Physics Problem Solving

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Physics Problem Solving Society
St Paul's School

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Who we are

- Dara Daneshvar, U8, `DaneshD@StPaulsSchool.org.uk`

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- Deepen understanding in physics

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U8 Olympiads

Competition	Date	Length	Format	U8	L8
Physics Challenge	Sept - Dec	1h	SAQ	Yes	Opt.
BPhO R1	8 Nov	1h, 1h40min	SAQ, LAQ	Yes	PhC
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- Section 2, 1h40min, Not-as-time-pressured, Long Answer Questions

L8 Challenges

Competition	Date	Length	Format
Senior Physics Challenge Online	20-24 Jan	2 * 30min	Online MCQ
Senior Physics Challenge	7 Mar	1h	MCQ, SAQ

Table: BPhO L8 Challenges

https://www.bpho.org.uk/Competitions/ for full schedule.

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Qu. 1 Estimations

Qu. 1 (a) [2]

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Fact (Mass-Energy Equivalence Equation)

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Fact (Energy-Momentum Relation Equation)

$$E^2 = (pc)^2 + (m_0 c^2)^2$$

where E is the total energy of a particle, p is its momentum, m_0 is its stationary mass and c is the speed of light.

Qu. 1 (c) [4]

An inventor designs a novel type of battery reputed to have an emf of 2V and an internal resistance of 1$\mu\Omega$. He claims that this device could deliver 1MW to an appropriate load.

Comment on the feasibility of this and any safety considerations in the employment of such a power source.

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Fact

Maximum power is dissipated to the external load when it has equal resistance with the internal resistance of the power source.

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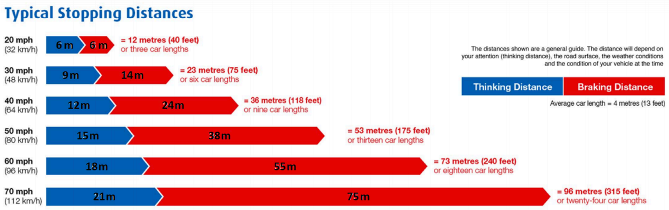
Therefore, the power $P = I^2 R = (1\text{MA})^2 \cdot 1\mu\Omega = 1\text{MW}$ *as claimed.*

Qu. 2 Stopping Distances

Qu. 2(a). [2 + 2]

- What is the kinetic energy of a car of mass 1000kg travelling at $30\,\mathrm{m\,s^{-1}}$?
- A car travelling at approximately $30\,\mathrm{m\,s^{-1}}$ in the country is required by law to halve its speed on entering a built-up area. What fraction of its kinetic energy is lost in doing this?



Qu. 2(b). [1 + 1]

- By inspection of the values given in the figure, suggest a relationship between the thinking distance, T, and the speed, v.
- The Thinking Distance in the table derives from empirical information about the behaviour of drivers. If you were to propose a theoretical explanation of this phenomenon, what assumption would be needed to explain your suggested relationship?

Qu. 2(c) i. [3]

Clearly, the speed and stopping distance have a different relationship. A student who has seen part (a) of this question suggests that the braking distance, B, is proportional to the square of the speed, v^2.
Using the data, devise a test to check this hypothesis and comment on the results of your test.

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Solution

1. *Draw a table, with B as a column, v^2 as a column, and B/v^2 as the final column. Compare the final column values.*
2. *Draw a graph, with B on the y-axis, v^2 on the x-axis, and verify they are all lying close to line of best fit.*

Qu. 2(c) ii. [1]

Again, the observed relationship is only an empirical finding. If you were to devise a theoretical explanation of the $B \propto v^2$ relationship, what assumption would you need to make about the braking behaviour of a car?

Fact (*suvat* equations)

For motion with uniform acceleration a, initial speed v, final speed u, elapsed time t and displacement s, we must have:

$$\begin{cases} a = \frac{v-u}{t} \\ s = ut + \frac{1}{2}at^2 \\ s = vt - \frac{1}{2}at^2 \\ s = \frac{1}{2}(u+v)t \\ 2as = v^2 - u^2 \end{cases}$$

Qu. 2(c) iii. [3]

Calculate the deceleration of a car when it brakes from a speed of $80\,\mathrm{km\,h^{-1}}$.

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Units!

Fact

$1\,\text{m}\,\text{s}^{-1} = 3.6\,\text{km}\,\text{h}^{-1}$.

Qu. 2(c) iv. [2]

Hence determine the (minimum) coefficient of (static) friction, μ, for contact between car tyres and the road. (μ is the ratio of the maximum braking force before skidding sets in, to the weight of the car).

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Solution

$$\mu = \frac{ma}{mg} = \frac{a}{g} = \dots$$

Try doing cancellation before actually plugging in the values (and don't be afraid of setting unknowns).

Qu. 2(c) v. [2]

It is often stated (incorrectly) that the value of μ cannot exceed unity. But, if tyres had this excellent level of grip, what would be the minimum stopping distance from $96\,\mathrm{km\,h^{-1}}$?