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TEN-YEAR SERIES · ANSWERS AND WORKED SOLUTIONS

2016 A-Level H1 Physics Paper 1

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ANSWER KEY

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WORKED SOLUTIONS

Q1 Answer B

Weight is a force, given by $W = mg$.

$$W = (0.500\text{kg})(9.81\text{m s}^{-2}) = 4.905\text{N}$$

Converting each option into newtons using SI prefixes ($\text{m} = 10^{-3}$, $\text{c} = 10^{-2}$, $\text{d} = 10^{-1}$, $\text{k} = 10^{3}$):

A. $500\text{mN} = 500 \times 10^{-3}\text{N} = 0.5\text{N}$ -- too small

B. $500\text{cN} = 500 \times 10^{-2}\text{N} = 5.0\text{N}$ -- matches

C. $500\text{dN} = 500 \times 10^{-1}\text{N} = 50\text{N}$ -- too large

D. $0.05\text{kN} = 0.05 \times 10^{3}\text{N} = 50\text{N}$ -- too large

The calculated weight, 4.905N, rounds to approximately 5.0N, which matches option B.

Q2 Answer A

This is an order-of-magnitude estimation question, requiring reasonable estimates for quantities not given.

Estimate the population of Singapore: $N \approx 5.6 \times 10^{6}$ people.

Estimate the average mass of a person: $m \approx 60\text{kg}$.

Total mass:

$$M = Nm = (5.6 \times 10^{6})(60\text{kg}) = 3.4 \times 10^{8}\text{kg}$$

This is closest in order of magnitude to option A ($3 \times 10^{8}\text{kg}$). Options B, C and D are each successively a factor of 10 too large -- they would correspond to unreasonable average masses of 600 kg, 6000 kg and 60,000 kg per person respectively.

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Q3 Answer **A**

Precision relates to the spread of repeated readings (random error) –- tightly clustered readings are precise, widely scattered readings are not, regardless of where they sit relative to the true value.

Accuracy relates to how close the readings are, on average, to the actual value –- this is affected by systematic error.

Reading the diagram:

Set 1: the four readings are widely spread out along the line, but they straddle the actual value roughly symmetrically. This means Set 1 has large random error (not precise), but little systematic error –- the average of the readings is close to the actual value (accurate).

Set 2: the four readings are tightly clustered right at the actual value. This means Set 2 has small random error (precise) and little systematic error (accurate).

Set 3: the four readings are tightly clustered, but consistently offset to the right of the actual value. This means Set 3 has small random error (precise), but a clear systematic error –- the readings are consistently too high (not accurate).

Evaluating each option:

A. Set 1 (widely spread) is indeed less precise than Set 3 (tightly clustered). Correct.

B. Set 2's average reading sits on the actual value; Set 1's average also sits close to the actual value (its spread straddles the actual value symmetrically). Both are similarly accurate, so Set 2 is not less accurate than Set 1. Incorrect.

C. Set 3 is offset from the actual value (systematic error present); Set 1 is centred on the actual value (little systematic error). So Set 3 has more, not less, systematic error than Set 1. Incorrect.

D. Set 3's readings are tightly clustered (small spread $\rightarrow$ small random error); Set 1's readings are widely spread (large random error). So Set 3 has less, not more, random error than Set 1. Incorrect.

Hence the correct statement is A.

Q4 Answer **C**

$$R = \frac{\rho l}{A}, \qquad A = \frac{\pi d^2}{4}$$

Since A depends on the square of the diameter, its percentage error is twice the percentage error in d.

For quantities combined by multiplication/division, percentage (fractional) errors add:

$$\frac{\Delta R}{R} \times 100\% = \frac{\Delta \rho}{\rho} \times 100\% + \frac{\Delta l}{l} \times 100\% + 2\left(\frac{\Delta d}{d} \times 100\%\right)$$

Given: $l = (92.0 \pm 0.5)\text{m}$, $d = (0.800 \pm 0.005)\text{mm}$, $\rho = (1.70 \pm 0.05) \times 10^{-8}\Omega\,\text{m}$.

Percentage error in l:

$$\frac{0.5}{92.0} \times 100\% = 0.54\%$$

Percentage error in d (doubled for A):

$$2 \times \frac{0.005}{0.800} \times 100\% = 2 \times 0.625\% = 1.25\%$$

Percentage error in ρ:

$$\frac{0.05}{1.70} \times 100\% = 2.94\%$$

Total percentage error in R:

$$0.54\% + 1.25\% + 2.94\% = 4.7\% \approx 5\%$$

This matches option C.

