2}mv^2$):

$$1\mathrm{W} = 1\mathrm{J\,s^{-1}} = 1\mathrm{kg\,m^2\,s^{-2}s^{-1}} = 1\mathrm{kg\,m^2\,s^{-3}}$$

$$10\mathrm{W} = 10\mathrm{kg\,m^2\,s^{-3}}$$

This matches option A. (Option C repeats the same units but with the wrong power-of-ten prefix already folded in twice; B and D incorrectly have $\mathrm{s^{-1}}$ instead of $\mathrm{s^{-3}}$.)

Q2 Answer D

Systematic error shifts all readings consistently away from the true value –- a small systematic error means the average of the readings is close to the true value ($g = 9.81\mathrm{m\,s^{-2}}$).

Random error causes readings to scatter around their average –- a large random error means the readings are widely spread out (large range/standard deviation), even if their average is accurate.

Computing the mean and spread for each student's five readings:

A: mean $\approx 9.60\mathrm{m\,s^{-2}}$, range $= 0.33\mathrm{m\,s^{-2}}$ –- mean noticeably below 9.81 (sizeable systematic error) and widely spread (large random error).

B: mean $\approx 9.81\mathrm{m\,s^{-2}}$, range $= 0.04\mathrm{m\,s^{-2}}$ –- mean matches 9.81 closely (small systematic error) and tightly clustered (small random error).

C: mean $\approx 9.51\mathrm{m\,s^{-2}}$, range $= 0.09\mathrm{m\,s^{-2}}$ –- mean well below 9.81 (large systematic error), but tightly clustered (small random error).

D: mean $\approx 9.81\mathrm{m\,s^{-2}}$, range $= 0.31\mathrm{m\,s^{-2}}$ –- mean matches 9.81 closely (small systematic error), but widely spread (large random error).

Only D combines a mean close to the true value (small systematic error) with a wide spread of readings (large random error).

Q3 Answer **C**

Rearranging the given equation for fluidity φ:

$$\frac{V}{t} = \frac{\pi\varphi r^4 \Delta p}{8l} \Longrightarrow \varphi = \frac{8lV}{\pi r^4 \Delta p\, t}$$

Since 8 and π are dimensionless, find the base units of φ by combining the base units of l, V, r, Δp and t:

- l: length, m
- V: volume, $\mathrm{m^3}$
- r^4: (length)^4, $\mathrm{m^4}$
- Δp: pressure $= \mathrm{N\ m^{-2}} = (\mathrm{kg\ m\ s^{-2}})\mathrm{m^{-2}} = \mathrm{kg\ m^{-1}\ s^{-2}}$
- t: time, s

Numerator (lV):

$$\mathrm{m} \times \mathrm{m^3} = \mathrm{m^4}$$

Denominator ($r^4 \Delta p\, t$):

$$\mathrm{m^4} \times (\mathrm{kg\ m^{-1}\ s^{-2}}) \times \mathrm{s} = \mathrm{kg\ m^3\ s^{-1}}$$

Combining:

$$[\varphi] = \frac{\mathrm{m^4}}{\mathrm{kg\ m^3\ s^{-1}}} = \mathrm{kg^{-1}\ m^{4-3}\ s^1} = \mathrm{kg^{-1}\ m\ s}$$

This matches option C.

Q4 Answer **C**

In a vacuum, the stone experiences only gravity throughout its flight. This means its acceleration is constant –- equal to g, directed vertically downward –- at every point of the trajectory, regardless of the stone's position or velocity at that instant.

Evaluating each option:

A. At Y (typically the highest point, if Y is the apex), the vertical component of velocity is momentarily zero –- but this is not because the acceleration is zero; the acceleration is still g downward at that instant (it is what causes the vertical velocity to keep changing, from positive to negative, through zero at the peak). Incorrect.

B. The acceleration is constant throughout the flight (magnitude g, always directed downward) –- it does not reverse direction between X and Z. Incorrect.

C. Since gravity alone acts throughout the flight (in a vacuum), the acceleration is g downward at X, Y, and Z alike. Correct.

