2011 Physics GA 1: Written examination 1

GENERAL COMMENTS

The number of students who sat for the 2011 Physics exam 1 was 7012. The mean score was 57 per cent, which corresponded to the middle of the C^+ grade range. The majority of students completed Detailed Study 2.

Students should be aware of the following general information.

- Students need to be more careful with their handwriting. If the assessor cannot decipher what is written, no marks can be awarded.
- Written explanations must address the question asked. Students who copy generic answers from their A4 sheets of pre-written notes will not attain full marks.
- Students should show their working. Credit can be given for working even if the final answer is incorrect.
- Students must follow the instructions given in questions. Some questions specifically require working to be shown; if this is not done, full marks cannot be obtained.
- It is expected that formulas are copied correctly from the data sheet provided with the examination or from the student's A4 sheet of pre-written notes.
- Attempting a question a number of different ways will reduce the marks awarded unless all methods are correct. Students should make their intended working clear by crossing out the rest.

Particular areas of concern in this paper were:

- circular motion on inclined planes
- more complex projectile questions
- questions requiring application and understanding of Newton's laws
- questions exploring the cause and derivation of apparent weight
- springs and energy conversions
- the formation and basic analysis of series and parallel circuits
- light intensity modulation
- clipping of an electrical signal
- simple mathematical operations and manipulation of numbers presented in scientific notation.

SPECIFIC INFORMATION

For each question, an outline answer (or answers) is provided. In some cases the answer given is not the only answer that could have been awarded marks.

Section A – Core
Area of Study 1 – Motion in one and two dimensions

Question 1

Marks	0	1	Average
%	9	91	0.9

This question was extremely well done, with students competently applying Newton's second law to find the net force on the system, which was 1250 N.

Errors included using an incorrect mass or transcribing the 0.5 m s^{-2} acceleration as 0.5, which was then read as 5 and gave an incorrect answer of 12 500 N.

Question 2

Marks	0	1	2	Average
%	45	3	52	1.1

With tension being the only force acting on the trailer, most students were able to utilise Newton's second law to derive a tension of 1000 N.

Question 3

Marks	0	1	2	Average
%	20	2	77	**1.6**

Most students were able to correctly apply an equation for constant acceleration to calculate the distance of 6.25 m.

The main error with this question was incorrect mathematical processing.

Question 4

Marks	0	1	Average
%	16	84	**0.9**

Most students were able to correctly substitute data into the formula $F_{net} = \frac{mv^2}{r}$ to calculate the net force as 3375 N.

Some students incorrectly included the weight force (mg) in their calculations. Failing to square the speed was a common error.

Question 5

Marks	0	1	2	Average
%	33	35	33	**1**

Students needed to draw a horizontal arrow pointing to the left, indicating the direction of the net force. Students needed to describe how this net force resulted from either the direct addition of the two given forces (R and mg) or from the addition of any components of these two forces.

Many students knew that the net force should be towards the centre of the bike's circular motion but were unsure as to where that central position was. Many students drew arrows that were not horizontal.

Many students applied linear inclined plane equations (for example, F_{net}= mgsinθ), which was inappropriate in this setting. The actual force component providing the centripetal acceleration was Rsinθ, which some students impressively stated. A high-scoring response needed to indicate that the vertical component of R was equal in magnitude to the weight force, mg, resulting in the net force being equal to the horizontal component of the reaction force, R.

Question 6

Marks	0	1	2	Average
%	34	4	62	**1.3**

Many students were able to use either $\tan\theta = \frac{v^2}{gr}$ or $\tan\theta = \frac{F_{net}}{mg}$, resulting in a correct calculation of 48.4° as the angle of inclination of the banked track. Sine or cosine formulas were also sometimes used successfully once the vector addition (F_{net} = R + mg) was drawn as a triangle.

The most common errors made by students were to use trigonometric formulas with the incorrect magnitudes (effectively getting fractions upside down) or using incorrect sides of the triangle.

Question 7

Marks	0	1	2	Average
%	35	22	43	**1.1**

The required answer was 1.5 N accompanied by an explanation with correct references to Newton's second or third law.

Newton's second law: $\boldsymbol{F_{net\ on\ B}} = \mathbf{mg_B} + \boldsymbol{F_{A\ on\ B}} + \boldsymbol{F_{C\ on\ B}} = 0$. Therefore: $-1.0 + (-0.5) + F_{C\ on\ B} = 0$, $F_{C\ on\ B} = +1.5$ N.
Newton's third law: $\boldsymbol{F_{B\ on\ C}} = \boldsymbol{-F_{C\ on\ B}}$ but the force of B on C is due to the weight of both A and B, which is 1.5 N.