Q5 Answer C

The velocity of the car relative to the train passenger is given by the relative-velocity equation:

$$\overrightarrow{v}_R = \overrightarrow{v}_C - \overrightarrow{v}_T = \overrightarrow{v}_C + (-\overrightarrow{v}_T)$$

Taking east as $+x$ and north as $+y$:

$$\overrightarrow{v}_C = (v_C, 0), \qquad \overrightarrow{v}_T = (0, v_T)$$
$$\overrightarrow{v}_R = \overrightarrow{v}_C - \overrightarrow{v}_T = (v_C, -v_T)$$

v_R has a positive east component (v_C, unchanged direction) and a negative north component (i.e. a component to the south, since we subtract v_T). Geometrically, this is constructed by keeping v_C pointing east and reversing v_T so it points south (i.e. drawing $-v_T$), then adding them tail-to-tip: the resultant v_R points towards the south-east.

Evaluating each option:

A. Shows v_T pointing north and v_C pointing east combined to give a resultant pointing north-east –- this is the vector sum $v_C + v_T$, not the difference. Incorrect.

B. Shows v_C pointing west (reversed) –- this misrepresents the car's actual (eastward) velocity. Incorrect.

C. Shows v_C pointing east (correct, unchanged) and the vertical side pointing south (i.e. $-v_T$), with the resultant v_R pointing south-east. This matches $\overrightarrow{v}_R = \overrightarrow{v}_C - \overrightarrow{v}_T$. Correct.

D. Shows v_C pointing west (reversed) –- again misrepresents the car's actual direction. Incorrect.

Hence C correctly represents v_R.

Q6 Answer B

Before the collision: X moves at a constant (higher) velocity, so x–t is a straight line with a steady, steeper positive gradient.

During the collision: X and Y stick together (a perfectly inelastic collision). The collision itself happens over a negligibly short time, so displacement cannot jump instantaneously –- the x–t graph must stay continuous (no vertical step). This eliminates any graph with a sudden jump in x.

After the collision: by conservation of momentum,

$$m_X u_X = (m_X + m_Y)v$$

Since $m_Y > 0$, the combined mass $(m_X + m_Y) > m_X$, so the combined velocity $v < u_X$ –- the trucks continue moving in the same direction, but more slowly than before. This means the x–t graph after the collision must still have a positive, but smaller (less steep), gradient than before –- displacement keeps increasing, just more gradually.

Evaluating each option:

A. Shows a vertical drop in x –- displacement cannot jump instantaneously. Incorrect.

B. Shows a steep positive-gradient line (X's original higher speed) smoothly joining a shallower positive-gradient line (the combined, reduced speed after sticking together), continuous throughout. Correct.

C. Shows the gradient becoming steeper after the kink, implying the trucks speed up after collision –- this contradicts momentum conservation with an initially stationary Y. Incorrect.

D. Shows x resetting to zero periodically (a sawtooth) –- there is only one collision, and displacement does not reset. Incorrect.

Hence B correctly represents the motion.

Q7 Answer **C**

Falling from rest in a vacuum, displacement follows $s = \frac{1}{2}gt^2$.

At time t (end of first interval):

$$x = \frac{1}{2}gt^2$$

At time $2t$ (end of second interval), total displacement from the start:

$$s(2t) = \frac{1}{2}g(2t)^2 = \frac{1}{2}g(4t^2) = 4\left(\frac{1}{2}gt^2\right) = 4x$$

Distance fallen during the second interval (from t to $2t$) is the difference between the total displacement at $2t$ and at t:

$$\Delta s = s(2t) - s(t) = 4x - x = 3x$$

This matches option C. (This is the classic result that, for a body released from rest, distances fallen in successive equal time intervals are in the ratio $1 : 3 : 5 : 7 \ldots$ -- here the first interval covers x and the second covers $3x$.)

Q8 Answer **A**

By Newton's second law, the resultant force on an object equals the rate of change of its momentum:

$$F = \frac{\Delta p}{\Delta t}$$

For a constant force acting over a time Δt, the impulse J is defined as:

$$J = F\Delta t = \Delta p$$

So impulse is equal to the change in momentum it produces –- matching statement A.

Evaluating each option:

A. Impulse = change in momentum. This follows directly from $J = F\Delta t = \Delta p$. Correct.

B. Force $\times$ velocity has units $\mathrm{N\,m\,s^{-1}} = \mathrm{W}$ (watts) –- this is power, not impulse. Incorrect.

C. Force $\times$ distance has units $\mathrm{N\,m} = \mathrm{J}$ –- this is work done, not impulse. Incorrect.

D. "Rate of change of momentum" is the definition of force ($F = \Delta p/\Delta t$), not impulse –- impulse is the change in momentum itself, not its rate. Incorrect.

Hence the correct statement is A.

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Q9 Answer **C**

Let a be the magnitude of the common acceleration (Y accelerates downward, X accelerates up the slope, connected by an inextensible thread over a frictionless, massless pulley).

