Examiners' Report
Principal Examiner Feedback

January 2021

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

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 students 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, students showed good ability in the more basic applications and simple recall questions 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 **Q13(b)** and the Stokes' Law question **Q18(c)(ii)**.

Explanations of physical phenomena were less well attempted, it was very common for students to miss key mark-bearing points, particular examples being the fireboat question **Q14** where there was a general confusion between Newton's Second and Third laws and in the bungee jumper question **Q15** where students did not for the most part address the question of what was doing the work, as asked for by the question.

A recurring theme in questions where a conclusion needed to be drawn was students not scoring the final mark due to there being no comparison of a correctly calculated result with the condition that it needed to satisfy. This applied particularly **Q13(b)** and **Q18(c)(ii)**.

A problem that is becoming more prominent with modern calculators is the presence of fractions, surds and irrational numbers in final answers. It should be stressed that such answers are not acceptable for a physics question. Physical quantities should always be expressed as decimal numbers with appropriate units if they are to score the final mark.

The standard of English in nearly all papers was very good.

SECTION A

Multi-Choice Items

	Subject	Correct response	Comment
1	Motion equations	**C**	Apply $v^2 = u^2 + 2\,a\,s$ with $v = 0$.
2	Conservation of energy	**C**	Initial GPE minus the final KE.
3	Motion graphs	**D**	The acceleration graph shows the gradient of the velocity graph.
4	Acceleration	**B**	Apply $s = u\,t + \frac{1}{2}\,a\,t^2$ with $u = 0$.
5	Hooke's Law	**C**	Only stiffness is a property of a wire, the others are material properties.
6	Conservation of momentum	**A**	Momentum is a vector quantity and is conserved in a closed system.
7	Determination of viscosity	**C**	Ball bearing needs distance WX to reach terminal velocity before measurement begins.
8	Vectors	**C**	All except momentum are scalar quantities.
9	Newton's 3rd Law	**B**	Third Law pairs do not both act on the same body.
10	Power	**C**	Time required = work done ÷ power.

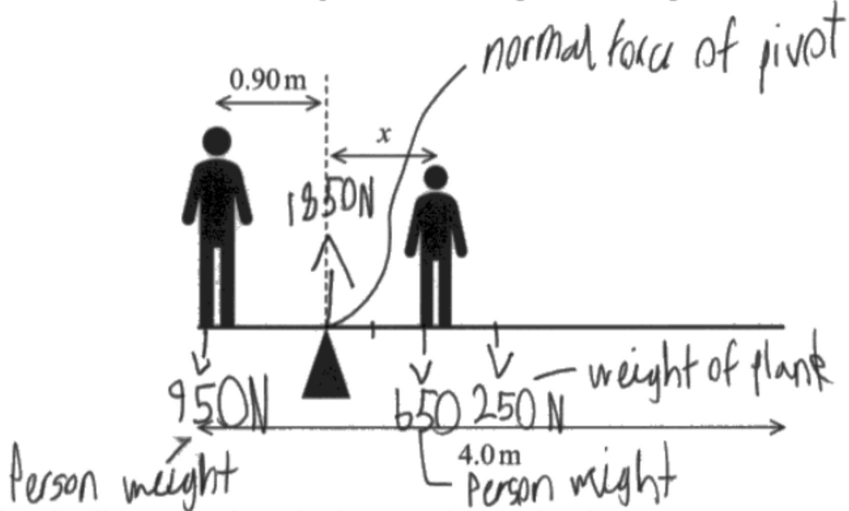
SECTION B

Exemplar items show examples of answers which scored full marks.

Question 11(a)

This question tested a student's knowledge of centres of gravity and reaction forces. Most candidates scored the mark for downward forces, though many placed the position of the centre of gravity too far to the right. Fewer students realised that an upward force is also required, and that this acts at the position of the pivot.

11 A uniform plank of length 4.0 m is pivoted 0.90 m from one end. The weight of the plank is 250 N. A person of weight 950 N stands at one end of the plank. A person of weight 650 N stands a distance x from the pivot so that the plank is in equilibrium, as shown.