D. X and Z are at the same height, on the way up and the way down (or vice versa) respectively. By the symmetry of projectile motion, the vertical speeds at X and Z are equal in magnitude, but the vertical velocity (a vector) is directed oppositely at these two points (one upward, one downward) –- so the vertical component of velocity at X is not equal to that at Z; it is equal in magnitude but opposite in sign. Incorrect.

Hence the correct statement is C.

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Q5 Answer A

Falling from rest, using $s = \frac{1}{2}gt^2$ with $s = 4.50\text{m}$, $g = 1.62\text{m s}^{-2}$ (on the Moon):

$$t = \sqrt{\frac{2s}{g}} = \sqrt{\frac{2(4.50)}{1.62}} = \sqrt{5.556}$$

$$\boxed{t \approx 2.36\text{s}}$$

Using $v = gt$ (or $v^2 = 2gs$):

$$v = gt = (1.62)(2.357)$$

$$\boxed{v \approx 3.82\text{m s}^{-1}}$$

Both values match option A. (Options C and D use an incorrect time of 5.56s, which would arise from a slip such as omitting the factor of 2 or the square root; option B pairs the correct time with an inconsistent speed.)

Q6 Answer A

Distance travelled = area under the speed–time graph.

Car X (constant speed v): $x_X(\tau) = v\tau$.

Car Y: rises linearly from 0 to $2v$ over $[0, 2t]$, then falls linearly from $2v$ to 0 over $[2t, 4t]$.

Position of Y at $\tau = 2t$ (area of the triangle from 0 to $2t$):

$$x_Y(2t) = \frac{1}{2}(2t)(2v) = 2vt$$

Position of X at $\tau = 2t$:

$$x_X(2t) = v(2t) = 2vt$$

Since $x_X(2t) = x_Y(2t)$, the cars are at the same position at $2t$.

Checking what happens either side of $2t$: on $[0, t]$, Y's speed is below v (Y is still accelerating up from rest), so X pulls ahead first. On $[t, 3t]$, Y's speed exceeds v (above the horizontal line on the graph), so Y is gaining on X throughout this interval. Since the two are level again exactly at $2t$ (within this Y-faster interval), car Y must be catching up to and passing car X at $\tau = 2t$ –- i.e. Y overtakes X at $2t$.

Checking option B ($3t$):

$$x_X(3t) = 3vt$$

$$x_Y(3t) = 2vt + \left[2v(t) - \frac{v}{2t}(t)^2\right] = 2vt + 1.5vt = 3.5vt$$

Since $x_Y(3t) > x_X(3t)$, Y is still ahead at $3t$ –- X has not overtaken Y yet. B is incorrect.

Checking option C ($2t$): both distances equal $2vt$ (shown above), not a 2:1 ratio. C is incorrect.

Checking option D ($4t$):

$$x_X(4t) = 4vt, \qquad x_Y(4t) = \frac{1}{2}(4t)(2v) = 4vt$$

Equal again, not a 2:1 ratio. D is incorrect.

Hence the correct statement is A.

Q7 Answer **B**

Newton's second law applies to the net force along the direction of acceleration –- here, down the slope.

- R is the normal reaction, always perpendicular to the slope surface. A force perpendicular to the direction of motion has zero component along the slope, so it contributes nothing to the acceleration down the slope (it only balances the perpendicular component of weight).
- P is the weight, acting vertically downward. Since the slope is inclined, weight has a nonzero component along the slope ($mg\sin\theta$), which drives the acceleration.
- Q acts along the slope surface (parallel to it, opposing the motion –- e.g. friction). Being parallel to the direction of motion, it has its full magnitude acting along the slope, directly affecting the net force and hence the acceleration.

Since only forces with a component along the slope affect the acceleration down the slope, R is excluded, while P and Q both contribute. Hence the correct answer is B.

Q8 Answer **C**

Momentum is always conserved in a collision provided there is no net external force on the system (the two vehicles form an isolated system during the brief collision) –- this holds regardless of whether the collision is elastic or inelastic.

