# 1.1 Measurements in Physics

## Mark Schemes

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| Course | DP IB Physics |
| Section | 1. Measurement & Uncertainties |
| Topic | 1.1 Measurements in Physics |
| Difficulty | Medium |



To be used by all students preparing for DP IB Physics HL
Students of other boards may also find this useful

1

The correct answer is **B** because:

- 450 nm = $450 \times 10^{-9}$ m
  - 1 nanometre is the multiplier $\times 10^{-9}$
- This is converted into micrometres, which is a multiplier of $10^{-6}$ m
  - This means the power of ten is 3 times bigger
    - $10^{-9} \times 1000 = 10^{-6}$ m = μm
    - $10^{-9} \times 10^{3} = 10^{-6}$ m = μm
  - So, for the magnitude of the number to be the same,450 must be 1000 times smaller
    - $450 \div 1000 = 0.45$
    - $450 \div 10^{3} = 0.45$
- The final answer is $0.45 \times 10^{-6}$ m = 0.45 μm

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| **A** is incorrect as | pm has a magnitude of $10^{-12}$. This is 1000 smaller than a nm.<br><br>For the magnitude of the wavelength to be the same 450 must be 1000 times bigger. This gives a value of $450\,000 \times 10^{-12}$ = 450 000 pm, not 4.5 pm |
| **C** is incorrect as | mm is 1 000 000 times bigger ($\times 10^{6}$) than a nm. For the magnitude of the wavelength to be the same 450 must be 1 000 000 times smaller. So, 450 ÷ 1 000 000 = 0.00045. Therefore, the value in mm should be 0.00045 mm and not 0.0045 |
| **D** is incorrect as | km is 1000 times bigger than m and 1000 × 1000 × 1000 = $1000^{3} = 10^{9}$ times bigger than nm. So, 450 should be $10^{9}$ times smaller = 0.00000045. Therefore, the final answer in km is 0.00000045 km and not 0.45 km |

This question is checking your understanding of the magnitudes (sizes) of multipliers. It is easier to do this question if you look at the Metric (SI) multipliers section on page 6 of your data booklet. It can get confusing quickly to try to remember the different magnitudes of the multipliers. Also, don't be afraid to check with pen and paper that you have calculated the changes in multiplying or dividing by powers of ten correctly.

2

The correct answer is **D** because:

- The base unit of energy can be obtained from substituting the SI base units into the equation for kinetic energy
    - $KE = \frac{1}{2}mv^2$
    - $J = kg\,(m\,s^{-1})^2 = kg\,m^2\,s^{-2}$
- Now substitute the SI base units for answer D:
    - $[g][\rho][h][V] = (m\,s^{-2})\,(kg\,m^{-3})\,(m)\,(m^3) = kg\,(m\,m^{-3}\,m\,m^3)\,s^{-2}$
    - Therefore, $[g][\rho][h][V] = kg\,m^2\,s^{-2}$
- Therefore, $g\rho hV$ has the same units as energy

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| **A** is incorrect as | the units of $[\rho]\,[g]^2\,[h] = (kg\,m^{-3})\,(m\,s^{-2})^2\,m = kg\,s^{-4}$ |
| **B** is incorrect as | the units of $[\rho]\,[h]\,[V]\,[g]^{-1} = (kg\,m^{-3})\,(m)\,(m^3)\,(m\,s^{-2})^{-1} = kg\,s^2$ |
| **C** is incorrect as | the units of $[\rho]\,[g]\,[h]^{-1}\,[V]^{-1} = (kg\,m^{-3})\,(m\,s^{-2})\,(m)^{-1}\,(m^3)^{-1}$<br>$= kg\,m^{-6}\,s^{-2}$ |

This question requires a methodical approach. You should substitute the SI base units into each equation, then simplify to check whether they are equivalent to the Joule. Remember to check the addition of powers carefully!

2

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This question requires a methodical approach. You should substitute the SI base units into each equation, then simplify to check whether they are equivalent to the Joule. Remember to check the addition of powers carefully!