(a) Add to the diagram to show the forces acting on the plank.

Question 11(b)

This was a standard turning moments problem for which all students should be able to score some marks. Most were able to correctly calculate a turning moment, but a significant number did not find the distance to the centre of gravity correctly. The final mark was for correctly re-arranging the equation to find x, which most students who had set up the correct equation were able to do. A clearly labelled sketch, with distances marked on, would greatly aid students with visualising and extracting the correct equation for this problem.

(b) Calculate the distance x.

(3)

Clockwise moments = Anticlockwise moments

moment = F×d Taking moments from the pivot.

$(250N \times 1.1m) + (650 \times x) = (950 \times 0.9)$

$650x = 580$

$x = 0.892m$

$x =$ 0.89m

Question 12(a)
Question 12(b)

This was generally a very well answered question, with a significant number of students scoring full marks. The principal cause of error in part (a) was confusion over vertical height resulting in either the wrong gain in GPE for Method #1 or the wrong force for Method #2. Students could still gain full marks in part (b) by use of the "show that" value, though common mistakes were either forgetting to multiply the weight of the average person by 15, or multiplying rather than dividing by the efficiency (or both).

(a) A single passenger of mass 72 kg stands on the walkway.
The speed of the walkway is $0.51\,\text{m}\,\text{s}^{-1}$.

Show that the rate at which the walkway does work on the passenger is about 200 W.

(3)

Work done = force x distance

$72 \times 9.81 = 706.32$

$706.32 \sin 30° \times 0.51$

$= \underline{180.11\ \text{W}}$

(b) The walkway system has an efficiency of 78%.

Calculate the power input to the system when 15 passengers of average mass 72 kg are standing on the walkway.

(3)

$$\frac{200 \times 15}{\text{input}} = 0.78$$

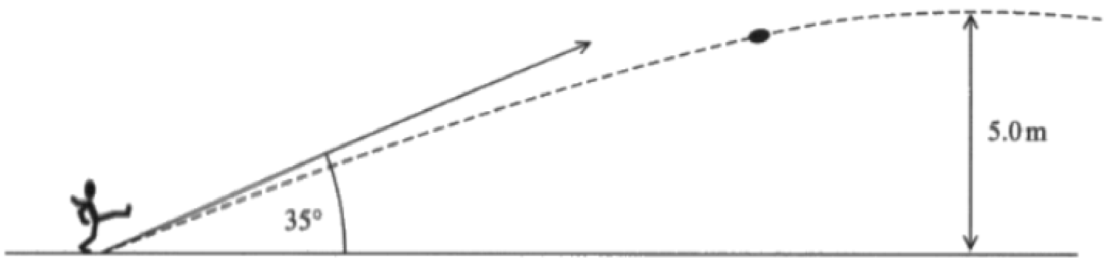
$$\frac{3000}{x} = 0.78$$

$x = 3846.153846 \approx 3846\ \text{W}$

Power input = 3846 W

Question 13(a)
Question 13(b)

This was a straightforward projectiles question that tested resolution of velocity and kinematics in part (a) and an application in part (b). The first part was generally well done, those who successfully worked out the vertical component generally scoring the other marks unless they misapplied the trigonometry. The second part lent itself to a variety of approaches, but students should remember that calculating the time to maximum height and doubling it only works for a projectile that returns to its initial height. A significant number of students scored full marks in this question. The final marking point was to make a comparison of correctly calculated values, which many good students forgot to do.



(a) Show that the initial speed of the ball is about 17 m s^{-1}.

(3)

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

~~5.0ms~~ $v^2 = u^2 + 2as$

$0 = u^2 - 2 \times 9.81\,ms^{-2} \cdot 5m$

$u = 9.9\,ms^{-1}$

speed $= \dfrac{9.9\,ms^{-1}}{\sin 35°} = 17.3\,ms^{-1}$

To score, the ball must be more than 3.00 m above the ground when it reaches the goal.

Deduce whether an initial speed of 17.0 m s^{-1} is sufficient to score.