Kinetic energy is conserved only in a perfectly elastic collision. An inelastic collision, by definition, is one in which kinetic energy is not conserved –- some of it is converted into other forms of energy (heat, sound, deformation of the vehicles).

Since the question states the collision is inelastic: kinetic energy is not conserved, while momentum is conserved –- matching row C.

Q9 Answer **D**

A Newton's third law pair must satisfy all of the following:

- Same type of force (here, gravitational).
- Equal in magnitude, opposite in direction.
- Act on two different objects, each force acting on the other body in the interacting pair.

W is the gravitational force exerted by the Earth on the book. Its third-law partner must therefore be the gravitational force exerted by the book on the Earth –- equal in magnitude to W, opposite in direction (pulling the Earth upward toward the book), and of the same (gravitational) type.

Evaluating the options:

A. This describes a different force pair entirely (floor–table contact/support forces), not gravitational, and not paired with W. Incorrect.

B. Friction is a contact force between the book and the table –- a completely different type of force from the gravitational force W. Newton's third law pairs must be the same type of force. Incorrect.

C. A table exerts a normal contact force on the book, not a gravitational force. This is the force that balances W (Newton's first law equilibrium), but balancing forces are not the same as a third-law pair, and this is not gravitational anyway. Incorrect.

D. The gravitational pull of the book on the Earth is the same type of force (gravitational), equal in magnitude to W, opposite in direction, acting on the other body (the Earth) in the interacting pair. Correct.

Hence the correct answer is D.

Q10 Answer **B**

The arrangement (left to right) is: mass M –– string T_2 –– mass $2M$ –– string T_1 –– mass $3M$ –– applied force F.

Whole system (total mass $M + 2M + 3M = 6M$), by Newton's second law:

$$a = \frac{F}{6M}$$

String T_1 connects $3M$ to the combined block $(M + 2M)$ on its left. Treating M and $2M$ together as a single system of mass $3M$ being pulled by T_1:

$$T_1 = (M + 2M)\, a = 3M \left(\frac{F}{6M}\right) = \frac{F}{2}$$

String T_2 connects $2M$ to mass M on its left. Treating M alone as the system being pulled by T_2:

$$T_2 = M\, a = M \left(\frac{F}{6M}\right) = \frac{F}{6}$$

So $T_1 = \frac{F}{2}$ and $T_2 = \frac{F}{6}$, matching row B.

Q11 Answer **A**

Gravitational force on X: the gravitational field arrows point upward. The gravitational force on any mass acts in the same direction as the gravitational field (field strength = force per unit mass, in the direction of the field). So the gravitational force on X is directed upward.

Electric force on X: the electric field arrows point to the right. The electric force on a charge is $\vec{F} = q\vec{E}$; since X is negatively charged, the force on X is opposite to the field direction –– i.e. directed to the left.

Resultant force: combining an upward component (gravitational) with a leftward component (electric) gives a resultant directed up and to the left –– matching arrow A.

Hence the correct answer is A.

Q12 Answer **D**

The beam is stated to be balanced –– i.e. in equilibrium. For any rigid body in equilibrium, both conditions must hold simultaneously:

$$\text{Resultant force} = 0 \qquad \text{and} \qquad \text{Resultant torque (moment)} = 0$$

This is true by definition of equilibrium, regardless of the specific values of F_1, F_2, the weight, or the exact position of the pivot. D is therefore always true.

Evaluating the other options:

A. $F_1 = F_2$ would only be guaranteed if the pivot were exactly midway between the two forces' lines of action (equal lever arms). Since the pivot's position relative to F_1 and F_2 is not stated to be symmetric, this cannot be assumed. Not necessarily true.

B. Similarly, there is no basis to conclude $F_2 > F_1$ –– the relationship between F_1 and F_2 depends on their distances from the pivot, which are not given as equal. Not necessarily true.

C. A couple consists of exactly two forces, equal in magnitude, opposite in direction, and not sharing the same line of action, producing a resultant torque but zero resultant force. Here there are four forces in equilibrium (including a pivot support force and the weight), so this is not a couple. Incorrect.

