Physics Challenge 2017

Mark-scheme

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 **one** mark should be deducted from the total.

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

Section 1 – Multiple Choice Questions [1 mark each]

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

Section 2 – Short Answer Questions

Marks for these two questions should be awarded for a clear explanation of the underlying physical principals using correct scientific terminology.

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:

11. Measuring acceleration [5 marks]

- Before the aircraft accelerates, the pendulum is vertical as there is no horizontal component of force acting on the pendulum
- As the aircraft accelerates, the supporting string must pull the pendulum bob forwards, whereas the weight still acts vertically
- Therefore there is an unbalanced force due to the horizontal component of the tension in the string
- The unbalanced force causes the pendulum bob to accelerate (N2L)
- The horizontal force on the bob, and the vertical force holding the pendulum up, are provided by the tension in the string acting at an angle to the vertical

OR

- The string is attached to the mass and so when the aircraft accelerates the mass must accelerate.
- Therefore there is a horizontal force on the mass in the direction of the acceleration of the aircraft.
- There is also a vertical force on the mass due to gravity/weight.
- So there must be a vertical component of tension provided by the string.
- So the string provide both a horizontal force and a vertical force on the bob.

12. Cooling curve [5 marks]

- The temperature drops as water loses energy and cools
- The rate of heat loss, and hence rate of change in temperature, depends on the difference between the temperature of the water and the surrounding room temperature.
- Initially the water cools quickly as the temperature is well above room temperature
- When the water loses energy its temperature reduces so the rate at which it loses energy reduces and the rate at which the temperature falls is less.
- Therefore, after some time the water is cooling more slowly as the temperature of the water is closer to room temperature
- Eventually the water settles at a constant temperature which is equal to room temperature

Section 3 – Longer Answers

Question 13

(a) Use of conservation of energy gives ½ $mv^2=mg\Delta h$ (g constant) [1]

Use of $\Delta h = 330000\,m$ [1]

To give $v = 2540\,m\,s^{-1}$ [1]

(b) The velocity would be less [1]

because the capsule is not slowed down so much and therefore doesn't need such a high initial velocity (owtte to justify the first point) [1]

(c) Straight line graph from the origin [1]

With a gradient of $100\,m\,s^{-2}$ [1]

Correct velocity on y-axis e.g. $2500\,m\,s^{-1}$ [1]

Correct time on x-axis e.g. correspondingly $t = 25\,s$ [1]

(d) Area under graph or suvat used [1]

To give length = 31 km (if $v=2500\,m\,s^{-1}$ used) or 32 km if $v=2540\,m\,s^{-1}$ used [1]

(e) Material would not be strong enough to support own weight or some other valid and reason based on science or engineering. Do not accept answers such as 'too long' and ignore reference to acceleration would not be constant [1]

(f) Use of formula and correct units to give $v=11300\,m\,s^{-1}$ [1]

(g)(i) Asteroids are much smaller with lower surface gravity **and therefore** the escape velocity will be considerably lower and the technology will be feasible (also accept idea that lower gravity makes it easier to build the launcher). Must have connection between facts about asteroid and escape velocity to score mark – not simply 'they are smaller' [1]

(g)(ii) The smaller radius and surface gravity means the escape velocity is smaller **and therefore** the gas molecules in the atmosphere have enough (thermal) energy / velocity to escape. A reasoned answer is required to score the mark. [1]

Question 14

(a) $P = VI = 1.6 \times 0.2 = 0.32\,W \approx 0.3\,W$ [1]

(b) $E = Pt = 0.32 \times 60 \times 60 = 1152\,J \approx 1150\,J$ [1]

(c) The number of marks awarded depends on the sophistication of approach:

Basic: Assumption that V and I do not change over time period giving use of $E = VIt$ with $I = 200mA$ and $V = 1.6V$ for 8 hours which gives $E = 9216\,J$ [max = 2]

Intermediate: Summation of energy for each period of time and use of $E = VIt$

$E = (0.2 \times 1.6 \times 3 + 0.175 \times 1.4 \times 3 + 0.15 \times 1.2 \times 1 + 0.14 \times 1.1 \times 1) \times 3600$

$E = 7300\,J$ [max = 3]

High level: Summation of average energy for each period

$E = (0.2x1.6x1 + 0.188x1.5x2 + 0.163x1.3x3 + 0.145x1.15x1 + 0.83x0.65x1) \times 3600$

$E = 6370\,J$ [max = 4]

(d) Maximum capacity could be $200 \times 3 + 175 \times 3 + 150 + 140 = 1415\,mAh$ assuming current remains constant between readings and therefore claim not justified

Attempt to calculate mAh capacity in some way [1]

Evaluation of claim consistent with their calculation [1]

(e) Show $E = ½ \times 15 \times 2.8^2 = 58.8\,J$ [1]

(f) Capacitor: Energy density = $58.8 / (\pi \times 0.6^2 \times 0.75) = 70\,J\,cm^{-3}$ [1]

AA Cell: Energy density = $6370 / (\pi \times 0.725^2 \times 5) = 770\,J\,cm^{-3}$ [1]

Correct calculation of volume and use of units (mm→cm) [1]

The AA sized cell made from supercapacitors would have a lot less energy stored and so it would last for much less time (conclusion and justification) [1]

(g) Attempt to use $E = VIt$ with either the average voltage or calculating Vt as the area under the graph and using energy from previous question as 58.8 J (60 J) [1]

To give $I = E / Vt = 58.8 / (1.4 \times 1) = 42$ Amps [1]