Physics Challenge 2023

Mark-scheme

Note to teachers:

The paper is designed to be challenging. Questions based on unfamiliar physics require students to analyse the information given. The mathematical content may involve unfamiliar units. Students are asked to estimate reasonable values and evaluate or justify arguments.

The questions are designed to be accessible to all students independent of exam board or syllabus. If a question is deemed to be unfair due to the particular syllabus studied, teachers are encouraged to use the opportunity to comment on the paper. All comments are taken seriously and used to refine future papers.

Preamble:

Please award marks as indicated below.

Equivalent valid reasoning should gain equal credit to the solutions presented here.

Error carried forward marks may be awarded where an incorrect answer is used as part of the data needed for a subsequent question, providing that the resulting answer is not plainly ridiculous.

If incorrect units are used <u>more than once</u> then a maximum of **one** mark should be deducted from the total.

If an inappropriate number of significant figures is given <u>more than once in final answers</u> then a maximum of **one** mark should be deducted from the total.

Section A – Multiple Choice Questions   [1 mark each]

1	2	3	4	5	6	7	8	9	10
C	C	D	B	D	A	A	B	C	A

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Section B – Short Answer Questions

Marks for these two questions should be awarded for a clear explanation of the underlying physical principals using correct scientific terminology at a level appropriate for students of this age.

Answers that are incomplete, contain errors in physics or use terminology incorrectly cannot be awarded full credit.

Markers are **encouraged to be generous** and award credit where possible.

Question 11 (Insulation)

Award 0 marks:	No valid attempt made to answer question
Award 1 mark:	Single valid point presented but other-wise incorrect or incomplete One explanation from conduction, convection or radiation
Award 2 marks:	Partially correct answer but major error(s) or omission(s) in reasoning Two valid explanations from conduction, convection or radiation
Award 3 marks:	Mostly correct answer, only minor error(s) or omission(s) in reasoning Reference to conduction, convection and radiation but one or more explanations incomplete or incorrect
Award 4 marks:	Essentially correct answer, no errors or omissions of reasoning but answer is not clear on first reading, is confused or uses terminology incorrectly Conduction, convection and radiation correctly used to explain how the insulation is used
Award 5 marks:	Completely correct answer, no errors, omissions of reasoning or incorrect use of terminology, clear on first reading Conduction, convection and radiation correctly used to explain how the insulation is used and is clear on first reading

Question 12 (Incorrect series circuit)

The bulbs are not lit	[1 mark]
Because the resistance of the voltmeter is very high	[1 mark]
Therefore the current in the circuit is zero	[1 mark]
The reading on the voltmeter is (approximately) 6 V	[1 mark]
Because the there is no potential difference across either of the bulbs	[1 mark]

Give credit for any equivalent solution such as reference to potential dividers

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Section C – Longer Answer Questions

Question 13

(a)   1 kWh = 1000 x 60 x 60 J = 3600 000 J = 3.6×10^6 J   [1]

(b)   Mass of container = $\pi \times 2.5^2 \times 4 \times 5200 = 410\,000$ kg   [1]

         GPE = 410 000 x 9.8 x 300 = 1.2×10^9 J   [1]

         Energy stored = 1.2×10^9 / 3.6×10^6 = 330 kWh   [1]

(c)   ΔGPE / second = 800 000 / 0.94 = 850 kW   [1]

         Δh / second = 850 000 / (9.8 x 410 000) = 0.21 m/s   speed = 0.21 m/s   [1]

(d)   Δt = s/v   Δt = 300 / 0.21 = 1400 seconds   Δt = 23.5 minutes   [2]

(e)   Maximum force from cables = 8 x ⅓ x 2100 000 = 5600 kN   [1]

         Maximum resultant force on mass = 5600 000 – (410 000 x 9.8) = 1600 kN   [1]

         Maximum acceleration = 1600 000 / 410 000 = 3.9 m/s^2 which is just less than 4.0 m/s^2 [1]

(f)   Idea: Cables must support their own weight when 300 m long   [1]

                                                    as well as that of the mass   [1]

         Weight of one 300 m long cable = π x (8.7 x 10   / 2) x 300 x 7850 x 9.8 = 140 kN   [1]

         Weight supported by each cable at 300 m = 140 kN + (410 000 x 9.8 / 8) = 640 kN [1]

         Max load = ⅓ of 2100 kN = 700 kN. At 300 m, cable does not exceed max load and is suitable [1]

                                                                          (16 marks)

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Question 14

(a) $225^2 / 365^2 = (\text{radius Venus})^3 / 1^3$ [1]

Calculation done in AU [1]

Mean orbital radius of Venus = 0.724 AU [1]

(b) A larger separation gives a greater parallax angle [1]

Which is easier to measure and/or reduces uncertainty [1]

(c) Any attempt to use trigonometry as the diagram is not to scale, the planets are very small in comparison to the distances and D = distance between Earth and Venus [1]

$\tan(0.0130 / 2) = (d / 2) / D$ [1]

Giving $D = 4.21 \times 10^7$ km [1]

(d) $(1 - 0.724)$ AU = 0.276 AU [1]

0.276 AU = 4.21×10^7 km [1]

1 AU = 1.53×10^8 km = 153 million km ≈ 150 million km [1]

(e) Orbital speed Venus = $2 \times \pi \times 0.724 \times 153 \times 10 / (225 \times 24 \times 60 \times 60)$ = 35.8 km/s [1]

Any consistent units are acceptable e.g. AU/day etc

(f) Students need to realise that, due to the distances involved, the arc length travelled by Venus across the face of the sun is approximately a straight line and hence the system forms a triangle.

Distance travelled during transit ≈ $2 \times 0.276 \times 153 \times 10^6 \times \tan(0.25)$ = 369 000 km [1]

Transit time = 369 000 / 35.8 = 10 300 seconds, 10 300 seconds ≈ 3 hours [1]

(14 marks)

Although an enormous number of simplifications have been made in this question it is hoped that students will still appreciate the immense challenges facing astronomers before the advent of modern technology.

END OF SOLUTIONS

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