(5)

Time for travelling 22m horizontally: $\cancel{t = \frac{s}{v} = \frac{22}{17.3\cos 35} = 1.55s}$

$t = \frac{s}{v} = \cancel{\frac{22}{17\cos 35} = 1.29s}\ \frac{22}{17\cos 35°} = 1.58\,s$

Vertical distance from the ground when 22m reached:

$s = ut + \frac{1}{2}at^2 = \cancel{35\ldots}\ \cancel{17\sin 35^2 \ldots}\ \cancel{17\sin 35° \times 1.29 - \frac{1}{2} \times g \times 1.29^2}$

$= \cancel{4.42m}\ 17\sin 35 \times 1.58 - \frac{1}{2}g \times 1.58^2 = 3.16m$

~~3.16 > 3 4.42 > 3, hence 17ms⁻¹ is sufficient to score~~

3.16 > 3, hence 17ms^{-1} is sufficient to score

Question 14(a)(i)
Question 14(a)(ii)

The first of these two questions tested a student's ability to use density and volume considerations to translate a mass flow into a velocity. Most candidates were able to calculate the volume flow rate, but then use of the correct volume formula for a cylinder did not always follow, with typical errors being use of diameter instead of radius and the sphere formula (!).

The second part was generally answered well, but there were too many answers with units of kg m s^{-1} instead of the correct kg m s^{-2}, which, being a rate of change of momentum, is also a force, so N is also correct.

A significant number of students scored zero in these two items.

(a) The mass of seawater pumped each second is 300 kg. The pipe has a diameter of 10.0 cm.

density of seawater = $1030\,kg\,m^{-3}$

(i) Show that the speed at which the seawater is projected from the pipe is about $37\,m\,s^{-1}$.

(4)

as $\rho = \frac{m}{V}$, $V = \frac{m}{\rho} = \frac{300\,kg\,s^{-1}}{1030\,kg\,m^{-3}} = 0.291\,m^3\,s^{-1}$

$A = \frac{1}{4}\pi d^2 = \frac{1}{4}\cdot\pi\cdot(10\times10^{-2})^2 = 0.00785\,m^2$

$v_{(projected)} = \frac{V}{A} = \frac{0.291\,m^3}{0.00785\,m^2} = 37.0846\,m/s = \cancel{37\,m/s}$ 37 m

Because it's projected per second.

$v = \frac{s}{t} = 37\,m/s$

(ii) Determine the rate at which the momentum of the seawater is changed by the pump. You may assume that the seawater is initially stationary.

(2)

momentum = mv

$p = 300 \times 37 = 11100\,kg\,m\,s^{-1}$

Rate of change of momentum = $11100\,kg\,m\,s^{-1}$

Question 14(b)

Newton's Third Law is about two forces, so both forces needed to be clearly identified to score both marks for this question. It was more usual for a candidate to score the second marking point for giving a clear direction of the reaction force and citing the Third Law, but far fewer identified the force of the pump on the water, which is the other of the pair.

(b) Projecting water from the pipe causes a force to be exerted on the pump.

Explain the direction of the force on the pump.

(2)

The pump exerts ~~[illegible]~~ force on the water and due to N3L the water exerts an equal and opposite force on the pump. Thus the direction of the force on the pump will have exactly the opposite direction of the direction of the force exerted on the water.

Question 14(c)

This was a question about Newton's Second Law, and it was clear that many students thought that they needed to continue talking about the Third Law. The item scored particularly poorly, principally due to students not reading the question carefully enough. Although most students understood the idea of balanced forces few gave a satisfactory answer to the actual question. All three horizontal forces play a role in explaining why the new constant speed is lower than the initial constant speed, and the process in between involves a resultant backward force, slowing the boat, and thus reducing the drag force. Many students did not mention any resultant force, others talked about a reduced driving force or reducing the acceleration. This question proved to be the least well answered in the whole paper.

(c) Initially the pump is turned off and the fireboat moves forwards through the water at a constant speed. The boat's engine provides a constant forward force.