$a^m \times a^n = a^{m+n}$ e.g. $2^5 \times 2^3 = 2^8$

$a^m \div a^n = a^{m-n}$ e.g. $5^7 \div 5^3 = 5^4$

3

The correct answer is **D** because:

- The range of visible light is about 400 – 700 nm
- Red light has the longest wavelength of any colour of visible light
  - So, 700 nm is a good estimate for the wavelength of red light

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| **A** is incorrect as | with a frequency of 500 MHz ($500 \times 10^6$), this would equate to a wavelength of = 0.6 m. Typical infrared wavelengths range from 780 nm – 1 mm so the estimated value is far too high |
| **B** is incorrect as | in kg, 250 μg works out as $(250 \times 10^{-6}) \times 10^{-3} = 2.5 \times 10^{-7}$ kg. The mass of a proton is $1.67 \times 10^{-27}$ kg so the estimated value is far too high |
| **C** is incorrect as | typical values for the Young Modulus of rubber are usually in the 0.001 – 0.5 GPa range so the estimated value is far too high |

Having a knowledge of a range of quantities such as lengths, frequencies, wavelengths, expected experiment results from the SL course will help in checking your answers to different questions, as you can identify more easily whether the answers "make sense".

4

The correct answer is **C** because:

- Convert kW h into Joules:
    - $1\text{ kW} = 1000\text{ W} = 1000\text{ J s}^{-1}$
    - $1\text{ h} = 60 \times 60 = 3600\text{ s}$
    - $\frac{8}{9}\text{ kW h} = \frac{8}{9} \times 1000 \times 3600 = \frac{8}{9} \times 3600\,000$
    - $\frac{28\,800\,000}{9} = 3.2 \times 10^{6}\text{ J}$
- Convert joules into eV:
    - $1\text{ eV} = 1.60 \times 10^{-19}\text{ J}$
    - $\frac{3.2 \times 10^{6}}{1.60 \times 10^{-19}} = 2 \times 10^{25}\text{ eV} = 2.0 \times 10^{25}\text{ eV}$

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| **A** is incorrect as | $\frac{3.2 \times 10^{6}}{1.60 \times 10^{-19}} = 2 \times 10^{25}$ eV and not $2 \times 10^{-13}$ eV.<br><br>According to the rules of indices when powers to the same base are divided then the powers are subtracted |
| **B** is incorrect as | 1 hour is 60 minutes and 1 minute is 60 seconds<br><br>So, to convert from 1.5 kW h into J<br><br>$\frac{8}{9}\text{ kW} = \frac{8000}{9}\text{ J s}^{-1}$<br><br>and<br><br>$1\text{ hr} = 60 \times 60 = 3600$<br><br>so,<br><br>$\frac{8}{9}\text{ kW h} = \frac{8000}{9} \times 3600 = 3.2 \times 10^{6}\text{ J}$ |

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| | and not $\frac{8}{9}$ kW h = $\frac{8000}{9}$ x 60 = $\frac{160000}{3}$ × $10^4$ J |
| **C** is incorrect as | $3.2 \times 10^6$ is $\frac{8}{9}$ kW h in Joules and not in eV as the units state |

Be careful with the indices and calculations as this is a non-calculator paper! When dividing a large number such as $\frac{28\,800\,000}{9}$, first do $\frac{288}{9}$ (32) then just add on the remaining 5 0's ($32 \times 10^5$).

$$a^m \times a^n = a^{m+n} \quad \text{e.g. } 2^5 \times 2^3 = 2^8$$

$$a^m \div a^n = a^{m-n} \quad \text{e.g. } 5^7 \div 5^3 = 5^4$$

5

The correct answer is **C** because:

- Pressure is equal to $P = \frac{F}{A}$
- Therefore, pressure has units of:
  - $\frac{[F]}{[A]} = \frac{N}{m^2} = \text{N m}^{-2}$
- Newton's second law states that:
  - $F = ma$
- The SI base units for force is:
  - $\text{N} = \text{kg} \times (\text{m s}^{-2})$
- The base units for pressure are then $\text{N m}^{-2} = (\text{kg m s}^{-2})\,\text{m}^{-2} = \text{kg m}^{-1}\,\text{s}^{-2}$
- On the right hand side, we can combine units to give
  - $(\text{kg m}^{-3})(\text{m s}^{-2})(\text{m}) = \text{kg m}^{-1}\,\text{s}^{-2}$
- This is equal to the left hand side, so the correct answer is **C**

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| **A** is incorrect as | the N $m^{-1}$ on the LHS is the incorrect unit for pressure. Area has the SI units of $m^{-2}$ |
| **B** is incorrect as | the units are correct on the LHS, but on the RHS, the unit for density is incorrect. Density = $\frac{\text{mass}}{\text{volume}}$ so, kg $m^{-3}$ are the SI units for density and not kg $m^{-2}$. The base units then simplify from (kg $m^{-2}$) (m $s^{-2}$) (m) to kg $s^{-1}$ which is incorrect |
| **D** is incorrect as | the kg $m^{-1}$ $s^{-1}$ on the LHS is the incorrect base unit for pressure |

This question requires careful substitution and careful simplifying of powers. It is easy Mathematics but also easy to make mistakes. Make sure you do the question twice, and check you get the same answer each time.

