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# Examiners' Report
# June 2022

## International A Level Physics WPH11 01

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## Introduction

This paper was concerned with the physics of forces, including gravitational forces, tension, reaction, and forces in fluids due to drag and upthrust as well as the effects of forces on the motion of objects in one and two dimensions. The effects of forces on the shape and structure of the materials of which the objects are made was also examined, and candidates were expected to apply abstract principles of mechanics to contexts they should have studied as well as new or more unfamiliar contexts.

On the whole, candidates were well prepared for this exam and showed good ability in the more basic applications and simple recall questions such as Q11(a), the Newton's third law question, Q12(b) on the steel cable and Q14(a), the regenerative brakes question. Candidates were able to deploy a good range of different strategies to solve problems where there were a variety of possible approaches, such as in Q13(b), the coat hook question and Q19, the viscometer question.

Explanations of physical phenomena were less well attempted; this was particularly evident in Q15, the Galilean thermometer question, where candidates did not clearly show to which part of the narrative their explanations referred and often became confused as to what exactly it was that they were trying to explain. In Q14(b)(ii), Q16(b) and 19(c) candidates often failed to address the main physical process at play, although there were many good attempts made. Candidates should be encouraged not to rush into answering questions without first reading them thoroughly.

In questions where a conclusion needed to be drawn or explained candidates were on the whole showing a comparison of a calculated result with the condition that it needed to satisfy, though some candidates were losing the final mark by neglecting this. This applied to Q13(b), Q18(c) and Q19(b)(ii).

Final answers must be correctly rounded, not truncated, and truncated values in multi-stage calculations will not generally yield the required value for the final mark. It is advisable that candidates should use calculators to retain all significant figures for values carried forward and only round answers for the final line.

It was very pleasing to see the high standard of English in many papers, although there were a significant number of papers where the candidate's command of English did not seem adequate for the demands of this paper.

**SECTION A**

**Multi-Choice Items**

| | Subject | Correct response | Comment |
|---|---|---|---|
| **1** | Power and units | **C** | Time taken = work done ÷ power. |
| **2** | Upthrust and drag | **B** | Upthrust is constant but drag increases with speed. |
| **3** | Scalars and vectors | **D** | Work is a scalar. |
| **4** | Stress/Strain graphs | **C** | Young modulus is given by the gradient of the tangent at the origin. |
| **5** | Determination of *g* | **B** | Overestimating distance fallen gives higher value for *g*. |
| **6** | Newtons's 2nd law | **B** | Acceleration is greater for a smaller mass. |
| **7** | Elastic strain energy | **D** | For same force, strain energy is proportional to extension. |
| **8** | Velocity/Time graphs | **D** | Displacement is found from the area under the graph, area below the *t* – axis counting as negative. |
| **9** | Work | **D** | Work done is force multiplied by distance moved in the direction of the force. |
| **10** | Spring stiffness | **B** | Stiffness = change in force ÷ change in length. |

Multi-choice items were generally well-answered, candidates who scored well in Section A generally went on to score a good mark overall in the paper.

**SECTION B**

Exemplar items show examples of answers which scored full marks unless otherwise stated.

## Question 11 (a)

### The Levitating Magnet

Candidates needed to say why these two particular forces are not a Newton 3rd law pair, and those who referenced the diagram correctly were able to access both marks. General statements about the conditions required were not enough, for example stating that the forces should be of the same type would only score marks if it was stated that these two are not.

Candidates generally answered this question well and many gained both marks with most candidates getting at least one of the two options.

Give two reasons why these forces are **not** a Newton's 3rd law pair.

**(2)**

They are not the same type of force.

They act on the same body. (2 bodies are required)

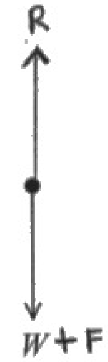
## Question 11 (b)

The Newton 3 rd law pair of the upward magnetic force *F* on the disc is a downward magnetic force *F* on the base. This caused some confusion for many candidates, with a good many not showing this force at all. Most candidates were able to draw an upward force on the base, which is the reaction from the table, although a significant number mislabelled it. There were also a few candidates who did not notice the context and wrote “upthrust” or “drag”.

(b) The magnetic base has weight *W* and rests on a horizontal table.

Complete the free-body force diagram below for the magnetic base.