Hence the correct answer is D.

Q13 Answer **C**

The answer is (C). $V_f - V_i$

Work done by an expanding gas against a constant external pressure P is given by:

$$W = P\,\Delta V = P\,(V_f - V_i)$$

This follows from $W = \int P\,dV$ with P constant, so the quantity to multiply P by is simply the change in volume, $V_f - V_i$.

Hence the correct answer is C.

Q14 Answer **C**

From the speed–time graph, v decreases linearly from V at $t = 0$ to 0 at $t = T$, so the deceleration is constant: $g = V/T$.

Speed at $t = T/2$:

$$v\left(\frac{T}{2}\right) = V - g\left(\frac{T}{2}\right) = V - \frac{V}{2} = \frac{V}{2}$$

Kinetic energy at $T/2$:

$$KE = \frac{1}{2}m\left(\frac{V}{2}\right)^2 = \frac{1}{8}mV^2$$

Height at $t = T/2$, using $h(t) = Vt - \frac{1}{2}gt^2$ and $T = V/g$:

$$h\left(\frac{T}{2}\right) = V\left(\frac{T}{2}\right) - \frac{1}{2}g\left(\frac{T}{2}\right)^2 = \frac{V^2}{2g} - \frac{V^2}{8g} = \frac{3V^2}{8g}$$

Potential energy at $T/2$:

$$PE = mgh\left(\frac{T}{2}\right) = mg\left(\frac{3V^2}{8g}\right) = \frac{3}{8}mV^2$$

Ratio:

$$\frac{PE}{KE} = \frac{\frac{3}{8}mV^2}{\frac{1}{8}mV^2} = 3$$

(Check by energy conservation: total mechanical energy $= \frac{1}{2}mV^2 = \frac{4}{8}mV^2$, and indeed $\frac{3}{8}mV^2 + \frac{1}{8}mV^2 = \frac{4}{8}mV^2$. ∎)

Hence the correct answer is C.

Q15 Answer **D**

As Y (mass $2m$) descends and X (mass m) rises through the same distance d (connected by an inextensible string over the pulley):

Y loses GPE (it moves down), so its change in GPE is negative:

$$\Delta GPE_Y = -(2m)gd$$

X gains GPE (it moves up), so its change in GPE is positive:

$$\Delta GPE_X = +mgd$$

Plotting ΔGPE against distance moved d:

- The X line has a positive slope of gradient mg.
- The Y line has a negative slope of gradient $-2mg$ –- twice as steep (in magnitude) as X's line, and in the opposite (negative) direction, since Y's mass is twice X's.

This matches graph D, which shows X's line rising with positive gradient and Y's line falling with a steeper negative gradient (twice the magnitude of X's).

Hence the correct answer is D.

Q16 Answer **A**

The phase difference depends only on how far apart P and Q are, as a fraction of a wavelength:

$$\Delta\phi = \frac{\Delta x}{\lambda} \times 2\pi$$

A whole number of wavelengths adds nothing, so only the distance beyond a whole wavelength matters.

- Measure one wavelength λ along the dotted line, between two successive points where the string crosses it going upwards.
- P is about 0.18λ past the upward crossing just before it. Q is about 0.32λ past the upward crossing just before it.
- So Q is 1.14λ from P, which is 0.14λ beyond one whole wavelength.

$$\Delta\phi = 0.14 \times 2\pi \approx 0.9 \text{ rad}$$

This is option A.

P and Q both sit near crests, so it is tempting to say they are in phase. Measure: Q is further past its crest than P is.

Q17 Answer **A**

Let the smaller wave have amplitude a, so the larger wave has amplitude $2a$.

At point P (waves in phase, phase difference 0): the amplitudes add directly.

$$A_P = a + 2a = 3a$$

At point Q (phase difference π rad, i.e. antiphase): the amplitudes subtract.

$$A_Q = 2a - a = a$$

Intensity is proportional to amplitude squared ($I \propto A^2$):

$$\frac{I_P}{I_Q} = \frac{A_P^2}{A_Q^2} = \frac{(3a)^2}{(a)^2} = \frac{9a^2}{a^2} = 9$$

Hence the correct answer is A.

