Examiners' Report
Principal Examiner Feedback

October 2021

Pearson Edexcel International Advanced Subsidiary Level in Physics (WPH11)
Paper 01 Mechanics and Materials

General Remarks

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 students were expected to apply abstract principles of mechanics to contexts they should have studied as well as new or more unfamiliar contexts.

Overall, students had been well prepared for this exam and showed good ability in the more basic applications and simple recall questions such as the momentum question **Q12** and the sledge question **Q13** and were able to deploy a good range of different strategies to solve problems where there were a variety of possible approaches, such as in the projectiles question **Q16(b)** and the Stokes' Law question **Q17(b)**.

Explanations of physical phenomena were limitedly attempted; this was seen in the toy car question **Q15** where the majority attempted an explanation in terms of energy when the question asked for an account of the forces at play. Similar encounter in part (a)(ii) of the Stokes' law question **Q17** where the question was about Newton's first law. Students are highly encouraged not to rush into answering questions without first reading them thoroughly.

A recurring theme in questions where a conclusion needed to be drawn or explained was not showing a comparison of a calculated result with the condition that it needed to satisfy. This applied to **Q13(b)** and **Q16(c)** and **Q19(a)**.

Many students also couldn’t score marks due to poor rounding of answers, particularly in questions where numbers had to be carried forward within questions such as **Q17(b)(iii)**. 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 students 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 very high standard of English in nearly all papers.

SECTION A

Multi-Choice Items

	Subject	Correct response	Comment
1	Interpretation of graphs	**B**	Acceleration is rate of change of velocity.
2	Newton's 3rd law	**C**	Forces are equal in magnitude and opposite in direction.
3	Elastic energy	**C**	Apply $\Delta E_{el} = ½F\Delta x$
4	Resolution of vectors	**C**	sin 22.6° = 5.5 m s^{-1}/ velocity
5	Moment of a force	**B**	Cannot balance as sum of moments is always anti-clockwise
6	Addition of vectors	**A**	Normal force must be at right angles to the slope and vectors must add to zero.
7	Uniform acceleration	**A**	Application of $s = ut + ½ a t^2$ with $u = 0$
8	G.P.E.	**B**	Weight is mg and height is h. Apply $\Delta E_{grav} = mg\Delta h$
9	Stokes' Law	**A**	Recall conditions for Stoke's law.
10	Newton's 2nd law	**D**	Resultant force = $T - mg - D = ma$, re-arrange.

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

SECTION B

Exemplar items show examples of answers which scored full marks.

Question 11

This question tested a student's understanding of energy conservation. Most were able to calculate the increase in kinetic energy correctly by using the correct formula but majority did not realise that the total energy available was the sum of the kinetic energy and work done.

mass of car = 0.160 kg
speed of car at bottom of slope = $2.6\,m\,s^{-1}$

(a) Calculate the increase in kinetic energy of the car as it accelerates down the slope.

(2)

$\frac{1}{2} \times 0.16 \times 2.6^2 = 0.5408$

Increase in kinetic energy = 0.5408 J

(b) As the car accelerates down the slope, the work done against frictional forces is 0.26 J.

Calculate the vertical displacement of the car.

(2)

~~0.5408 − 0.26 = 0.2808 J~~

0.5408 + 0.26 = 0.8008

$h = \frac{\text{KE} + \text{GPE}}{mg}$ ∴ $h = \frac{0.8008}{0.16 \times 9.81} = 0.51$ m

Vertical displacement of car = 0.51 m

(Total for Question 11 = 4 marks)

Question 12(a)

This was a recall question where students could demonstrate that they understood that it is the total momentum of a *system* that is conserved, and that this is conditional on the absence of external forces. A majority forgot to include the condition, and a number did not make it clear enough that they were referring to a system rather than a single object. Some confused momentum with moment, and others talked about conservation of energy.

12 An aluminium sphere collides head-on with a stationary steel sphere. The two spheres move off separately after the collision.

(a) State the principle of conservation of momentum.