(2)



## Question 12 (a)

### The Steel Cable

The description of elastic limit was not well stated by most candidates. Merely stating that the cable no longer behaves elastically does not tell the examiner that the candidate understands what 'elastic' means, and many candidates neglected to mention that for elastic behaviour, the return to original length occurs **after the load is removed**.

(a) State what is meant by the elastic limit.

(1)

The maximum force which the material can still return to original length if force removed. Beyond it is plastic deformation

## Question 12 (b)(i)

Most candidates were able to score both marks for this question. Occasionally a spurious unit was seen which prevented the second mark from being scored. A ratio of two quantities with the same unit does not have a unit and may also be expressed as a percentage. Candidates should be reminded that marks are not awarded for final answers expressed as fractions.

(b) The elastic limit of a steel cable was reached when a force of $13.4 \times 10^6$ N was applied. The extension of the cable was 0.126 m.

length of cable = 6.00 m
cross-sectional area of cable = $9.60 \times 10^{-3}$ m$^2$

(i) Calculate the strain of the cable at its elastic limit.

(2)

$$\text{Strain} = \frac{0.126}{6.00} = 0.021$$

Strain = 0.021

## Question 12 (b)(ii)

Similar to the previous question, most candidates were able to score both marks for this question. There were the occasional incorrect or missing units, and, rarely, candidates muddling stress with strain and answering the questions the wrong way around, thus scoring no marks.

(ii) Calculate the stress in the cable at its elastic limit.

(2)

Stress = $F/A$

Stress = $\frac{13.4 \times 10^{6}}{9.60 \times 10^{-3}}$

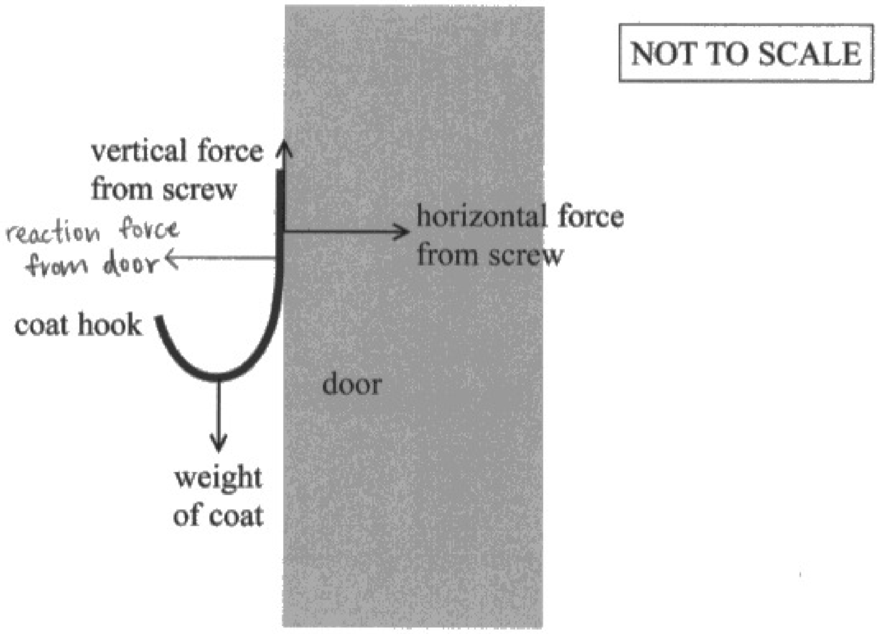
Stress = $1.4 \times 10^{9}\ \text{N m}^{-2}$

## Question 13 (a)

**The Coat Hook**

Very few candidates scored both marks for this question. The hook is an extended body in equilibrium, requiring the moments to balance. As drawn in the paper there is an unbalanced anti-clockwise moment which must be balanced by the reaction force. Few candidates realised this, with most drawing a reaction force in line with and opposite the force from the screw. Without the correct annotation, even that did not score a mark.

(a) The diagram below shows three of the forces that act on the coat hook when a coat is hung from it. The weight of the coat hook may be neglected.