When the pump is turned on, water is projected forwards and the fireboat slows to a lower constant speed.

Explain why the boat now has a lower constant speed.
Your answer should refer to all the horizontal forces on the boat.

(3)

By N3, there is a backward force when the pump is on.
Initially, the forward force is equil to the viscous drag.
Then, as viscous drag + backforce > forward force, the resultant force is backward and the boat decelerates.
As viscous drag decreases as velocity falls, a new ~~[illegible]~~ balance is reached at lower velocity ~~[illegible]~~, which apply Drag + Backward force = forward force.

Question 15

This was an example where those who addressed the actual question scored well, and many simply gave a GCSE level answer in term of energy stores. The question was about work done by what and on what. Ultimately all the work is done *on* the bungee *by* the weight of the jumper (the force of gravity). In the initial stages this work accelerates the jumper increasing the KE, but in the last stage the work done on the bungee includes all the work initially done to increase the KE, reducing the KE to zero. A common mistake made by many who provided good answers was to say that work was done *by* the bungee in decelerating the jumper. Marks gained in this question were generally just for correctly describing the flood and ebb of KE. Many candidates seemed to think this was a terminal velocity question.

Explain, in terms of work done, how the kinetic energy of the bungee jumper changes during the three stages of the fall.

(6)

Stage 1. ~~the~~ The kinetic energy increases. ~~as the grav~~ ~~gravitational~~ ~~potential energy is transferred into kinetic energy~~. The work done by the weight ~~decreases~~ transfers ~~to~~ Egrav to Ek.

Stage 2. The kinetic energy continues to increase to a maximum at a decreasing rate. The work done by the resultant force, Weight − tension. ~~The gravitational potential energy is transfered into kinetic~~ transfers Egrav to Ek and Eel.

State 3. The kinetic energy decreases to 0. as the speed reduces to zero. The work done by the resultant force, tension − weight. transferr Egrav and Ek to Eel.

Question 16(a)

Most students knew that a micrometer is the correct instrument for this application, and a few also correctly identified *digital* callipers. Vernier callipers do not have sufficient accuracy to read to the quoted precision, so that answer was not accepted. A few were still suggesting rulers or metre rules, sadly.

16 A steadily increasing tensile force was applied to a sample of a titanium alloy.

The sample had an original length of 40.0 cm and diameter of 5.05 mm.

(a) State a suitable measuring instrument to measure the diameter of the sample.

(1)

Micrometer Screw gauge.

Question 16(b)(i)

This was a standard question involving measuring the gradient of the straight section of the graph. Most successful attempts used an acceptable section of the line, or a tangent drawn at the origin. Students should make sure that they can measure quantities on graphs to at least a precision of half a millimetre to be sure of an answer inside an acceptable tolerance. A number of students thought that dividing the stress by the strain at point B would give the Young Modulus, sadly. Students should be reminded that a unit is required for a Young modulus.

(i) Determine the Young modulus of the sample.

(3)

E = gradient

$= \cancel{800}$

$$\frac{(600-0.0)\times10^{6}}{(0.005)}$$

$= 1.2\times10^{11}$ Pa

Young modulus =

Question 16(b)(ii)

This question required the student to calculate the cross-section and multiply it be the stress. Most students were able to do this successfully, the most usual errors being slips in calculation or a wrong formula for cross-section. The breaking stress was usually read from the graph correctly.

(ii) The sample broke at point B.

Determine the force required to break the sample.

(4)

$\sigma = F/A$

$F = \sigma \times A$

$\sigma \times \pi (d/2)^2$

$$F = (1290\times10^{6}) \times \pi \left(\frac{5.05\times10^{-3}}{2}\right)^2$$

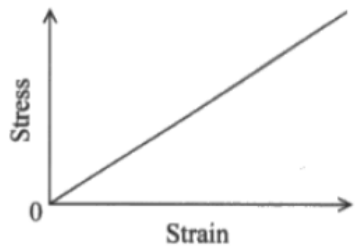
$F = 25838$ N

Force = 2.58×10^{4} N

Question 16 (b)(iii)

This question required the student to show what was represented by the area under the graph, so an initial statement of how to calculate the area was required, followed by substitution using physics formulae that are given on the formula sheet and the formula for volume. A common mistake was to simply ignore the factor of a half, rather than show where it comes from. Many students attempted an argument in terms of dimensions or units, which was not accepted. A significant number of students scored no marks for this item.