For Y (vertical, taking downward as positive):

$$3mg - T = 3ma \quad ...(1)$$

For X (along the frictionless slope, taking up-the-slope as positive):

$$T - 2mg\sin 30^\circ = 2ma \quad ...(2)$$

Adding (1) and (2) eliminates the tension T:

$$3mg - 2mg\sin 30^\circ = 5ma$$

With $\sin 30^\circ = 0.5$:

$$3mg - 2mg(0.5) = 5ma$$
$$3mg - mg = 5ma$$
$$2mg = 5ma$$
$$a = \frac{2}{5}g = 0.40g$$

This matches option C.

Q10 Answer **B**

X and Y have equal mass m and collide elastically while moving directly towards each other. Take rightward as positive.

For any 1D elastic collision, the relative speed of separation after the collision equals the relative speed of approach before it:

$$v_Y - v_X = u_X - u_Y = 3.0\text{m s}^{-1}$$

This must hold regardless of the individual (unknown) initial speeds, since only their difference (3.0 m s^{-1}) is given. Checking each option against $v_Y - v_X = 3.0\text{m s}^{-1}$ (taking "right" as $+$ and "left" as $-$):

A. $v_X = +0.5$, $v_Y = +2.5$: $v_Y - v_X = 2.5 - 0.5 = 2.0\text{m s}^{-1}$ -- does not match.

B. $v_X = -1.0$, $v_Y = +2.0$: $v_Y - v_X = 2.0 - (-1.0) = 3.0\text{m s}^{-1}$ -- matches.

C. $v_X = +1.0$, $v_Y = +2.0$: $v_Y - v_X = 2.0 - 1.0 = 1.0\text{m s}^{-1}$ -- does not match.

D. $v_X = -1.5$, $v_Y = +4.5$: $v_Y - v_X = 4.5 - (-1.5) = 6.0\text{m s}^{-1}$ -- does not match.

Only option B gives the correct relative separation speed of 3.0 m s^{-1} required for an elastic collision. (This is also consistent with the well-known result that equal masses effectively exchange velocities in a 1D elastic collision -- X, originally moving right, ends up moving left, and Y, originally moving left, ends up moving right and faster, having "taken over" X's forward momentum.)

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Q11 Answer **C**

Each point along the hanging slinky must support the weight of all the coils below it, transmitted as tension through that point of the spring. The higher up a coil is, the more weight it must support (all the coils beneath it), so it experiences a greater tension. By Hooke's law, greater tension produces a greater extension –- so the coils near the top are stretched further apart, while the coils near the bottom (supporting little or no weight below them) remain close together.

Evaluating each option:

A. Hooke's law is in fact still obeyed at every point of the spring –- it is the tension, not the validity of Hooke's law, that varies along the spring. Incorrect.

B. The spring is uniform, so mass per unit length is the same throughout; the coils at the bottom are not "heavier." Incorrect.

C. Correct –- each coil supports the weight of the coils below it, so tension (and hence extension) decreases from top to bottom. Correct.

D. The spring is hanging stationary –- it is in static equilibrium, not out of equilibrium. Incorrect.

Hence the correct explanation is C.

Q12 Answer **B**

Just before the book leaves the shelf, it pivots about the bottom-back corner still resting on the shelf edge. Taking moments about this pivot:

The weight W acts vertically downward through the book's centre of gravity, which (for a uniform book) is at the geometric centre –- a horizontal distance $x/2$ from the pivot, and a vertical distance $y/2$ above it. Since W is vertical, only the horizontal distance from the pivot contributes to its moment (the vertical offset $y/2$ is parallel to the force, so has no turning effect):

$$\text{Moment of } W \text{ about pivot} = W \times \frac{x}{2}$$

This moment tends to rotate the book so that its centre of gravity (which overhangs the shelf edge) swings downward –- i.e. the front of the book drops, which is a clockwise rotation (front-bottom corner swinging down and away from the shelf).

For the book to be held in equilibrium (not yet rotating), the student's finger and thumb must apply an equal and opposite moment at the top corner:

$$\text{Moment required} = \frac{Wx}{2} \text{anticlockwise}$$

Evaluating each option:

A. $Wy/2$ anticlockwise –- uses the wrong dimension (y, the height, has no moment arm about the pivot since W acts vertically). Incorrect.

B. $Wx/2$ anticlockwise –- matches the moment of W about the pivot, exactly opposing it. Correct.

C. $W(y-x)/2$ clockwise –- wrong dimension combination, and the wrong direction (clockwise would add to, not oppose, the weight's moment). Incorrect.

D. Wx anticlockwise –- double the correct magnitude (omits the factor of $\frac{1}{2}$ from the centre of gravity being at the midpoint). Incorrect.

Hence the required moment is B.