This proved to be one of the most difficult questions on the paper. Many students utilised Newton's third law but gave an answer of 1.0 N, implying that the interaction of forces between B and C was largely due to the weight of B alone. For future reference, teachers and students could do well to refer to this question as a good example of analysing the forces in a more complex system.

Question 8

Marks	0	1	2	Average
%	37	26	37	1

The required answer was 0 N, accompanied by an explanation of the physics involved, and extending beyond simple reference to terms such as 'freefall' or 'apparent weightlessness'.

Students were expected to explain that both blocks were accelerating at 10 (or 9.8) m s^{-2} and that there were subsequently no contact or reaction forces, or since the net force acting on C is equal to its weight force, there is no force by C on B in this situation.

Some students believed that the force by C on B remained the same as in Question 7. Many knew that the force had no magnitude in this case but couldn't adequately explain why. Many students struggled with this question.

Question 9

Marks	0	1	2	Average
%	26	1	73	1.5

This question was generally well understood and handled. Many students were prepared with the formula $v = \sqrt{gr}$ and easily calculated the minimum speed of 12.25 m s^{-1}. Alternatively, this could be found by understanding that at position A, the weight of the car and the normal reaction force acting on it both contribute to providing the necessary centripetal force: $N + mg = \frac{mv^2}{r}$. At the minimum speed, the normal reaction force would have no magnitude and the formulas can be transposed to provide the aforementioned speed formula.

Quite a few students were under the misapprehension that a speed of zero would allow the car to continue in its motion. Many students incorrectly used a 'conservation of energy' approach ($mgh = ½ mv^2$).

Question 10

Marks	0	1	2	Average
%	37	31	33	1

Melanie's apparent weight at position A was zero. This is because at position A with the car travelling at the predetermined minimum speed, the required centripetal force was completely provided by gravity as the weight force. There is no 'normal' reaction force acting on the car in this situation. This is the case for both the track pushing against the car and also for the car seat pushing against Melanie. Hence, her apparent weight is equal to zero.

The numeric part of this question was reasonably well done. Many students correctly placed a zero in the box but had difficulty explaining their answer beyond the statement 'N = 0'. Some students placed a number in the box but gave no explanation. Many students incorrectly stated that the net force on Melanie was zero at this position. A common incorrect answer was 600 N, which was the magnitude of the weight force and often resulted from this $F_{net} = 0$ thinking.

Question 11

Marks	0	1	2	3	Average
%	36	12	2	51	1.7

Well-prepared students attained full marks, while others did not perform well. Working was required and most students efficiently showed that at the bottom of the loop (position B) the resultant force must be upwards, in the same direction as the 'normal' surface reaction force giving rise to the formula: $\frac{mv^2}{r} = N - mg$. Substitutions could be made and the equation transposed to correctly give: $N = \frac{mv^2}{r} + mg = 121 + 600$ which was the required calculation for an apparent weight of 721 N.

Almost all students derived some value for the apparent weight from calculations that had involved the numbers 600, 60 and 121, with many students suffering from a lack of clear understanding of the uneven 'balance of forces' at the bottom of such a loop. Some students forgot to square the speed, resulting in an answer of 622 after adding the weight.

Question 12

Marks	0	1	2	Average
%	26	12	62	**1.4**

The correct answer was approximately 2.9 s, and this could have been achieved using a number of methods. For example, with the projectile path being symmetrical, the total time could be directly found using:

$$t = \frac{2u\sin\theta}{g} = \frac{2\times 24\times \sin 37^{\circ}}{10} = 2.89\ s$$

Alternatively, the time to get to the peak could be found by addressing the vertical motion and using:
v = u + a t = 24sin37° + (–10)t = 14.44 – 10 t = 1.44 s, which could then be doubled to get 2.88 s.

Another method could have been finding the horizontal range as: range = (u^2sin2θ) ÷ g = 55.4 m, and the horizontal velocity as 24cos37° = 19.2 m s^{-1}, and combining them to give: t = 55.4 ÷ 19.2 = 2.89 s.