(iii) The graph below shows a linear section of the stress-strain graph for the sample.



Show that the area under this graph represents the work done per unit volume in stretching the sample.

Area = ½ × Stress × Strain **(3)**

Workdone

$\cancel{E_{el}} = \frac{1}{2} F \Delta x$, $\frac{1}{2} \times \sigma \times \varepsilon$

$W = \frac{1}{2} F \Delta x$ Area $= \frac{1}{2} \times \frac{F}{A} \times \frac{\Delta x}{x}$

$F = \frac{2W}{\Delta x}$ Area $= \frac{1}{\cancel{2}} \times \frac{\frac{\cancel{2}W}{\cancel{\Delta x}} \times \cancel{\Delta x}}{Ax}$

Area $= \frac{W}{Ax} = \frac{W}{V} = \frac{\text{Workdone}}{\text{Volum}}$

Question 16(b)(iv)

The simplest way to answer this question is to get on and count squares without wasting time trying to find shortcuts, but first decide which size square to use and determine the number of J m^{-3} it represents. There were a huge number of different approaches deployed in this question, with large numbers of students providing long complex calculations involving trapezia, and other shapes, very difficult for examiners to follow. There were also a number of short-cut methods that seem to have been taught, sometimes giving correct answers, and other times not. The hint given in part (iii) that the result needed to be multiplied by the volume was lost on many students. The number of correct answers to this question was disappointingly low.

(iv) The area under any stress-strain graph represents the work done per unit volume.

Estimate the amount of work required to break the titanium alloy sample.

(4)

Workdone (per volume) $= \frac{1}{2} F \Delta x =$ Area under the graph

$= \frac{1}{2} \times 0.01 \times 1000 \times 10^6 + \left[(1000+1200) \times 0.01 \times \frac{1}{2}\right] \times 10^6 + 0.035 \times 1280 \times 10^6$

$= 6.08 \times 10^7$ J / ~~vol~~ m^3.

volume $= A \times X = \pi (5.05 \div 2 \div 1000)^2 \times 40 \div 100$

$\approx 8.01 \times 10^{-6}$ m^3

$\therefore$ workdone $= 6.08 \times 10^7 \times 8.01 \times 10^{-6} = 487$ J.

Work = 487 J

Question 17(a)
Question 17(b)

Part (a) was generally answered well, being a simple Hooke's Law problem. In "show that" questions it is important that students show the numbers substituted into the formula rather than just quoting the equation. Part (b) was also generally well answered, those who got to the correct value of the force were generally able to gain the final four marks. For those who did not, the difficulty was in the application of trigonometry.

(a) The force meter allows force to be measured by means of Hooke's law.

The extension of the spring inside the force meter allows the stretching force to be read from a scale.

When the force applied to stretch the spring is 15 N the extension of the spring is 8.0 cm.

Show that the stiffness of the spring is about 2 N cm^{-1}.

(2)

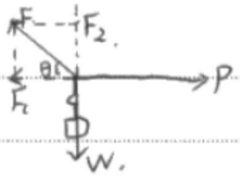
$k = \frac{F}{\Delta x} = \frac{15N}{8cm} = 1.875 N\cdot cm^{-1}$

(b) When m is equal to 0.55 kg, the value of P is 8.5 N.

Calculate the value of θ, and the extension of the spring in the force meter.

(6)

the free-body diagram:



so the $F_1 = \cos\theta \cdot F = P = 8.5N$.