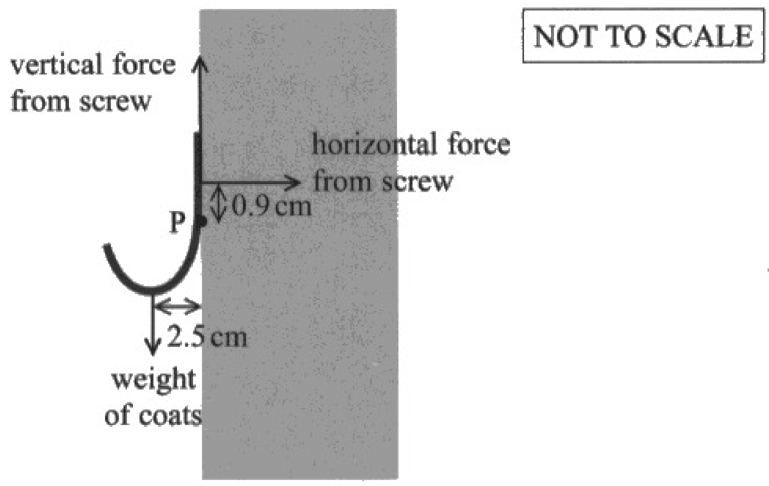

Add a labelled arrow to the diagram to show the additional force required for the coat hook to be in equilibrium.

**(2)**

## Question 13 (b)

There are a several different ways to approach this question, the most popular was to compare the moment due to three coats with the maximum moment available from the screw. This question was generally answered very well although many candidates did not obtain the final mark because they showed that the hook could support two coats but did not show that three coats were too many. Lack of a clear comparison was also a reason why many candidates did not score the final mark.

(b) If too many coats are hung on the coat hook, the hook will rotate and pull the screw out of the door. Point P is the position of the pivot as shown.




The maximum horizontal force from the screw is 150 N.

The mass of one coat is 2.6 kg.

Deduce whether a person could hang more than two of these coats from the hook.

**(4)**

~~to be in equilibrium:~~

~~$0.9(150) = 2.5(2\times(2.6g))$~~

$0.9\text{m}(150\text{N}) = 2.5\text{m}(x\text{N})$

$x = \frac{0.9(150)}{2.5} = 54\text{N}$

$\frac{54}{2.6g} = \frac{54}{2.6(9.81)} = 2.1$ coats

$\approx 2$ coats

No, the maximum amount of coats is 2.1, and coats are counted as a whole, so max 2 coats.

## Question 14 (a)

### The Regenerative Brakes

Most candidates scored well with this question. Those candidates that did not score full marks generally did not use the kinetic energy formula correctly, added the useful energy to the kinetic energy or had the efficiency equation upside down.

(a) A car travelling at $13.0 \text{ m s}^{-1}$ decelerated to rest.

The energy transferred to the car's battery during the deceleration was 73.9 kJ.

Calculate the efficiency of the regenerative braking system.

mass of car = 1560 kg

**(3)**

$\frac{1}{2} \times 1560 \times 13^2 = 131820 \text{ J}$

$\frac{73900}{131820} = 0.56$

Efficiency = 56% or 0.56

## Question 14 (b)(i)

This was a straightforward question that most candidates had little trouble answering. Confusion arose when candidates remembered that drag forces can slow a car down, so said that the greater the drag force the slower the car.

(b) (i) Drag forces act on the car as it moves through the air.

State how the drag forces vary with the velocity of the car.

(1)

As the velocity increases, the drag force on the car increases.

## Question 14 (b)(ii)

This question tested a candidate's ability to account for how the kinetic energy of the moving car was dissipated as the regenerative braking system slowed the car down. The work done against or by air resistance accounts for a greater proportion of the dissipated energy for greater initial velocity. Candidates should be encouraged to use correct technical language when answering these types of questions; very few candidates mentioned work done, and even fewer mentioned energy dissipation.

Explain why the efficiency of the regenerative braking system varies as shown in the graph.

(4)

As the initial velocity of the car increases
the air resistance* acting on the car increases.
As a result more work is done by dissipative
/non-conservative forces meaning that less
kinetic energy is conserved as the car is faster.
~~to water~~; More energy is transferred to the
surroundings /dissipated meaning the useful
energy output decreases more in proportion to
the total energy input, decreasing efficiency.
*and other resistive forces.

## Question 15

### The Galilean Thermometer (Linkage Question)

The question was principally about Archimedes' principle and many candidates did indeed give good answers once they began to talk about the relative sizes of the vertical forces acting on the bulb. Many candidates knew that flotation depends on the relative densities of the liquid and the bulb, but no marks were available for simply comparing densities, an explanation as to **why** the density is important was required.

A common error was to bring the viscosity of the liquid into the explanation. Viscosity only has an effect while the bulb is moving, but the speed at which the bulbs move is not relevant to how the thermometer works, so examiners ignored mention of viscosity unless contradictions arose. It is notable that confusion between the effect of upthrust and viscous drag also appeared in Q19(a).