Q18 Answer **B**

The answer is (B). $\frac{1}{2f}$

In the dot diagram, particles bunch closely together at compressions and spread apart at rarefactions –- the compressions repeat every wavelength λ.

Measuring the diagram: the distance from one compression to the next (one full wavelength) spans three evenly-divided intervals between dots. Point P lies at the middle of these three intervals (one interval past the first compression), while point Q coincides with the next compression itself.

The distance from P to Q measures out to half of one wavelength ($\lambda/2$) –- P is midway between two compressions, and Q is at the following compression.

Using $v = f\lambda$, the time for a wavefront (travelling at speed v) to cover a distance $\lambda/2$ is:

$$t = \frac{\lambda/2}{v} = \frac{\lambda/2}{f\lambda} = \frac{1}{2f}$$

Hence the correct answer is B.

Q19 Answer **C**

The wire PQ shown is vibrating in its second-harmonic stationary-wave pattern: a node at P, an antinode (where X is marked), a node roughly midway along the wire, a second antinode (the trough shown), and a node at Q.

Key property of a stationary wave: every point between two adjacent nodes oscillates in phase with every other point in that same segment, while points in the next segment (across a node) oscillate exactly out of phase (phase difference of π rad) with the first segment. This relationship does not vary smoothly with position –- it is constant within each segment and jumps abruptly by π at each node.

Since X sits in the first segment (between P and the middle node):

- For all points from P up to the middle node: phase difference from X $= 0$.
- For all points from the middle node to Q: phase difference from X $= \pi$ (this segment vibrates in antiphase with X, consistent with the trough being displaced oppositely to X's antinode at every instant).

This is a single step function –- flat at 0, then jumping to and staying at π –- which matches graph C (not a smooth curve as in A, not a continuous ramp as in B, and not a step to 2π as in D, since only one node is crossed between X and Q).

Hence the correct answer is C.

Q20 Answer **B**

The answer is (B). $\frac{ps}{\lambda L}$

Fringe spacing for a double-slit interference pattern is:

$$\Delta y = \frac{\lambda L}{s}$$

The number of fringes observed over a distance p on the screen is the distance divided by the fringe spacing:

$$N = \frac{p}{\Delta y} = \frac{p}{\left(\frac{\lambda L}{s}\right)} = \frac{ps}{\lambda L}$$

Hence the correct answer is B.

Q21 Answer **C**

The answer is (C). $1.25 \times 10^{17}\text{s}^{-1}$

Current is the rate of flow of charge: $I = \frac{Q}{t} = ne$ per unit time, so the rate of flow of electrons is:

$$\frac{n}{t} = \frac{I}{e}$$

With $I = 20.0\text{mA} = 2.00 \times 10^{-2}\text{A}$ and $e = 1.60 \times 10^{-19}\text{C}$:

$$\frac{n}{t} = \frac{2.00 \times 10^{-2}}{1.60 \times 10^{-19}} = 1.25 \times 10^{17}\text{s}^{-1}$$

Hence the correct answer is C.

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Q22 Answer B

The answer is (B). 2.0Ω

Find the heater resistance R using circuit P (no internal resistance, so the full 12 V is across the heater):

$$P_P = \frac{V^2}{R} \quad \Rightarrow \quad R = \frac{V^2}{P_P} = \frac{12.0^2}{24.0} = 6.0\Omega$$

Find the current in circuit Q (same heater resistance $R = 6.0\Omega$, output power 13.5W):

$$P_Q = I^2 R \quad \Rightarrow \quad I = \sqrt{\frac{P_Q}{R}} = \sqrt{\frac{13.5}{6.0}} = \sqrt{2.25} = 1.5\text{A}$$

Apply Kirchhoff's voltage law for circuit Q (EMF $= 12.0\text{V}$, internal resistance r, external resistance R):

$$\varepsilon = I(R + r)$$
$$12.0 = 1.5\,(6.0 + r)$$
$$6.0 + r = \frac{12.0}{1.5} = 8.0$$
$$r = 8.0 - 6.0 = 2.0\Omega$$

Hence the correct answer is B.