(2)

The total momentum is conserved provided no external forces acts upon the system. So the total momentum before a collision will be equal to total momentum after the collision.

Question 12(b)

This question was well answered overall, though some gave no indication that the direction of motion was reversed. A minus sign is sufficient to show this, but a statement to that effect is also acceptable.

Calculate the velocity v of the aluminium sphere immediately after the collision.

mass of aluminium sphere = 2.7 kg
mass of steel sphere = 7.9 kg

(3)

$(\rightarrow)$

$(10 \times 2.7) + (0 \times 7.9) = (v \times 2.7) + (5.0 \times 7.9)$

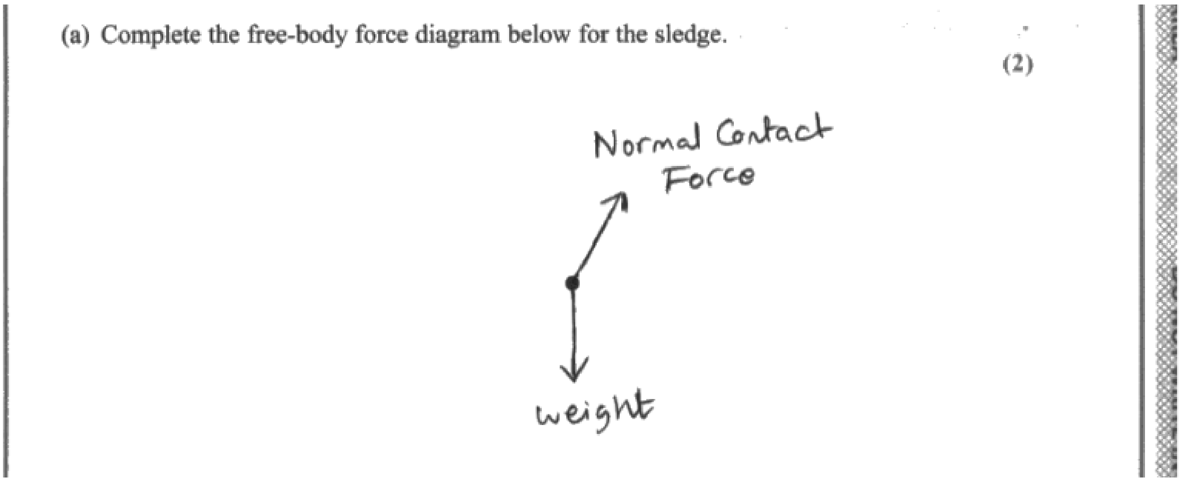
$v = \frac{(10 \times 2.7) - (5.0 \times 7.9)}{2.7}$ 4.63 ms^{-1} backwards.

$v = -4.63\ ms^{-1}$

v = 4.63 ms^{-1}

Question 13(a)