As with many multi-mark extended response questions there were a significant number of blank responses. Centres should remind candidates that many of the marks are available for simple statements, even when there is confusion about how to approach a full answer. In this question a statement of Archimedes' principle, or a statement that the weight of a bulb is constant, are worth indicative content marks by themselves, so marks can be scored even without a full explanation.

Responses scoring full marks for this question were very rare. Centres should encourage candidates to construct clear narratives for these types of question. In this case the narrative is: the bulb floats, the temperature rises, the bulb sinks. A clear account of each stage in the right order is the most likely way to score all the marks.

Explain why a particular bulb will float until the temperature of the liquid exceeds a certain value.

The bulbs float when weight equals upthrust in magnitude (opposite in direction). The weight of the fluid displaced is the same as the weight of the bulb. As temperature increases, the density of the liquid decreases. This decreases the upthrust on the bulb as upthrust = density of liquid x volume of bulb x g. Volume of bulb and g are constants so upthrust is proportional to the density of the liquid. The weight is constant but upthrust decreases. There is an unbalanced force on the bulb and it accelerates downwards as the resultant force is downwards. ~~resg~~ It only sinks when the weight of the disc is greater than the weight of fluid displaced

$m_{bulb} \times g = m_{water} \times g \rightarrow m_{bulb} \times g = \rho_{liquid} \times V_{bulb} \times g$. Each bulb has a different mass so they all sink at different temperatures. mass of bulb is proportional to the density at which they sink. Heavier bulbs sink in greater density liquids and lighter bulbs in lesser densities. Since the density is changed by temperature, the ~~value it which the~~ certain value at which it sinks varies per bulb

## Question 16 (a)

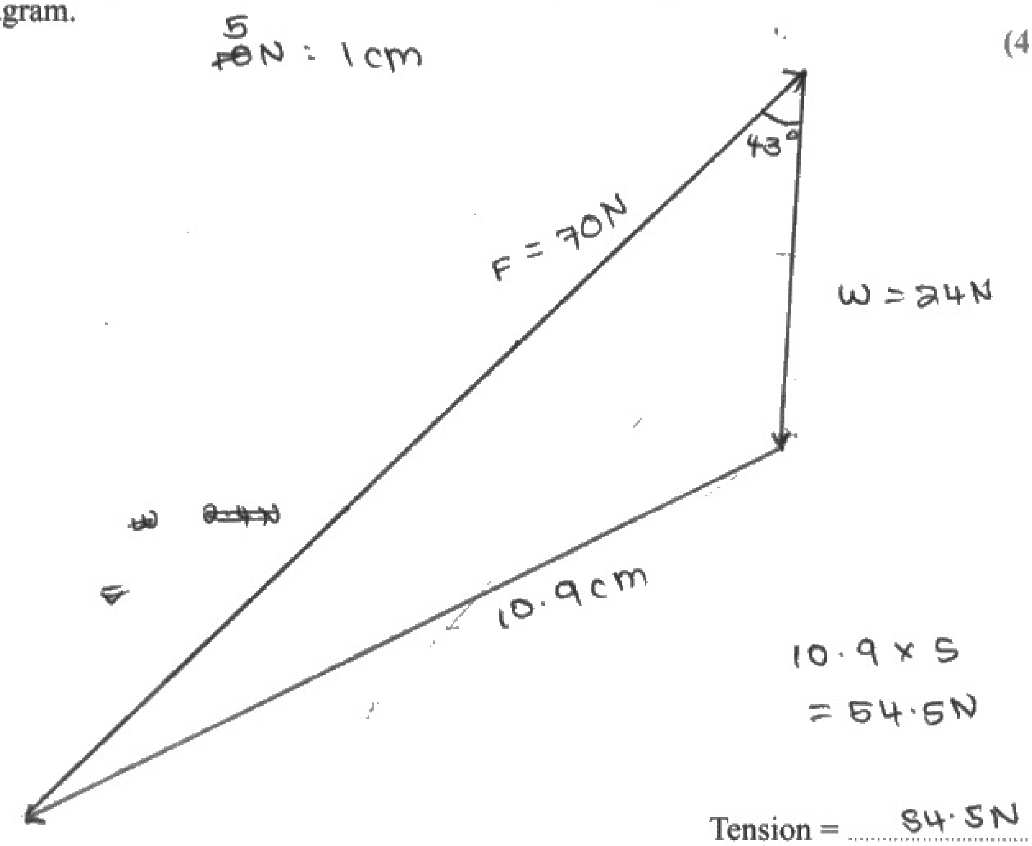
**The Kite**

Candidates are expected to know how to draw an accurate parallelogram or triangle of forces in order to find the resultant or equilibrant of two forces not at right angles. Many candidates clearly know how to do this using the cosine rule, but only one mark was available for using that method (although candidates are encouraged to check their answers this way if they know how to do it).