Q23 Answer D

Electrical energy provided by the supply is $W = VIt$, where V is the supply's terminal voltage (14 V, the d.c. supply voltage), I is the charging current, and t is the time.

$$t = 6\text{h} = 6 \times 3600\text{s} = 21\,600\text{s}$$
$$W = VIt = (14)(2.5)(21\,600)$$
$$W = 35 \times 21\,600 = 756\,000\text{J} \approx 760\text{kJ}$$

Hence the correct answer is D.

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Q24 Answer C

X is in series with the battery; Y and the variable resistor are connected in parallel with each other, and this combination is in series with X.

Illustrating with numbers (EMF $E = 12\text{V}$, $X = 2\Omega$, $Y = 4\Omega$):

Before (variable resistor $R_v = 8\Omega$):

$$R_p = \frac{Y R_v}{Y + R_v} = \frac{4 \times 8}{12} = 2.667\Omega, \qquad R_{total} = X + R_p = 4.667\Omega$$

$$I_{total} = \frac{E}{R_{total}} = \frac{12}{4.667} = 2.571\text{A}$$

$$V_p = I_{total} R_p = 6.857\text{V}, \qquad I_Y = \frac{V_p}{Y} = 1.714\text{A}$$

$$P_X = I_{total}^2 X = 13.2\text{W}, \qquad P_Y = I_Y^2 Y = 11.8\text{W}$$

After decreasing the variable resistor ($R_v = 2\Omega$):

$$R_p = \frac{4 \times 2}{6} = 1.333\Omega, \qquad R_{total} = 3.333\Omega$$

$$I_{total} = \frac{12}{3.333} = 3.6\text{A}$$

$$V_p = 3.6 \times 1.333 = 4.8\text{V}, \qquad I_Y = \frac{4.8}{4} = 1.2\text{A}$$

$$P_X = 3.6^2 \times 2 = 25.9\text{W}, \qquad P_Y = 1.2^2 \times 4 = 5.76\text{W}$$

Comparing: P_X rose from 13.2W to 25.9W (increases), while P_Y fell from 11.8W to 5.76W (decreases).

Why this happens physically: decreasing R_v decreases the parallel combination's resistance, so total resistance falls and total current (through X) rises –- increasing P_X. At the same time, the lower R_v diverts a larger share of that current away from Y, and the parallel voltage also drops, so the current through Y (and hence P_Y) falls.

Hence the correct answer is C.

Q25 Answer B

The two resistors are connected in parallel with each other, across the battery (with the voltmeter reading this same combined p.d.):

$$R_p = \frac{(32.0)(18.0)}{32.0 + 18.0} = \frac{576}{50} = 11.52\Omega$$

Total circuit resistance (external parallel combination plus internal resistance):

$$R_{total} = r + R_p = 1.50 + 11.52 = 13.02\Omega$$

Current drawn from the battery:

$$I = \frac{\varepsilon}{R_{total}} = \frac{12.0}{13.02} = 0.9217\text{A}$$

Voltmeter reading (terminal p.d., equal to the p.d. across the parallel combination):

$$V = I R_p = (0.9217)(11.52) = 10.6\text{V}$$

Hence the correct answer is B.

Q26 Answer **D**

The lamps are connected in series, so a single break anywhere (the lamp with the broken filament, which behaves as an open circuit / infinite resistance) stops current from flowing anywhere in the loop –- the ideal voltmeters (infinite resistance) provide no alternative path either.

Since $I = 0$ everywhere in the circuit:

- Every working lamp has $V = IR = 0 \times R = 0\text{V}$ across it.
- By Kirchhoff's voltage law, the sum of all p.d.s around the loop must equal the supply e.m.f. (240 V). Since all five working lamps drop 0V each, the entire 240 V must appear across the one broken lamp.

