Physics Challenge 2020

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 more than once then a maximum of **one** mark should be deducted from the total.

If an inappropriate number of significant figures is given more than once in final answers 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	A	E	D	D	A	B	C	C	D

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.

Award 0 marks:	No valid attempt made to answer question
Award 1 mark:	Single valid point presented but other-wise incorrect or incomplete
Award 2 marks:	Partially correct answer but major error(s) or omission(s) in reasoning
Award 3 marks:	Mostly correct answer, only minor error(s) or omission(s) in reasoning
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
Award 5 marks:	Completely correct answer, no errors, omissions of reasoning or incorrect use of terminology, clear on first reading

Any valid explanation should be awarded credit

Example solutions might include, but are not limited to:

Question 11: [5 marks]

- Heating the gas means the particles gain more kinetic energy and move faster
- The open end of the tube means the gas pressure must remain constant
- Pressure is caused by the collisions between the gas particles and the walls of the container
- When the gas particles have more kinetic energy they exert a greater force on the walls of the container (because there is a greater change in momentum)
- To maintain the same pressure, the particles must hit the walls of the container less often
- Therefore they must move further between collisions meaning the gas has expanded
- The molecules push the mercury up the tube until it again has the same pressure above and below

Accept answers in terms of the resultant force acting on the mercury makes it move and so the volume increases meaning the gas has expanded or any other similar argument.

Question 12: [5 marks]

- An ammeter is connected in series with the bulbs (given)
- Therefore the current through the bulbs also flows through the ammeter
- The current in a series circuit depends on the total resistance of the components in the circuit
- Adding the ammeter into the circuit should not change the current being measured
- Therefore the ammeter must have zero (or a comparatively very low) resistance so that the total resistance remains effectively unchanged (with the addition of the ammeter)

Section C – Longer Answer Questions

Question 13

(a) State Wd = F x s and the divide both sides by time interval Δt, recognition that P = Wd / Δt [1]

(b) (i) Use P = 400 W and equation in (a) to give 400 = F x 7 giving F = 57.1 N [1]

(b) (ii) 1 watt = 1 joule/second and 1 hour = 3600 seconds ∴ 1 Wh = 3600 J [1]
300 Wh = 300 x 3600 = 1.08 MJ ≈ 1.1 MJ [1]

(b) (iii) Use of Wd = F x s [1]
Recognise Wd = 1.1 MJ and F = 60 N from previous section [1]
Giving distance = 19 km using calculated values or 18 km using 1.1 MJ / 60 N = 18,333 m [1]

Credit any alternative approach such as t = E / P and s = vt

(b) (iv) Lower speed means less drag, motor provides a smaller force to maintain a constant speed [1]
Energy transferred from the fully charged battery is unchanged [1]
Using Wd = F x s with a lower value for force means distance is increased. Range is greater [1]
30 km could easily be valid at less than 7 m/s [1]

NOTE: Accept any valid argument e.g. in terms of power

NOTE: Accept any argument about the validity of the manufacturer's claim as long as it does not contradict any previous statement e.g. "range does not depend on speed therefore manufacturer's claim is not valid" gets one mark for assessing the claim

(c) (i) Between 5 cm x 20 cm = 100 cm^2 and 20 cm x 70 cm 1400 cm^2 [1]

(c) (ii) Sensible estimate of time exposed during day in seconds e.g. 6 hours = 21,600 s [1]
Area form (c)(i) converted to m^2 e.g. 800 cm^2 = 0.08 m [1]
Energy calculated from solar constant and time e.g. 1200 x 0.08 x 21,600 = 2.1 MJ [1]
Incudes efficiency e.g. 2.1 MJ x 0.15 = 310 kJ [1]
Sensible comment based on calculated values e.g. 310 kJ is 30% of capacity from (b)(ii) which is a significant increase in range [1]

NOTE: The comment mark must be justified by calculation, not just a bald statement

Question 14

(a) By the effect on other observable objects e.g. the orbit of stars around an unseen object [1]

(b) Calculated value of r_S = 1.93 x 10^{13} m [2]
Conversion of units, r_S = 128 AU or 40 AU = 6 x 10^{12} m [1]
128 AU > 40 AU and so claim is valid [1]

(c) (i) 1 light year = 3 x 10^8 x 365(.25) x 24 x 60 x 60 = 9.4 x 10^{15} m [1]
55 million light years = 9.4 x 10^{15} x 55 x 10^6 = 5.2 x 10^{23} m [1]

(c) (ii) Use the photograph to estimate d. The diameter of the dark area is 2.5 x diameter of the event horizon and the brightly glowing areas are each about the width of the dark shadow. Therefore the value of d is 7.5 x the diameter of the event horizon or 15 x r_S ≈ 3 x 10^{14} m [2]
Therefore angular size is $\tan^{-1}(3 \times 10^{14} / 5 \times 10^{23})$ = 34 x 10^{-9} degrees [1]

(c) (iii) Calculate λ = 3 x 10^8 / 230 x 10^9 = 1.3 x 10^{-3} m [1]
Use of R = 60 x 1.3 x 10^{-3} / (2 x 6400 x 10^3) = 6 x 10^{-9} degrees [1]
Which is smaller than the angular size of the object and therefore adequate [1]