Those candidates who drew the angle between the two forces correctly generally went on to score all the marks. Those who drew free body force diagrams but did not then construct the parallelogram generally scored no marks. The general exhortation to use a sharp pencil, ruler and to measure to the nearest millimetre or degree applies to questions like this one.

(a) Determine the magnitude of the tension in the string by using a scaled vector diagram.

**(4)**




Tension = 84.5N

## Question 16 (b)

This question tested candidates' understanding of force resolution by asking them to explain how measurements from a photograph could give a value for the tension in the kite string. Most candidates realised that an angle needed to be measured, but it was important to state how and which one. Good answers gave a clear account of the process and reasoning behind it. Common mistakes generally involved muddling the angle with the co-angle and vagueness with regard to how the weight of the mass and holder was to be determined.

## Question 17 (a)

### Question 17 (a)(i) The Bumper Cars

This question provided few difficulties for candidates and most scored all three marks. A few candidates showed the value by substituting 150 kg for car Q into the momentum equation to obtain a value of 248 kg for car P. Centres should warn candidates that a reverse working will not usually score full marks in a "show that" question, and also that the result of a calculation must be shown to one more significant figure than the "show that" value.

### Question 17 (a)(ii)

Most candidates seemed to know that the law of momentum conservation only applies when no external forces act, but a great many candidates did not state how the condition applied to **this situation**. Without mentioning the cars or the system no mark could be awarded.

### Question 17 (a)(iii)

This calculation could be done for either car, since the magnitude of the forces on each is the same. Most candidates were able to score full marks on this question.

## Question 17 (b)

The question asked for an explanation in terms of Newton's laws, so explanations that did not mention the laws by name did not score full marks. Most candidates scored marks for application of the third law. Fewer candidates were clear about there now being a non-zero resultant force on car P, with some saying that there was a reduced resultant force. A negative resultant force where there had been zero before is not "reduced".

(b) Explain why P decelerates during the collision. Your answer should make reference to Newton's laws of motion.

**(3)**

When P collides with Q, Q produces an equal and opposite force on P as P does on Q (Newton's 3rd law). This force is in the opposite direction of P's direction so P slows down. Due to Newton's 2nd Law, F=ma, a resultant opposite force is applied on P during collision so $a = -\frac{F}{m}$.

## Question 18

### Question 18 (a) The Golfer

Calculating the vertical component of the ball's velocity presented few difficulties for most candidates.

### Question 18 (b)

Most candidates who scored full marks on this part used the quadratic method, although several candidates successfully executed the two part calculation where the maximum height and time to maximum height were calculated and the time to fall from there to 11 m added. The most common incorrect approach was to find the time to maximum height and double it, giving a time that is too long.

### Question 18 (c)

Most candidates that attempted this question had little difficulty in multiplying the horizontal component of velocity with the time found in part (b). Many candidates did not obtain the final mark because there was no comparison made with a relevant value in the final line.

(a) Show that the vertical component of the ball's initial velocity was about 30 m $s^{-1}$.

(2)

vertical

52 × sin(41) = 34.1 m/s

(b) Show that the time taken by the ball to reach the ground was about 7 s. You should ignore the effects of air resistance.

(3)

s = 11
u = 52 sin(41)
v =
a = −9.81
t =

$s = ut + \frac{1}{2}at^2$

$11 = 52\sin(41)t + \frac{1}{2} \times -9.81\,t^2$

$11 = 34.1t + (-4.905)t^2$

$-4.905t^2 + 34.1t - 11 = 0$

a = −4.905
b = 34.1
c = −11

$\frac{-34.1 \pm \sqrt{34.1^2 - 4 \times (-4.905) \times -11}}{2 \times -4.905}$

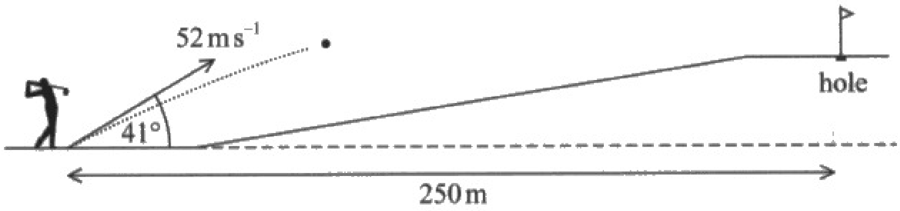
$= \frac{-34.1 \pm \sqrt{1162.81 - 215.82}}{-9.81}$