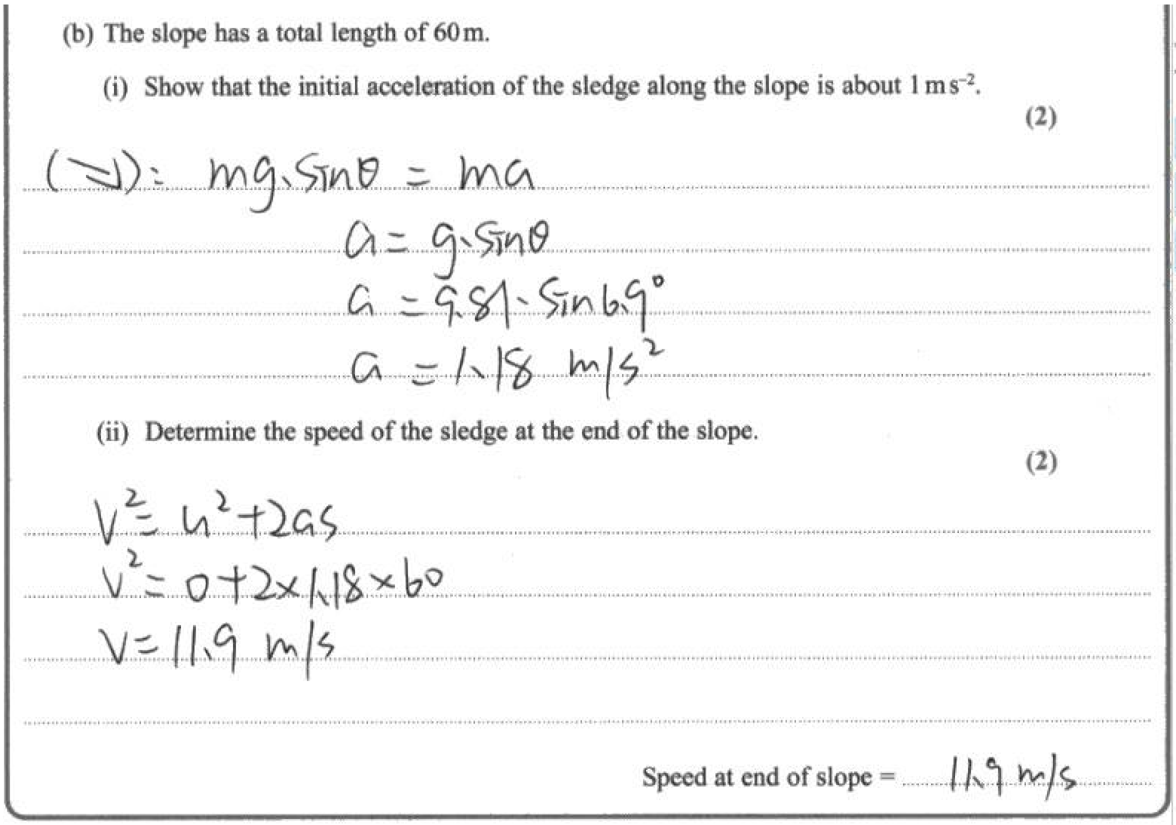
This was generally a well answered question, the most common misconception being that there was a force acting parallel to the plane. Students should understand that if they are told they can ignore friction there should not be any arrow to indicate a frictional force.


(a) Complete the free-body force diagram below for the sledge.

(2)

Question 13(b)

Many were unable to show why the acceleration was the parallel component of the acceleration due to gravity in the absence of any frictional force. However, most were then able to continue to score marks by using the "show that" value in parts (ii) and (iii). Several students persisted in using a = 9.81 m s^{-2} in subsequent parts despite having a "show that" value that they could use, demonstrating a fundamental misunderstanding of the physical situation.


(b) The slope has a total length of 60 m.

(i) Show that the initial acceleration of the sledge along the slope is about 1 m s^{-2}.

(2)

$(\searrow): mg \cdot \sin\theta = ma$

$a = g \cdot \sin\theta$

$a = 9.81 \cdot \sin 6.9°$

$a = 1.18 \text{ m/s}^2$

(ii) Determine the speed of the sledge at the end of the slope.

(2)

$v^2 = u^2 + 2as$

$v^2 = 0 + 2 \times 1.18 \times 60$

$v = 11.9 \text{ m/s}$

Speed at end of slope = 11.9 m/s

(iii) Determine the time taken for the sledge to travel to the end of the slope.

(2)

v=u+at

1.19=0+1.18t

t=10.1 s

Time taken = 10.1 s

Question 14(a)

The definition of limit of proportionality was mostly well answered but many students were unable to gain this mark because there was no sense of this being a *limit* not a single point where the extension is proportional to the force. Many have confused this limit with elastic limit, and a number included definitions of both thus demonstrating that they did not understand the distinction.

(a) State what is meant by the limit of proportionality.