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Q13 Answer **B**

Since the extension is proportional to the stretching force (Hooke's law) throughout, the elastic potential energy stored is:

$$E = \frac{1}{2}kx^2$$

where k is constant for the spring, so $E \propto x^2$.

Given: at extension $x_1 = 2.7\text{cm}$, $E_1 = 0.062\text{J}$.

Total extension after further stretching:

$$x_2 = 2.7\text{cm} + 5.1\text{cm} = 7.8\text{cm}$$

Using the proportionality $E \propto x^2$:

$$\frac{E_2}{E_1} = \left(\frac{x_2}{x_1}\right)^2$$

$$E_2 = E_1\left(\frac{x_2}{x_1}\right)^2 = 0.062\left(\frac{7.8}{2.7}\right)^2 = 0.062 \times 8.35 = 0.517\text{J}$$

Work done in the further stretching equals the increase in stored elastic potential energy:

$$W = E_2 - E_1 = 0.517 - 0.062 = 0.455\text{J} \approx 0.46\text{J}$$

This matches option B.

Q14 Answer **C**

Let the left end of the plank be $x = 0$ and set up positions along its length L.

Original positions: X at $x = L/4$, Y at $x = 3L/4$ (each $L/4$ from its nearer end). Weight W acts at the centre, $x = L/2$, which is exactly midway between X and Y. By symmetry, the original support forces are:

$$F_X = F_Y = \frac{W}{2}$$

New positions (both supports shifted $L/8$ to the right): X at $x = 3L/8$, Y at $x = 7L/8$. W still acts at $x = L/2$.

Taking moments about the centre (where W acts, so W contributes zero moment there): X is now a distance $L/2 - 3L/8 = L/8$ to the left of centre; Y is a distance $7L/8 - L/2 = 3L/8$ to the right of centre.

For rotational equilibrium, the clockwise moment of F_X about the centre balances the anticlockwise moment of F_Y:

$$F_X\left(\frac{L}{8}\right) = F_Y\left(\frac{3L}{8}\right) \Longrightarrow F_X = 3F_Y$$

Combined with vertical equilibrium $F_X + F_Y = W$:

$$3F_Y + F_Y = W \Longrightarrow F_Y = \frac{W}{4}, \qquad F_X = \frac{3W}{4}$$

Increase in the force at X:

$$\Delta F_X = \frac{3W}{4} - \frac{W}{2} = \frac{3W}{4} - \frac{2W}{4} = \frac{W}{4}$$

This matches option C.

Q15 Answer **C**

For a body of mass m starting from rest and accelerated by a constant force F (so constant acceleration $a = F/m$):

$$v = at \implies v \propto t$$

Evaluating each option in terms of t (and hence in terms of v, since $v \propto t$):

A. Distance travelled: $s = \frac{1}{2}at^2 \propto t^2$, so $s^2 \propto t^4 \propto v^4$ -- not proportional to v. Incorrect.

B. Kinetic energy: $E_k = \frac{1}{2}mv^2 \propto t^2 \propto v^2$ -- proportional to v^2, not v itself. Incorrect.

C. Power developed by the force: $P = Fv$. Since F is constant, $P \propto v$ directly (linear proportionality -- doubling v exactly doubles P). Correct.

D. Work done from rest: $W = Fs \propto t^2 \propto v^2$ (equivalently $W = E_k \propto v^2$) -- proportional to v^2, not v. Incorrect.

Hence the quantity directly proportional to speed is C.

Q16 Answer **D**

The object moves up a frictionless slope under a constant force F, so all work done by F converts entirely into g.p.e. and k.e. (energy conservation, no losses):

$$W = P + K$$

Since F is constant and the slope angle is fixed, work done $W = Fd$, where d is the distance travelled along the slope -- so $d \propto W$.

g.p.e. gained $= mgd\sin\theta \propto d \propto W$ -- g.p.e. is directly proportional to the work done.

When the work done increases to $4W$, the distance travelled (and hence the g.p.e. gained) also scales by the same factor of 4:

$$\text{new g.p.e.} = 4P$$

By energy conservation at the new total work done:

$$4W = (\text{new g.p.e.}) + (\text{new k.e.}) = 4P + (\text{new k.e.})$$

$$\text{new k.e.} = 4W - 4P = 4(W - P) = 4K \qquad (\text{using } K = W - P \text{ from the original case})$$

So both the g.p.e. and k.e. gained scale by the same factor of 4 as the work done -- this makes sense since g.p.e. is proportional to distance travelled (itself proportional to W), and k.e. is simply what remains of the (also 4×) work done after g.p.e. is accounted for.

This matches option D: g.p.e. = 4P, k.e. = 4K.

