Physics Challenge 2024

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
B	C	C	D	D	C	B	B	A	A

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 (refraction)

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 either refraction in glass block or dispersion in prism
Award 2 marks:	Partially correct answer but major error(s) or omission(s) in reasoning Two partial explanations for refraction in glass block and dispersion in prism
Award 3 marks:	Mostly correct answer, only minor error(s) or omission(s) in reasoning Reference to change in velocity to explain refraction at both boundaries of glass block and prism (towards and then away from normal) and an attempt to explain dispersion due to geometry of prism
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 Dispersion explained as different wavelengths refract through different angles overall whereas, for the glass block, the effect of dispersion at the first boundary is negated by the opposite effect at the second boundary so all wavelengths emerge parallel to each other forming a single parallel white light ray
Award 5 marks:	Completely correct answer, no errors, omissions of reasoning or incorrect use of terminology, clear on first reading As for 4 marks but is clear on first reading

Question 12 (balls falling)

All balls are the same size and shape and therefore experience (almost) the same drag [1 mark]

For the squash ball and golf ball the drag must be very small compared to the weight and so can be neglected [1 mark]

Therefore, for the golf ball and squash ball, W = mg and F = ma together imply that objects with different masses fall at the same rate [1 mark]

The ping-pong ball is significantly less massive and so drag will be significant compared to the weight which reduces the resultant force acting on the ping-pong ball [1 mark]

The ping-pong ball has a lower acceleration and therefore takes longer to reach the ground [1 mark]

Do not allow “squash ball and golf ball have similar masses so fall in similar times”. Neglecting drag, it has to be clear that the time to fall to the ground is independent of mass

Section C – Longer Answer Questions

Question 13

(a) Energy of atomic bomb = 15 000 x 1000 x 4.2 x 10^6 J = 6.3 x 10^{13} J **and …**

KE of asteroid = ½ x 100 x 10^6 x 15 000^2 = 1.13 x 10^{16} J [1]

1.13 x 10^{16} / 6.3 x 10^{13} = 178 ≈ 200 [1]

b) p = 100 x 10^6 x 15 000 = 1.5 x 10^{12} kg.m/s [1]

c) $p_{satellite}$ = 5000 x 40 000 = 2.0 x 10^8 kg.m/s [1]

tan(θ) = 2 x10^8 / 1.5 x10^{12} giving θ = 0.0076° [1]

v = √((2 x 10^8)^2 + (1.5 x 10^{12})^2) = 1.5 x 10^{12} m/s [1]

d) Use of tan (0.0076) = (2 x 6370) / distance [1]

Distance = 12 740 / 0.00013 ≈ 9.6 x 10^7 km [1]

e) Time for satellite to travel 9.6 x 10^7 km at 40 km/s is 2.4 x10^6 seconds (≈ 28 days)

In this time asteroid travels 2.4 x 10^6 x 15 km = 3.6 x10^7 km [1]

Therefore distance required = (9.6 + 3.6) x10^7 km = 1.3 x10^8 km (approx. 1AU, about right) [1]

f) Twice the velocity [1]

Doubling either mass or velocity doubles the momentum so both increase deflection angle equally, so there is no advantage to either (owtte) [1]

BUT doubling velocity also means satellite gets there more quickly so minimum detection range is smaller, which is advantageous (owtte) [1]

g) Ejected material would also have momentum but in opposite direction to the momentum of the satellite – as the satellite hits, ejected material is thrown off the surface (this mark is for identifying why the ejected material would make a difference) [1]

Therefore the change of momentum and hence change of direction would be greater than with just the satellite. The asteroid would be deflected through a larger angle (this mark is for concluding that the ejected material increases the angular change) [1]

Question 14

(a) 14 V – 12 V = 2 V [1]

(b) Using I = V / R, Current = 2 / 0.2 = 10 A [1]

(c) Using P = V x I applied to power supply, P = 14 x 10 = 140 W [1]

Using P = I^2 x R applied to resistance P = 10^2 x 0.2 = 20 W [1]

Efficiency = (140 – 20) / 140 = 0.86 ≈ 0.85 (85%) [1]

(d) Using P = I^2 x R applied to 0.05 Ω resistor P = 10^2 x 0.05 = 5.0 W [1]

(e) Heat capacity of battery = (1.6 x 130) + (1.0 x 1400) = 1600 J / °C [1]

Using Energy transfer = heat capacity x change in temperature

gives change in temperature per second = 5.0 /1600 [1]

Change in temperature per second = 0.0031 °C/s [1]

(f) Maximum temperature change = 50 °C – 20 °C = 30 °C [1]

Time taken to change by 30 °C = 30 / 0.0031 = 9700 seconds [1]

Which is 9700 / 60 / 60 = 2.69 hours ≈ 2 ½ hours [1]

(g) 10 Amps for 2.68 hours = 26.9 Ah 26.9 Ah / 50 Ah = 0.54 (54%) [1]

(h) Percentage increases as resistor value increases (no marks for simple statement) [2]

Percentage is a function of current x time

Current is a function of 1/R

Time is a function of 1/power which is therefore a function of R^2

Percentage is a function of 1/R x R^2 , percentage is a function of R

Percentage charged = 2.67 (R + 0.05)

Award marks for the student's argument.

1 mark for a partial argument to support a correct conclusion

2 marks for a complete argument to support a correct conclusion

A correct argument can be by calculation using a different value of R