Voltmeter X is connected directly across the broken lamp, so it reads the full supply voltage:

$$V_X = 240\text{V}$$

Voltmeter Y is connected across a working lamp, which carries zero current and therefore has zero p.d. across it:

$$V_Y = 0\text{V}$$

Hence the correct answer is D.

Q27 Answer **B**

The wire forms two overlapping loops, both carrying current I circulating in the same sense (as shown by the arrows). By the right-hand rule, each loop on its own produces a magnetic field directed the same way through its interior (e.g. out of the page).

- Point A lies entirely outside both loops –- it receives only the weak, spread-out field outside the loops. Weakest.
- Point C lies inside only the lower loop –- it receives the field contribution from one loop only.
- Point D lies near the edge of a loop (close to the wire but inside only one loop) –- again only one loop contributes, and being close to the boundary the field is not at its strongest central value.
- Point B lies inside the overlap region, i.e. inside both loops simultaneously. Since both loops' fields point the same way here, their contributions add directly, giving the strongest resultant flux density of all four points.

Hence the correct answer is B.

Q28 Answer **B**

Adjacent turns of the solenoid carry current in the same direction as each other at any instant (since it's all one continuous coil). Parallel wires carrying current in the same direction attract one another –- this is true regardless of whether that shared instantaneous current is flowing in the "positive" or "negative" sense, since the force depends on the product of the two (identical-sign) currents, which is always positive.

With an a.c. supply of frequency f, the current completes one full sine-wave cycle every $1/f$ seconds, passing through two current maxima (one positive peak, one negative peak) each cycle, with the current –- and hence the attractive force –- momentarily falling to zero twice per cycle (at each zero-crossing).

Since the turns are pulled together (compress) whenever there is a nonzero current, and this attraction peaks twice every cycle (once each half-cycle, regardless of the current's sign), the turns compress twice per cycle, i.e. at frequency $2f$.

Hence the correct answer is B.

Q29 Answer **C**

Photon wavelength is inversely proportional to the transition's energy gap ($E = hc/\lambda$), so a transition produces a shorter wavelength than λ exactly when its energy gap is larger than E_{QR} (the Q→R gap).

Measuring the level spacings from the diagram (vertical separation, proportional to energy):

- Gap P–Q is smaller than gap Q–R.
- Gap R–S is much larger than gap Q–R.

There are $\binom{4}{2} = 6$ possible downward transitions in total: P→Q, P→R, P→S, Q→R, Q→S, R→S.

Comparing each to the Q→R gap:

- P→Q: smaller gap than Q→R (measured directly from the diagram) → longer wavelength than λ. Does not count.
- Q→R: this is the reference itself (wavelength exactly λ, not smaller). Does not count.
- P→R: spans P→Q plus Q→R, so its energy gap is necessarily larger than Q→R alone → shorter wavelength. Counts.
- P→S, Q→S, R→S: all involve the very large R–S gap, so each is far larger than Q→R → shorter wavelength. All count.

This gives 4 transitions (P→R, P→S, Q→S, R→S) with wavelength shorter than λ.

Hence the correct answer is C.

Q30 Answer **C**

The answer is (C). $2E_k$

Since photoelectric emission just occurs (threshold) at wavelength λ, the threshold wavelength is λ, and the work function is $\phi = \frac{hc}{\lambda}$.

By Einstein's photoelectric equation, $KE_{\max} = \frac{hc}{\lambda'} - \phi$.

For incident wavelength $\lambda/2$:

$$E_k = \frac{hc}{\lambda/2} - \frac{hc}{\lambda} = \frac{2hc}{\lambda} - \frac{hc}{\lambda} = \frac{hc}{\lambda}$$

So $\frac{hc}{\lambda} = E_k$.

For incident wavelength $\lambda/3$:

$$KE_{\max} = \frac{hc}{\lambda/3} - \frac{hc}{\lambda} = \frac{3hc}{\lambda} - \frac{hc}{\lambda} = \frac{2hc}{\lambda} = 2E_k$$

Hence the correct answer is C.

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