Although this question was reasonably well done by most students, other students calculated the wrong time. Reversing the initial speed and the angle of inclination to derive 37sin24° or 37cos24° was common and indicated a need for students to take greater care. Many students used the horizontal speed component (24cos37°) when they should have used the initial vertical speed component. Many students using the second of the three detailed methods neglected to double the (upward or downward) time for the total time. It was also common in Questions 12 and 13 for students to incorrectly use projectile motion formulas such as for the total time or maximum height. Students must ensure that formulas on their A4 sheets of pre-written notes are correct, and that they are transferred correctly in exam responses.

Question 13

Marks	0	1	2	Average
%	32	4	63	**1.3**

There were as many as five alternative methods to find the correct maximum height of approximately 10.4 m. Four of these methods involved 'constant acceleration equations', and the fifth used the formula: h = ($u^2\sin^2$θ) ÷ 2g. This caused problems for some students who either forgot to square the initial velocity or the value for sin37°.

Three of the possible methods involved the student using their time from Question 12, which made for some complicated calculations. Another common error was to forget that the initial vertical velocity component and the acceleration due to gravity were in opposite directions. This led to an incorrect response of 31.2 m.

Question 14

Marks	0	1	2	Average
%	30	3	67	**1.4**

There were a number of ways to respond to this question. Most simply, the increase in the kinetic energy of Fred and his sled needed to be equated to the loss of gravitational potential energy so that the speed (16 m s^{-1}) could be primarily found, or the momentum of 960 kg m s^{-1} could be found directly from the kinetic energy.

This question was well handled, with few students making calculation errors.

Question 15

Marks	0	1	2	Average
%	35	2	62	**1.3**

This question was handled well. Students used a variety of methods that resulted in the correct magnitude of the friction force being 160 N, including:

- calculating the frictional force as equal to the rate of change of momentum: 960 ÷ 6 = 160
- finding the acceleration (–2.67 m s^{-2}) and using Newton's second law effectively: 60 × 2.67 = 160
- equating the decrease in kinetic energy as work done, and hence the frictional force = ΔEk ÷ d = 7680 ÷ 48 = 160.

Some students made calculation errors.

Question 16

Marks	0	1	2	Average
%	36	16	48	1.1

The spring constant was 33 N m^{-1}, which most students were able to attain. Some students used the wrong spring extension. This question highlighted the inability of many students to remember to convert from centimetres to metres prior to using Hooke's law.

Question 17

Marks	0	1	Average
%	58	42	0.4

The correct answer was graph D. As it oscillates, the spring will be fastest at its rest position (total length = 70 cm) when the strain potential energy is at a minimum. Therefore, the kinetic energy will increase and then decrease as the spring oscillates.

Question 18

Marks	0	1	Average
%	35	65	0.7

The correct answer was graph C. The total energy of the system remains constant as it is considered as an isolated system. Students performed better on this question than on Questions 17 or 19.

Question 19

Marks	0	1	Average
%	54	46	0.5

The correct answer was graph B. The gravitational potential energy varies directly with the length of the spring (U_g = mgh), and the stem information indicated that the gravitational potential energy was to be measured from the 80 cm length shown in the diagram.

Question 20

Marks	0	1	2	3	Average
%	55	23	14	8	0.8

The correct answer was graph F. With the spring (strain) potential energy being proportional to x^2, the shape of the graph was parabolic. With the total length between 60 cm and 80 cm, the spring (strain) potential energy should never be zero and the strain energy should 'approach' zero as the total length decreases approaching 40 cm. Furthermore, the spring (strain) potential energy should be less at 60 cm length than at 80 cm length.

Many students did not attain any marks for this question. Some students seemed to believe that the spring did not carry strain energy when it had a total length of 70 cm, favouring graph E. Many students showed some understanding of the proportionality of strain energy with spring length, favouring graphs G or H.

Question 21

Marks	0	1	Average
%	26	74	0.8

Students had few difficulties with this question, with the majority providing the correct answer of 10 N kg^{-1} – the same gravitational field strength as on Earth, since the person's weight was the same. Some students calculated the value for *g* and others made an error in their calculations.

Question 22

Marks	0	1	2	Average
%	40	19	41	1

The majority of students were able to transpose the formula $g = \frac{GM}{r^2}$ to $M = \frac{gr^2}{G}$ and substitute values successfully to calculate the planet's mass as 1.35×10^{20} kg. Many students incorrectly used a planet radius of 30 m instead of 30 000 m or neglected to square the radius.