(1)

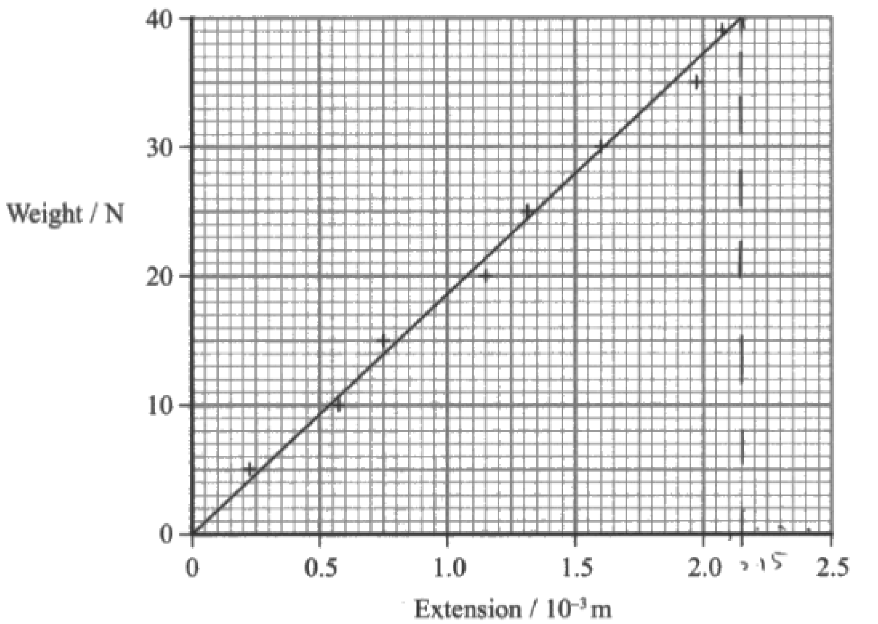
point upto which the material obeys hook's law.

Question 14(b)(i)

Technically, the gradient of a graph is a dimensionless number obtained by dividing the change in the y co-ordinate by the change in the x co-ordinate. In this case the line is straight and passes through the origin, so the whole line may be used to obtain the gradient, gradient = 40 ÷ 2.15 = 18.6. Many students chose arbitrary points along the line and obtained correct answers, but if the points encompassed less than half the drawn line only one mark could be awarded.

Answers where the gradient was expressed as the spring constant, which is the gradient × 10^3 N m^{-1} were also accepted.

(b) The student's graph is shown below.



(i) Determine the gradient of the graph.

(2)

$$\text{gradient} = \frac{\Delta y}{\Delta x} = \frac{40 - 0}{2.15 \times 10^{-3}}$$

$$= 18604.7 \text{ N/m}$$

Question 14(b)(ii)

The task was to use the gradient obtained in part (ii) to get the Young modulus, so some algebraic skill was required to obtain the correct equation. Common errors here included mistakes in calculating the cross-sectional area, power of ten errors and units.

(ii) Determine the Young modulus of stainless steel using your value for the gradient.

(3)

$Y = \frac{FL}{A x}$

$Y = \frac{F}{x} \times \frac{L}{A}$ (gradient)

$Y = \frac{\text{gradient} \times 2.6}{\pi \times \frac{(5.6 \times 10^{-4})^2}{4}}$

$= \frac{18604.7 \times 2.6}{\pi \times \frac{(5.6 \times 10^{-4})^2}{4}}$

$= 1.96 \times 10^{11}$ Pa

Young modulus = 1.96×10^{11} Pa

Question 13(c)

This was a relatively straightforward question that could be answered by a variety of methods which were all regularly seen, calculation of actual stress, maximum load or minimum cross-sectional area. Students were unable to score the final mark for a correct conclusion because they did not explicitly compare their value with the relevant critical value.

(c) The breaking stress for this stainless steel is known to be 480 MPa.

Deduce whether it is safe for the student to increase the weight to 100.0 N.

(3)

When the weight is 100.0 N,

Stress $= \frac{F}{A} = \frac{100.0}{\pi \times (\frac{5.6 \times 10^{-4}}{2})^2} = 4.06 \times 10^8$ Pa

$= 406$ MPa

∵ 406 MPa < 480 MPa

∴ The stress does not exceed the braking stress, so it is safe.