$F_2 = \sin\theta \cdot F = W = mg = 0.55kg \cdot 9.81 N kg^{-1} = 5.3955N$.

so $\frac{F_2}{F_1} = \frac{\sin\theta \cdot F}{\cos\theta \cdot F} = \tan\theta = \frac{5.3955N}{8.5N} \approx 0.6348$

$\theta \approx 32.4°$.

because $\cos\theta \cdot F = 8.5N$.

so $F = \frac{8.5N}{\cos\theta} \approx 10.07N$.

extension $= \frac{F}{\text{stiffness}} = \frac{10.07N}{1.875N\,cm^{-1}} \approx 5.37cm$

θ = 32.4°

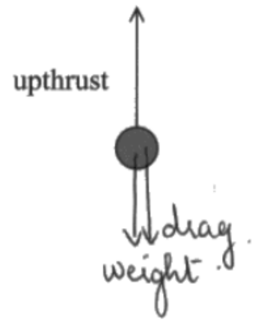
Extension of the spring = ~~8.0~~ 5.37cm

Question 18(a)

This question assessed a student's knowledge of the direction of a drag force, which is always opposite to the direction of motion. Many students did not read the question carefully enough to realise that the motion was upwards and that therefore the drag force acts downwards. Nearly all had the weight acting downwards, so this question scored relatively well.

(a) Complete the free body force diagram below to show all the forces acting on the polystyrene bead.

(2)



Question 18(b)
Question 18(c)(i)
Question 18(c)(ii)

There was a very even spread of marks across these three questions. Part (a) was a very straight-forward application of Archimedes' Principle and most students were able to gain marks here. The second part was surprisingly badly done, with more than half failing to remember that Stokes' Law only applies for non-turbulent (laminar) flow. The final part was well-answered by many students, most of whom could calculate v_R correctly from the given formula. The main confusion of this part was the value of the drag force, which had to be calculated from the difference in the weight and the upthrust. Marks were lost by students comparing incorrect velocities, and, as always, by the failure to show an explicit comparison between the required value and the actual value.

(b) Show that the upthrust the oil exerts on the bead is about 3.1×10^{-4} N.

density of oil = 930 kg m^{-3}

(3)

upthrust = $\rho_l V g$

$= 930 \times \frac{4}{3}\pi\left(\frac{4\times10^{-3}}{2}\right)^3 \times 9.81$

upthrust = 3.057×10^{-4}

(c) Stokes' law shows how the viscous drag on a sphere is related to its velocity through a fluid.

Stokes' law is only valid if the bead is moving sufficiently slowly through the oil.

(i) State the reason for this condition.

(1)

Stokes' law can only be used in laminar flow, and laminar flow requaired slow speed.

(ii) For Stokes' law to be valid the speed of the bead through the oil must be less than v_R, where

$$v_R = \frac{10 \times \text{viscosity of oil}}{\text{density of oil} \times \text{diameter of the bead}}$$

Deduce whether Stokes' law can be applied to this bead.

viscosity of oil = 4.90×10^{-2} Pa s
weight of polystyrene bead = 1.05×10^{-5} N

(5)

$$V_R = \frac{10 \times 4.9 \times 10^{-2}}{930 \times \cancel{0}4 \times 10^{-3}}$$

$= 0.13\ ms^{-1}$

$F = 6\pi\eta vr$

$F = \cancel{1.05 \times 10^{-5}}\ 3.06 \times 10^{-4} - (1.05 \times 10^{-5}) = 2.96 \times 10^{-4}$ N

$2.96 \times 10^{-4} = 6\pi \times 4.9 \times 10^{-2} \times \cancel{6}V \times \frac{4}{2} \times 10^{-3}$

$V = 0.16\ ms^{-1}$

$0.16 > 0.13$

$\Rightarrow$ Stokes law can not be applied.

Conclusion

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 momentum, projectile and Stokes' Law questions.

Greater familiarity with the core experiments would be beneficial to students as these contexts will occur frequently in examinations. Practice in obtaining gradients and areas of graphs, and in justifying experimental procedures would give students more confidence in giving correct answers.

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 to those in previous series, namely:

- Time spent in performing, as well as describing and writing up, core practicals will benefit recall in an examination.
- 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.