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Q17 Answer **C**

At a steady (constant) speed, the driving force equals the total resistive force. Total resistance = rolling resistance (constant, 200N) + air resistance (proportional to speed squared, kv^2):

$$F = 200 + kv^2$$

Power delivered: $P = Fv = (200 + kv^2)v$

Using the given data at $v_1 = 15\text{m s}^{-1}$, $P_1 = 10\,500\text{W}$ to find k:

$$P_1 = (200 + kv_1^2)v_1$$
$$10\,500 = (200 + k(15)^2)(15)$$
$$\frac{10\,500}{15} = 200 + 225k$$
$$700 = 200 + 225k$$
$$k = \frac{500}{225} = 2.22\text{N s}^2\text{ m}^{-2}$$

At $v_2 = 30\text{m s}^{-1}$:

$$F_2 = 200 + k(30)^2 = 200 + (2.22)(900) = 200 + 2000 = 2200\text{N}$$
$$P_2 = F_2 v_2 = (2200)(30) = 66\,000\text{W} = 66\text{kW}$$

This matches option C.

Q18 Answer **C**

For two waves $y_1 = A_1 \sin(2\pi f_1 t + \phi_1)$ and $y_2 = A_2 \sin(2\pi f_2 t + \phi_2)$, the phase difference between them at any instant is:

$$\Delta\phi(t) = 2\pi(f_1 - f_2)t + (\phi_1 - \phi_2)$$

For $\Delta\phi$ to stay constant over time (not drift), the two waves must have the same frequency ($f_1 = f_2$) –- this is the essential condition, and is the standard definition of coherence. If the frequencies differed even slightly, the phase difference would continuously change with time.

For each wave to remain a genuine continuous progressive wave (rather than, say, a damped oscillation whose amplitude decays with time or distance), its amplitude must also stay constant –- this is implicit in the description "continuous progressive wave."

Evaluating each option:

A. Amplitude alone does not affect the phase relationship between the waves at all –- frequency must also be constant. Incomplete/Incorrect.

B. Wavelength is linked to frequency only via $v = f\lambda$ for a fixed wave speed; it is frequency (not wavelength directly) that governs how phase evolves with time. Incorrect.

C. Both frequency (to prevent the phase relationship drifting with time) and amplitude (for each wave to remain a well-defined continuous progressive wave) must remain constant. Correct.

D. Wavelength alone, without matching frequency, does not guarantee a time-independent phase difference. Incorrect.

Hence the correct answer is C.

Q19 Answer **C**

The Sun emits (essentially) parallel rays of light that fall on the Earth's curved surface. Because the Earth's axis is tilted, sunlight strikes the surface near the Equator almost perpendicularly, but strikes the surface near the poles at a shallow, glancing angle.

The same "bundle" of parallel rays (carrying a fixed amount of power) is spread over a much larger surface area when it strikes the ground at a shallow angle than when it strikes perpendicularly. Since intensity (power per unit area) is:

$$I = \frac{P}{A}$$

spreading the same power P over a larger area A (as happens near the poles) reduces the intensity –- this is why polar regions receive less energy per unit area per unit time and are colder.

Evaluating each option:

A. "Amplitude of the Sun's light" is not a meaningful description of what changes here –- the rays themselves aren't weaker, they are simply spread over a larger area. Incorrect.

B. Atmospheric depth is not indicated in the diagram and is not the reason given by the geometry shown. Incorrect.

C. Correct –- the oblique angle of incidence at the poles spreads the same incoming power over a larger area, reducing power per unit area (intensity). Correct.

D. The distance from the Sun to any point on the Earth's surface is essentially the same (the Earth's radius is negligible compared to the Earth–Sun distance) –- this is not the cause. Incorrect.

Hence the correct explanation is C.

Q20 Answer **B**

Diffraction of water ripples through a gap becomes most pronounced (maximum spreading) when the gap width is comparable to or smaller than the wavelength of the waves. In this limit, the gap behaves almost like a point source, re-radiating semicircular wavefronts that spread out over the full range of angles beyond the barrier –- very similar in form to the original circular wavefronts approaching the gap.

Here the gap width equals the wavelength ($d = \lambda$), which is exactly this regime of strong/maximal diffraction.

Evaluating each option:

A. Shows only a narrow, slightly-spread beam continuing mostly straight through –- this is the pattern expected when the gap is much larger than the wavelength ($d \gg \lambda$), i.e. minimal diffraction. Incorrect.

B. Shows full semicircular wavefronts spreading out over a wide range of angles beyond the gap, matching the circular wavefronts on the incident side –- this is the expected strong-diffraction pattern for $d \approx \lambda$. Correct.

C. Shows only a partial fan of spreading, less than full semicircular coverage –- this represents an intermediate case, not the maximal diffraction expected when $d = \lambda$. Incorrect.