Question 15

In common with responses in some previous series most have attempted to answer this question about forces in terms of energy. There were no marks available for discussions of energy as there was no requirement in the text of the question for any mention of energy. Also, they went on to describe the slowing down of the car *after* the spring had completely decompressed, which was not asked for in the question. To score marks in a linkage question it is imperative that students read the question very carefully, so that they answer the actual question, not simply recite a set narrative.

Explain why the floor exerts a forward force on the car and how this force affects the motion of the car as the spring returns to its original state.

1. Pulling the car backwards along the floor compresses the spring.
so there's a backward force on the floor from the spring in this toy car.
2. Due to Newton's third law, the floor exerts a forward force on the car
3. There's a forward force on the car from the floor.
so there's a forward resultant force in the horizontal direction
4. Due to Newton's second law. $F_R = ma$. so the car accelerates.
5. The spring returns to its original state.
Due to Hooke's law. $F = k\Delta x$
Force decreases with the decrease of extension.
6. So the force on floor decreases. Due to Newton's third law.
Force on car decreases. Resultant force decreases.
7. Due to Newton's second law. $F_R = ma$.
so acceleration decreases. So the car moves faster with a decreasing acceleration

Question 16(a)

This question was generally very well answered. Students were able to resolve the vertical component correctly and apply the correct equation to find the time required for the vertical component to drop to zero. A few candidates also calculated the maximum height achieved but did not carry this through to where it was required for part (b).

(a) Show that the rock would reach its maximum height about 3 s after the explosion.

(3)

R(↑)

$u = 50\sin 40$ m/s

$a = -9.81\text{ms}^{-2}$

$v = 0$ m/s

$t = ?$

$v = u + at$

$0 = 50\sin 40 - 9.81t$

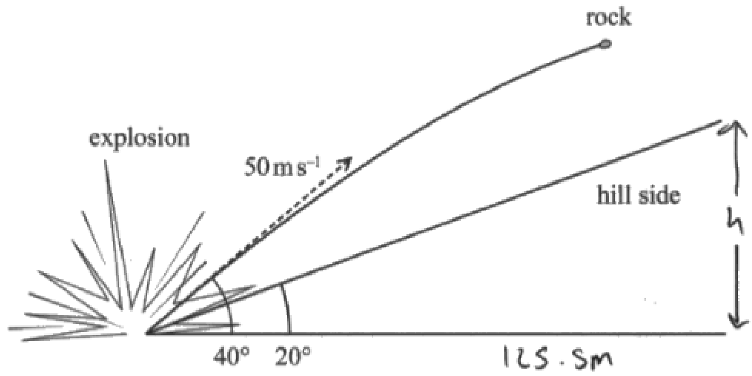
$9.81t = 50\sin 40$

$t = 3.28$ sec

≈ 3 sec

Question 16(b)

There were many correct methods for answering this question, the most common being to compare the height of the hill with the height of the rock at the time of greatest height, though others were often seen. Most scored some marks in this question, many had correct values for relevant quantities but were unable to make proper comparisons when drawing conclusions.



After a certain distance, the rock lands on the side of the hill.

Deduce whether the rock hits the ground before it reaches its maximum possible height.

(6)

R (→)
$u = 50\cos 40$
$t = 3.28s$
$s = ?$
$u = s/t$
$s = ut$
$= (50\cos 40)(3.28)$
$s = 125.49m$
(horizontal distance when maximum height is reached)

$\tan 20 = \frac{h}{125.49}$
$h = 45.67m$ (vertical max height)

R (↑)
$u = 50\sin 40$ m/s
$a = -9.81$ m/s
$v = 0$ m/s
$s = ?$

$v^2 = u^2 + 2as$
$0 = (50\sin 40)^2 + 2(-9.81)(s)$
$19.62s = 1032.94$
$s = 52.6m$

$52.65m > 45.67m$

~~rock has not~~ rock has not hit the ground at maximum height

Question 17(a)(i)

From their attempts to describe laminar flow, many students would clearly be able to recognise it if they saw it, but several were not able to actually to define it. Laminar flow has a precise definition which needs to be learned.