When multiplying two quantities with the same base the powers are added together.

$$a^m \times a^n = a^{m+n} \quad \text{e.g. } 2^5 \times 2^3 = 2^8$$

$$a^m \div a^n = a^{m-n} \quad \text{e.g. } 5^7 \div 5^3 = 5^4$$

6

The correct answer is **B** because:

- Mass per unit area would have the units:
  - $\frac{[m]}{[A]}$ = kg m$^{-2}$
- Density, $\rho$ is the mass per unit volume
- This means it has the units of
  - $\frac{[m]}{[V]}$ = kg m$^{-3}$
- Therefore, density and mass per unit area have different units
  - This means they also have different base units

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| **A** is incorrect as | emf and 'lost volts' are both potential differences, therefore are measured in volts. This means they have the same base units. The question is asking which pair has different base units |
| **C** is incorrect as | impulse is equal to the change in momentum<br><br>F = ma from Newton's Second Law<br><br>$I = F\Delta t = m\Delta v$<br><br>Therefore, both quantities are measured in kg m s$^{-1}$ |
| **D** is incorrect as | work is the same as energy transferred, so they both have units of Joules (J) |

It is important to check each pair of answers in the question. Do this even if you have already found two different pairs. If you find another two different pairs, it is easy to see you have made a mistake and can check your calculations.

7

The correct answer is **A** because:

- From the Data Booklet the Fundamental Constants needed are:
  - Fermi Radius, $R_0 = 1.2 \times 10^{-15}$ m
  - Speed of light in a vacuum, $c = 3.00 \times 10^8$ m s$^{-1}$
- We know that speed = $\frac{\text{distance}}{\text{time}}$
  - So, time = $\frac{\text{distance}}{\text{speed}}$
- For light passing through a Hydrogen nucleus
  - time = $\frac{1.2 \times 10^{-15}}{3 \times 10^8} = \frac{12 \times 10^{-16}}{3 \times 10^8}$
  - $12 \div 3 = 4$
  - $10^{-16} \div 10^8 = 10^{-24}$
- So, the answer has a magnitude of $10^{-24}$

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| **B** is incorrect as | $10^{-20}$ is too big for the time it takes light to pass through a hydrogen nucleus. Look carefully at the powers of ten involved and use the laws of indices to calculate $10^{-16} \div 10^8 = 10^{-24}$ |
| **C** is incorrect as | $10^{-15}$ is much too big for the time it takes light to pass through a hydrogen nucleus. Look carefully at the powers of ten involved and use the laws of indices to calculate $10^{-16} \div 10^8 = 10^{-24}$ |
| **D** is incorrect as | $10^{-7}$ is a huge value for the time it takes light to pass through a hydrogen nucleus. Look carefully at the powers of ten involved and use the laws of indices to calculate $10^{-16} \div 10^8 = 10^{-24}$ |

It is important to use your data booklet and know where the constants and equations are for each topic you have studied. This will make it much quicker for you in the exam to use this if you practice using it whilst revising.

8

The correct answer is **C** because:

- From the question

  $u = 0$ m $s^{-1}$ as glider starts from stationary

  $v = ?$

  $a = 10$ m $s^{-2}$

  $t =$

  $s = 31.25$ m

- Looking at the variables we have, and the fact that we want to calculate final velocity we should use the equation:
  - $v^2 = u^2 + 2as$
- Substituting the values into the equation to calculate $v$ gives:
  - $v^2 = 0^2 + 2 \times 10 \times 31.25$
  - $v^2 = 20 \times 31.25$
  - $v^2 = 625$
  - So, $v = \sqrt{625} = 25$ m $s^{-1}$
- The question requires the answer to an appropriate number of significant figures
- To do this we must first look at the numbers of significant figures from the quantities in the question
  - 1.00 m is written to 3 significant figures
  - 6.00 m is also written to 3 significant figures
  - 12 m $s^{-1}$ is written to 2 significant figures
  - $g = 10.0$ m $s^{-1}$ is written to 3 significant figures
  - 31.25 m is written to 4 significant figures

- The final answer must be written to the least number of significant figures given in the question
  - This is 2 significant figures
  - So, the final answer is 25 m $s^{-1}$

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| **A** is incorrect as | this is the answer written to 3 significant figures and not the required 2 significant figures |
| **B** is incorrect as | this is the answer written to 1 significant figure and not the required 2 significant figures |
| **D** is incorrect as | this is the answer rounded to the nearest ten but then written to 3 significant figures |

You must remember for all questions that the total number of significant figures in the answer is the least number given from the quantities in the question. *g* can be taken as 10 m $s^{-2}$ in paper 1, since it is non-calculator, however, must be 9.81 m $s^{-2}$ in paper 2 which does require a calculator.