D. Shows an asymmetric pattern directed off to one side –- diffraction through a gap that is illuminated symmetrically (as here) must produce a pattern symmetric about the direction of the original wave travel. Incorrect.

Hence B correctly shows the diffraction pattern.

Q21 Answer **C**

Two sources are coherent if they have (i) the same frequency and (ii) a constant phase difference between them.

Evaluating each option:

A. Two identical (but independent/separate) light sources emit light via spontaneous emission from vast numbers of atoms, with random, rapidly-changing relative phase –- even if their frequency spectra are identical, they are not coherent, since the phase difference between them is not constant. Incorrect.

B. Two loudspeakers emitting frequencies f and $2f$ have different frequencies, so their phase difference continuously changes with time. Incorrect.

C. The two sources have the same frequency and a fixed phase difference of 180° (π rad) between them, so both conditions hold. Correct.

D. Two tuning forks producing different frequencies cannot maintain a constant phase difference. Incorrect.

Hence the coherent pair is C.

Q22 Answer **C**

From the circuit, V_1 is connected in series within the main current loop (between the battery and the resistor's node), while V_2 is connected in parallel across the resistor.

An ideal voltmeter has infinite resistance and draws no current. Since V_1 sits directly in the only current path around the loop, its infinite resistance blocks all current flow –- no current can flow anywhere in the circuit ($I = 0$).

Since $I = 0$:

- The voltage drop across the resistor is $V = IR = 0$, so V_2 (which reads the voltage across the resistor) shows 0V.
- With zero current, there is no voltage drop across any connecting wire either. By Kirchhoff's voltage law, the entire battery e.m.f. must therefore appear across V_1 (the only component with a non-zero "resistance" causing a voltage difference), so V_1 reads the full 12V.

Evaluating each option:

A. $V_1 = 0$, $V_2 = 12$ –- reverses the correct readings. Incorrect.

B. $V_1 = 6$, $V_2 = 6$ –- would only apply if current flowed and the voltage divided; but no current flows here since V_1 is ideal and in series. Incorrect.

C. $V_1 = 12$, $V_2 = 0$ –- matches the reasoning above. Correct.

D. $V_1 = 12$, $V_2 = 12$ –- cannot both be true, since with $I = 0$ the resistor has zero voltage drop. Incorrect.

Hence the readings are C.

Q23 Answer **C**

Resistors in parallel have the same voltage V across each. Power dissipated in a resistor is:

$$P_R = \frac{V^2}{R}$$

Since V is the same for both resistors, the power dissipated is inversely proportional to resistance:

$$\frac{P_{10}}{P_{20}} = \frac{V^2/10}{V^2/20} = \frac{20}{10} = 2$$

So $P_{10} = 2P_{20}$ –- the smaller resistor dissipates more power (it draws more current for the same voltage).

Using the total power $P = P_{10} + P_{20}$:

$$P = 2P_{20} + P_{20} = 3P_{20}$$

$$P_{20} = \frac{P}{3}, \qquad P_{10} = 2P_{20} = \frac{2P}{3}$$

Evaluating each option (10 Ω, 20 Ω):

A. $P/5$, $4P/5$ –- ratio is 1:4, and wrongly has the smaller resistor dissipating less power. Incorrect.

B. $P/3$, $2P/3$ –- ratio 1:2, but wrongly has the smaller (10 Ω) resistor dissipating less power than the larger (20 Ω) one. Incorrect.

C. $2P/3$, $P/3$ –- ratio 2:1, with the smaller resistor (10 Ω) correctly dissipating more power. Correct.

D. $4P/5$, $P/5$ –- ratio 4:1, incorrect proportion (should be exactly 2:1 for 20 Ω vs 10 Ω). Incorrect.

Hence the correct division of power is C.

Q24 Answer **A**

A negative temperature coefficient (NTC) thermistor has resistance that decreases as temperature increases –- more thermal energy frees more charge carriers, so the material conducts more easily.

The relationship is non-linear: resistance falls off smoothly and steeply at first, then levels off, approaching a lower value at higher temperatures (a decreasing, curved characteristic –- never a straight line, and never increasing).

Since temperature is measured here in ordinary degrees (starting from the origin, not from absolute zero), the resistance at the lowest plotted temperature is a finite value –- not an extreme/near-infinite value. The graph should therefore start at a finite, moderately high resistance and curve smoothly downward towards a low value, without a near-vertical drop right at the origin.

Evaluating each option (as commonly presented in these graph-choice questions):

A. Starts at a finite resistance value, curves smoothly and steadily downward, levelling off at high temperature –- matches the expected NTC characteristic over a normal (non-cryogenic) temperature range. Correct.

B. Starts extremely high (near-vertical) right at the origin, implying resistance approaches infinity as temperature approaches the start of the scale –- this is only appropriate if the temperature axis extended down towards absolute zero, not for temperatures measured in ordinary degrees from a normal starting point. Incorrect.