> (i) State what is meant by laminar flow.
> **(1)**
>
> When the flow is steady at a given point the velocity of the particles moving through that point is the same.

Question 17(a)(ii)

Students thought that this question was about the conditions necessary for Stokes' law to apply when it was simply asking for a statement of how Newton's first law applies to this situation. It is not necessary for Stokes' law to apply in order for the speed to be constant, so mentions of small spheres, laminar flow and temperature were all irrelevant.

> (ii) State the condition necessary for the speed of the droplet to be constant.
> **(1)**
>
> The sum of upthrust and viscous drag force acting on the droplet must be equal to it's weight.

Question 17(b)

The first two parts of this question were intended to give students the hint that both weight and upthrust were required for part (iii). Most students had no difficulty with (i), though some stopped when they had calculated the mass rather than the weight, and the most common error in (ii) was to use the wrong density, making the weight equal to the upthrust.

(b) A spherical droplet has a volume of $3.35 \times 10^{-8}\,m^3$.

(i) Calculate the weight of the droplet.

density of water = $1.00 \times 10^3\,kg\,m^{-3}$

(3)

$\rho = \frac{m}{V}$

$1 \times 10^3 = \frac{m}{3.35 \times 10^{-8}}$

$M = 3.35 \times 10^{-5}$

$W = 3.35 \times 10^{-5} \times 9.81$

$W = 3.29 \times 10^{-4}$

Weight of droplet = 3.29×10^{-4} N

In part (iii) there were many marks not scored due to careless rounding or truncation of values from (i) and (ii), but generally students were able to apply Stokes' law correctly. Several students used a set piece formula for the velocity; this is acceptable if correctly done, but a possibly dangerous approach if incorrect quantities (particularly derived values for the drop radius) are substituted.

(ii) Show that the upthrust on the water droplet when it's completely submerged in oil is about 3×10^{-4} N.

density of oil = $0.94 \times 10^3\,\text{kg m}^{-3}$

(2)

$U = \rho g V$

$U = 0.94 \times 10^3 \times 9.81 \times 3.35 \times 10^{-8}$

$U = 3.09 \times 10^{-4}$ N

(iii) Calculate the terminal velocity of this water droplet in the oil.

viscosity of oil = 0.11 Pa s

(4)

$V = \frac{4}{3}\pi r^3$ $\quad r^3 = \frac{V}{\frac{4}{3}\pi}$

$F = 6\pi r \eta v$ $\qquad F = W - U$

~~$2 \times 10^{-5} = 6\pi$~~ $\qquad F = 3.29 \times 10^{-4} - 3.09 \times 10^{-4}$

$r = \sqrt[3]{\frac{V}{\frac{4}{3}\pi}}$ $\qquad F = 2 \times 10^{-5}$

$2 \times 10^{-5} = 6\pi \times (2 \times 10^{-3}) \times 0.11 \times v$

$r = 2 \times 10^{-3}$ $\qquad v = 4.8 \times 10^{-3}$

Terminal velocity = 4.8×10^{-3} ms^{-1}

Question 18(a)(b)

The most common error in this item was attempting to find some component of the weight along the slope. Students who knew the composite formula for power (power = force × velocity) were able to answer this question easily, or else derive the formula from given equations. Part (b) could also be answered with the "show that" value, but a common mistake was to apply the trigonometrical function incorrectly.

(a) Show that the total force that the team exerts on the block is about 14 kN.

(2)

$P = \frac{E}{t} = \frac{Fd}{t} = Fv$

$F = \frac{P}{V} = \frac{6.25 \times 10^3}{0.450} = 13\,888.8\ldots$

$\simeq 13900\,N = 13.9\,kN$ (3SF)

(b) Determine the total work done by the team.