To multiply a whole number by a decimal, split up the decimal as follows:

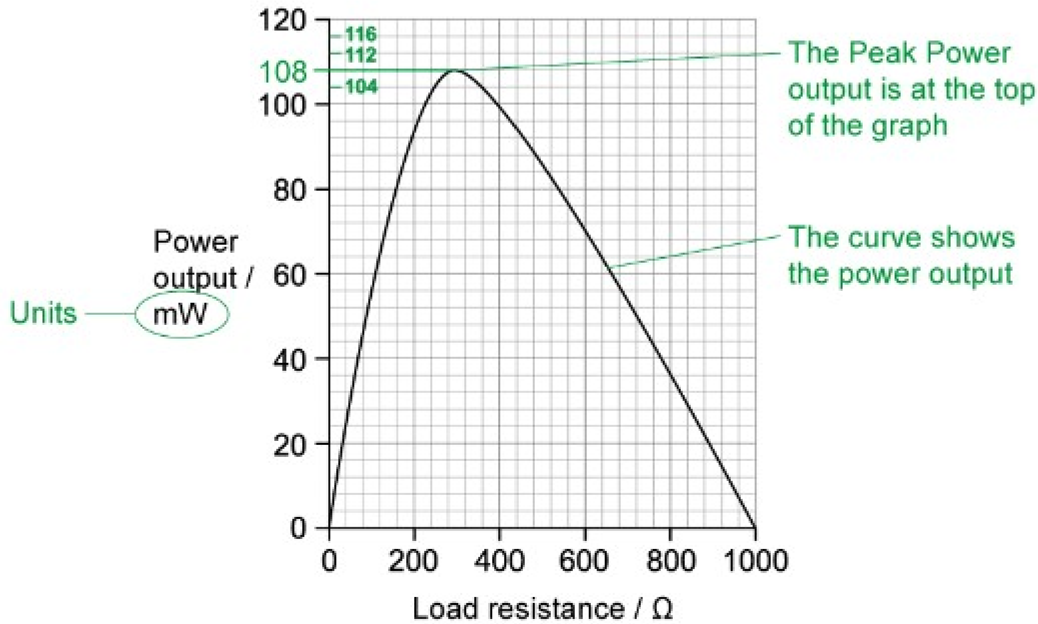
$$20 \times 31.25 = (20 \times 31) + (20 \times 0.25) = 620 + 5 = 625$$

9



The correct answer is **D** because:

- The cell is a square of side length 60 cm
- This must be converted into metres (1 cm = $1 \times 10^{-2}$ m)
- So, the square has a side length of $60 \times 10^{-2}$ m
  - The area is therefore: $(60 \times 10^{-2}) \times (60 \times 10^{-2}) = 3600 \times 10^{-4}$ $m^2$
- Calculate the total power arriving at the cell:
  - $0.6 \times$ area of cell $= 0.6 \times (3600 \times 10^{-4}) = 2160 \times 10^{-4}$ W $= 216 \times 10^{-3}$ W




- From the graph, peak power = 108 mW = 108 × $10^{-3}$ W
- The ratio of

$$\frac{\text{electrical energy at peak power}}{\text{energy arriving at the cell from the Sun}} = \frac{108\times10^{-3}}{216\times10^{-3}} = \frac{1}{2} = 0.50$$

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| **A** is incorrect as | the area of the cell has not been converted into metres. Metres are the standard SI units for length and not mm |
| **B** is incorrect as | the peak power was not converted from mW to W. There are 1000 mW in 1 W |
| **C** is incorrect as | this is the solar power arriving from the Sun on the cell and not the ratio of the electrical energy at peak power/energy arriving at the cell from the Sun |

You must remember for all questions that the total number of significant figures in the answer is the least number given from the quantities in the question. There are no units in the answer for this question because it is a ratio of $\frac{power}{power}$ which has the same units on the numerator and denominator, which cancel out.

10

The correct answer is **B** because:

- The final value of the displacement must have the same number of significant figures as the least significant figures of the values used in the problem
    - From SUVAT equations, both the acceleration and time will be used to calculate the displacement
- The acceleration of 9.81 m $s^{-2}$ has 3 significant figures
- The time of 0.081 s has 2 significant figures
- Therefore, the displacement must be to 2 significant figures

This is true throughout your IB Physics course, and is especially important in any practical questions. Your final answer can be no more precise than the least precise measurement in the problem. Therefore, it is important you can clearly read the number of significant figures of any number!