C. Nearly flat at first before curving down –- this looks more like a small/gradual change rather than the pronounced, continuous decrease expected of an NTC thermistor. Incorrect.

D. Resistance increases with temperature –- this is the characteristic of a positive temperature coefficient device, not an NTC thermistor. Incorrect.

Hence A best represents the NTC thermistor's resistance-temperature characteristic.

Q25 Answer **B**

For a wire of resistivity ρ, length L, and radius r:

$$R = \frac{\rho L}{\pi r^2}, \qquad P = \frac{V^2}{R} = \frac{V^2 \pi r^2}{\rho L}$$

We need the combination of changes that makes $P_{new} = 2P_0$.

A. Double L only (V, r unchanged): $R \to 2R_0$, so $P = \frac{V^2}{2R_0} = \frac{P_0}{2}$ –- halves the power. Incorrect.

B. Double V and double L (r unchanged): $R \to 2R_0$ (from doubling L), so

$$P = \frac{(2V)^2}{2R_0} = \frac{4V^2}{2R_0} = 2\left(\frac{V^2}{R_0}\right) = 2P_0$$

–- exactly doubles the power. Correct.

C. Double V and double r (L unchanged): doubling r gives $R \to R_0/4$ (since $R \propto 1/r^2$), so

$$P = \frac{(2V)^2}{R_0/4} = \frac{4V^2 \times 4}{R_0} = 16P_0$$

–- increases power by a factor of 16, far more than double. Incorrect.

D. Double r only (L, V unchanged): $R \to R_0/4$, so $P = \frac{V^2}{R_0/4} = 4P_0$ –- quadruples the power. Incorrect.

Hence the change that exactly doubles the power output is B.

Q26 Answer **B**

The circuit is a 6V cell in series with the filament lamp and the variable resistor; the voltmeter reads the voltage V across the lamp, as the variable resistance R is increased.

At $R = 0$: almost none of the cell's e.m.f. is dropped across the variable resistor, so nearly the full e.m.f. appears across the lamp –- V is at its maximum here.

As R increases: more of the total voltage is dropped across the variable resistor, leaving progressively less for the lamp –- so V must decrease as R increases.

As $R \to \infty$: the current in the circuit tends to zero, so the voltage across the lamp ($V = IR_{\text{lamp}}$) also tends to zero.

So the graph must show V starting at a maximum when $R = 0$ and decreasing smoothly and continuously towards zero as R increases –- a monotonically decreasing curve.

Evaluating each option:

A. Starts at $V = 0$ when $R = 0$ and rises to a peak before falling –- the opposite of what's expected at $R = 0$ (should start at maximum, not zero). Incorrect.

B. Starts at a maximum V when $R = 0$ and decreases smoothly and continuously towards a low value as R increases. Correct.

C. Starts at an intermediate value and increases before curving –- V should decrease, not increase, as R increases. Incorrect.

D. Shows V increasing linearly with R –- again the wrong direction; more series resistance leaves less voltage for the lamp. Incorrect.

Hence the correct graph is B.

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Q27 Answer **C**

The network has two parallel sections in series with each other, all made of identical resistors R.

Left section: branch 1 (current I_1) has a single resistor R; branch 2 (current I_2) has two resistors in series, $2R$. These two branches are in parallel across the same pair of nodes, so they share the same voltage, and current divides inversely with resistance:

$$\frac{I_1}{I_2} = \frac{2R}{R} = 2 \Longrightarrow I_1 = 2I_2$$

Since $I_1 + I_2 = I_{\text{total}}$ (the single current supplied by the source, as this is the only path through the left section):

$$2I_2 + I_2 = I_{\text{total}} \Longrightarrow I_2 = \frac{I_{\text{total}}}{3}, \qquad I_1 = \frac{2I_{\text{total}}}{3}$$

Right section: branch 3 (current I_3) has three resistors in series, $3R$; branch 4 (current I_4) has four resistors in series, $4R$. Again in parallel, sharing the same total current:

$$\frac{I_3}{I_4} = \frac{4R}{3R} = \frac{4}{3} \Longrightarrow I_3 = \frac{4}{3}I_4$$

$$\frac{4}{3}I_4 + I_4 = I_{\text{total}} \Longrightarrow I_4 = \frac{3I_{\text{total}}}{7}, \qquad I_3 = \frac{4I_{\text{total}}}{7}$$

Comparing all four currents (taking $I_{\text{total}} = 1$ for comparison):

$$I_1 = \frac{2}{3} \approx 0.667, \quad I_3 = \frac{4}{7} \approx 0.571, \quad I_4 = \frac{3}{7} \approx 0.429, \quad I_2 = \frac{1}{3} \approx 0.333$$

Ranking from largest to smallest:

$$I_1 > I_3 > I_4 > I_2$$

This matches option C.