(3)

$W = F \times d$

$= 13.9 \times 10^3 \times \frac{4.35}{\sin 6}$

$= 578\,454.88\ldots$

$\simeq$ ~~580 0~~ $578\,000\,J \simeq 5.78 \times 10^5\,J$

Total work done = $5.78 \times 10^5\,J$

Question 18(c)(d)

Part (c) was well answered as the it was simply to calculate the gain in GPE, though some students attempted to add the KE also, which is not required as the stone is already moving.

The efficiency was nearly always correctly calculated, with the mark being also awarded for correctly substituted errors carried forward. Students are encouraged to be suspicious if they obtain an efficiency of more than 100% and perhaps review their answers looking for their mistake.

(c) Show that the useful work done on the block is about 90 kJ.

(2)

$= 2.10 \times 10^3 \times 9.81 \times 4.35$

$= 89\,614.35 \simeq 89\,600\ J = 89.6\ kJ$ (3SF)

(d) Determine the efficiency of the system.

(2)

eff $= \frac{89.6 \times 10^3}{5.78 \times 10^5} \times 100$

$= 15.5\%$ (3SF)

Efficiency = 15.5%

Question 19(a)

Very many candidates were able to show that the anticlockwise moment due to the wind initially exceeds the clockwise moment due to the weight of the parasol, but it was extremely rare to see the additional point that the overall anticlockwise moment does not decrease with the angle of tilt, but in fact increases, so there is no possibility of the parasol ceasing to topple once it has started.

Marks were also not scored here when students stated a conclusion without explicitly comparing relevant quantities.

Explain why the parasol will topple. Your answer should include a calculation. **(4)**

~~Force~~ moment exerted by weight on the base when it doesn't starts topple is :

$W \times \frac{l}{2}$ = 110N × $\frac{0.44}{2}$ m = 24.2 ~~Nm~~ Nm.

Moment from the wind :

F × L = 14N × 1.8 m = 25.2 Nm.

25.2 Nm > 24.2 Nm

~~So the parasol will topple but not being blowed away.~~ When wind becomes strongle, the distance that ~~force~~ weight acts on base decreases. So ~~it~~ moment will decreases. parasol become topple.

Explain why the parasol will topple. Your answer should include a calculation. **(4)**

↺ moment = 1.8 × 14 = 25.2 > ↻ moment = 0.22 × 110 = 24.2

- it rotates anticlockwise
- ~~As~~ it rotates ↻ moment decreases as ⊥ distance from the pivot decreases.
- it will further rotate until it topples

Question 19(b)

This question was generally well answered, though there were a great many blank answers in this last item. There were several ways to approach the question with most opting to use the horizontal component of the tension. Common mistakes were mostly in the application of trigonometry.

Determine, by taking moments about the centre of the base, the vertical force that the base exerts on the ground.

Assume that the force which the ground exerts on the base acts through the midpoint of the base.

(5)

Anticlockwise moment = 25 × 1.8 = 45 Nm.

Clockwise moment = T sin44° × 1.5 = T1.04 Nm

45 = T × 1.04

T = 43.2 N

Total force = W + T cos 44°

= 110 + 43.2 cos 44°

= 141 N

Force exerted on the ground = 141 N

Concluding Remarks

Many students 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 some students presented, especially in the moments, projectile and Stokes' law questions.

More time spent in reading the details of questions would greatly improve performance, particularly in the extent ended open response question and in the Stokes' law question. Practice in rearranging and combining formulae would also be of great benefit, in this paper particularly in the power question and the Young modulus question.

Students should 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. Ambiguous statements do not score marks, as an examiner cannot be expected to guess which meaning a student intended.

The recommendations for improving student performance remain similar those in previous series, namely:

- Practice in applying principles in a wide variety of different contexts will help build confidence and initiative.
- Encouraging students to spend time in close reading of questions, and in re-reading both question and their answer, will help students avoid ambiguities and contradictions.
- Learning basic definitions, and especially taking care to define quantities used, will avoid students failing to gain credit for concepts they do in fact understand.
- Encouraging students to use calculators correctly, to round answers to three significant figures in the last line only but to carry all significant figures forward from line to line in their calculations. Judicious use of calculator memory can avoid rounding errors.

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