$= \frac{-34.1 \pm \sqrt{946.99}}{-9.81}$ = ~~0.[illegible]~~ → rej

= 6.6 s

= 6.6 s

(c) The hole is a horizontal distance of 250 m from the starting point of the ball, as shown.




Deduce whether the ball landed within 5.0 m of the hole. You should ignore the effects of air resistance.

(3)

horizontal

$u = 52\cos(41)$

$v = \frac{s}{t}$

$s = v \times t$

$s = 52\cos(41) \times 6.6$ sec

$s = 259.02$ m

$s = 259$ m

The ball did not land within 5.0 m of the hole as the interval was $245 \leq x \leq 255$ m but the ball surpassed the interval at 259 m

## Question 19 (a)

### The Falling Sphere Viscometer

Candidates had no trouble identifying the problem of an increasing temperature, although some were distracted by fluid density, which has very little effect. Additional detail about how the change in viscosity might affect terminal velocity was not necessary, though some candidates mentioned terminal velocity without mentioning why it would be affected.

## Question 19 (b)(i–ii)

### Question 19 (b)(i)

This was a simple three step calculation that candidates had little difficulty with. The most common cause of error was in calculating the volume of the sphere, a formula that candidates are expected to know.

### Question 19 (b)(ii)

There were many ways to deduce whether Stokes' law applied. A popular way was to calculate the theoretical terminal velocity and compare it with the observed velocity, another was to calculate the theoretical drag and upthrust and compare it with the weight of the sphere. Common errors included forgetting to multiply mass by *g* in obtaining the upthrust or forgetting about the upthrust altogether.

## Question 19 (b)(iii)

This was a simple recall question and most candidates were able to give one of the correct options. Centres should remind candidates that if only one condition is asked for only one should be given, there is no advantage in a second, and a risk that if it is wrong it will negate the mark. Examples of wrong extra options included "constant temperature" and "terminal velocity", neither of which are required for Stokes' law. The most popular answer was that there should be laminar flow around the sphere.

## Question 19 (c)

The falling sphere viscometer relies on Stoke' law being obeyed, so answers needed to describe how the terminal velocity must be kept low. Very few candidates scored full marks on this question, and many just quoted the terminal velocity formula without any explanation, despite being instructed not to use calculations.

Something about the effect of lower viscosity on drag, and how the diameter affects drag and weight were required. There were many blank answers. A simple statement that the viscosity of blood is less than that of glycerol would have scored a mark.

## Paper Summary

Many candidates showed high levels of skill and knowledge of physics in this paper and it was very pleasing to see some of the excellent examples of the efficient solutions candidates presented, especially in Q13(b), the coat hook question and Q18(c), the golfer question.

Based on their performance on this paper, candidates should:

- practice drawing scaled vector diagrams. This would have been of great benefit for Q16(a).
- be encouraged to annotate calculations more clearly to help both themselves and others to follow an argument or calculation, particularly in the final lines where a conclusion is to be drawn.
- remember that ambiguous statements do not score marks, as an examiner cannot be expected to guess which meaning a candidate intended.
- practice applying principles in a wide variety of different contexts. This will help build confidence and initiative.
- spend time in close reading of questions, re-reading both the question and their answer. This would help avoid ambiguities and contradictions and greatly improve performance, particularly in Q15, the Galilean thermometer question and in Q19(c), the falling sphere viscometer question.
- learn basic definitions, and define quantities used. This will prevent candidates failing to gain credit for concepts that they do in fact understand.
- be encouraged to use calculators correctly, to round answers to three significant figures in the last line only and to carry all significant figures forward from line to line in their calculations. Judicious use of calculator memory can avoid rounding errors.
- remember that rather than leaving entire questions blank they can score marks with some simple statements without necessarily knowing how to finish a question.

## Grade boundaries

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