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Q28 Answer **C**

P, Q, R, S sit at the four corners of a square (in the diamond orientation shown, with P at the left vertex, Q at top, R at right, and S at bottom). All four wires carry equal currents in the same direction (into the page).

Parallel currents flowing in the same direction attract each other. So the force on P from each of the other three wires is attractive –- directed from P towards that wire.

Let the square's side length be a. Then:

- P to Q: distance a (adjacent corner, along one side)
- P to S: distance a (adjacent corner, along the other side)
- P to R: distance $a\sqrt{2}$ (diagonal, opposite corner)

The force between two long parallel wires is $F = \frac{\mu_0 I^2}{2\pi d}$, so:

$$F_{PQ} = F_{PS} = \frac{\mu_0 I^2}{2\pi a} = F_1, \qquad F_{PR} = \frac{\mu_0 I^2}{2\pi a\sqrt{2}} = \frac{F_1}{\sqrt{2}}$$

Directions (with P at the left vertex of the diamond): the pull towards Q is at 45° above the horizontal (up-and-right); the pull towards S is at 45° below the horizontal (down-and-right); the pull towards R is directly horizontal (straight right), since R is the diametrically opposite corner.

Combining F_{PQ} and F_{PS}: by symmetry, their vertical components (one up, one down, equal magnitude) cancel. Their horizontal components add:

$$2F_1 \cos 45^\circ = 2F_1 \left(\frac{\sqrt{2}}{2}\right) = F_1\sqrt{2} \quad \text{(directed to the right)}$$

Adding F_{PR} (also directed to the right, straight along the diagonal towards the centre of the square):

$$F_{net} = F_1\sqrt{2} + \frac{F_1}{\sqrt{2}} = F_1\left(\sqrt{2} + \frac{1}{\sqrt{2}}\right) > 0$$

All contributions point in the same horizontal direction –- to the right, i.e. towards R and towards the centre of the square. There is no vertical component (it cancels by the P–Q/P–S symmetry) and no component into/out of the page (the wires and forces all lie in the plane of the square).

Evaluating each option:

A. "Into the plane of the paper" –- the magnetic force between straight parallel current-carrying wires lies in the plane containing the wires, not perpendicular to it. Incorrect.

B. "To the left" –- this would mean P is repelled from the others, but parallel same-direction currents attract. Incorrect.

C. "To the right" –- matches the net attraction from Q, S and R combining along the horizontal. Correct.

D. "Zero" –- the forces from Q, S and R do not cancel; their horizontal components reinforce each other. Incorrect.

Hence the net force on P is C.

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Q29 Answer **B**

The de Broglie wavelength of a particle relates its momentum to Planck's constant:

$$\lambda = \frac{h}{p} = \frac{h}{mv}$$

Rearranging for speed:

$$v = \frac{h}{m\lambda}$$

Substituting $h = 6.63 \times 10^{-34}\,\text{J s}$, $m = 6.7 \times 10^{-27}\,\text{kg}$, $\lambda = 2.3 \times 10^{-14}\,\text{m}$:

$$v = \frac{6.63 \times 10^{-34}}{(6.7 \times 10^{-27})(2.3 \times 10^{-14})}$$

$$v = \frac{6.63 \times 10^{-34}}{1.541 \times 10^{-40}} = 4.30 \times 10^{6}\,\text{m s}^{-1}$$

This matches option B.

Q30 Answer **B**

By Einstein's photoelectric equation, the maximum kinetic energy of an emitted photoelectron is the photon energy minus the work function:

$$E_{k,\max} = hf - \phi = \frac{hc}{\lambda} - \phi$$

Step 1 –- Photon energy, using $h = 6.63 \times 10^{-34}\,\text{J s}$, $c = 3.0 \times 10^{8}\,\text{m s}^{-1}$, $\lambda = 2.8 \times 10^{-7}\,\text{m}$:

$$E_{\text{photon}} = \frac{hc}{\lambda} = \frac{(6.63 \times 10^{-34})(3.0 \times 10^{8})}{2.8 \times 10^{-7}} = 7.10 \times 10^{-19}\,\text{J}$$

Step 2 –- Convert the work function to joules, using $1\,\text{eV} = 1.6 \times 10^{-19}\,\text{J}$:

$$\phi = 4.2\,\text{eV} \times 1.6 \times 10^{-19}\,\text{J eV}^{-1} = 6.72 \times 10^{-19}\,\text{J}$$

Step 3 –- Maximum kinetic energy:

$$E_{k,\max} = 7.10 \times 10^{-19} - 6.72 \times 10^{-19} = 3.8 \times 10^{-20}\,\text{J}$$

This matches option B.

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