Question 23

Marks	0	1	2	Average
%	47	12	40	1

The correct period of orbit was 3.22×10^6 s.

This proved to be a difficult question for some students. The majority of students were able to transpose other formulas or state the appropriate formula for the orbital period: $T = \sqrt{\frac{4\pi^2 R^3}{GM}}$; however, many students then made substitution or calculation errors. It seemed that many students were not clear about which mass or orbital period to substitute into the formula.

Area of Study 2 – Electronics and photonics

Question 1

Marks	0	1	2	Average
%	32	5	63	1.3

The most appropriate method was to find $R_C + R_D = 4\ \Omega$ which connected in parallel with R_B results in an equivalent resistance of 1.3 Ω. This, added to the 2 Ω of resistor A, resulted in a total resistance of 3.3 Ω.

Many students coped well with this question, while others seemed to struggle with the fundamental concept of finding the total resistance of a simple circuit. Many students seemed to think that three of the resistors were in parallel with each other.

Question 2

Marks	0	1	2	Average
%	38	26	36	1

Most students were able to establish that the total current in the circuit was 3 A (3.03 A), but then had difficulty seeing how the current then divided. R_B presented half the resistance of the ($R_C + R_D$) branch, causing the current to divide in a 2:1 ratio. Hence the current through resistor B was 2 A (2.02 A).

Question 3

Marks	0	1	2	Average
%	38	1	61	1.3

There were a couple of ways that this question could have been answered. With many students having previously calculated the total current through the circuit, which all passed through resistor A, they then used Ohm's Law to find that the voltage across A was approximately 6.0 V. Some students successfully used a voltage divider approach.

Question 4

Marks	0	1	2	Average
%	67	4	28	0.6

This proved to be one of the more difficult questions on the exam. Students needed to have a quantitative understanding of (at least part of) the circuit. Essentially, students needed to know the current through D (1.0 A) or the voltage across D (2.0 V) before using a formula for power to find the power dissipated in resistor D to be 2.0 W.

Many students had trouble getting started, which highlighted the need for more time to be spent on basic circuitry. Some students 'round off' numbers too early, resulting in errors in the final answer.

Question 5

Marks	0	1	Average
%	3	97	1

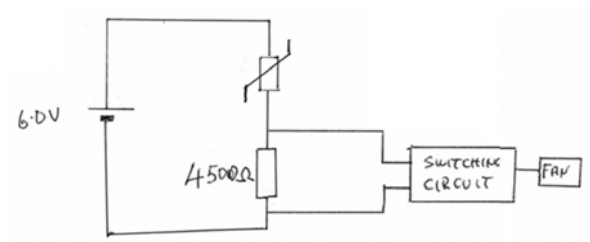
Resistance of 1500 Ω.

Question 6

Marks	0	1	2	3	Average
%	21	40	11	29	1.5

At 20°C the resistance of the thermistor is 1500 Ω. For the resistor to have 4.5 V across it in a voltage divider situation, it would need to have a resistance of 4500 Ω so the ratio of voltage to resistance is the same for both the resistor and the thermistor; i.e. current = (4.5 ÷ 4500) = (1.5 ÷ 1500). As the temperature increases, the resistance of the thermistor decreases, taking a lesser 'share' of the voltage. The resistor subsequently takes a greater share of the voltage and maintains the running of the fan.

Most students were able to attain at least one mark for this question. Deciding on the size of the resistor was more difficult than drawing the circuit in correct alignment . The thermistor and resistor needed to be in series with the battery with the switching circuit across the resistor.



Students drew the circuit in many different forms. A common error was to use a 500 Ω resistor, having miscalculated the current ratio using 1/3 of 1500 instead of 3 × 1500.

Question 7

Marks	0	1	2	Average
%	31	6	62	1.3

With 3 V across the LED, 6 V remained across the resistor. With the current through both being 0.15 A, a simple calculation was required to find the resistance of 40 Ω for the resistor.

This question was well completed. A common error was to use 3 V (or even 9 V) across the resistor.

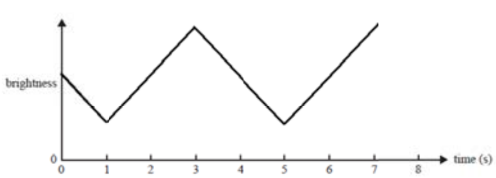
Question 8

Marks	0	1	2	Average
%	34	16	51	1.2

With the power of the light on the photodiode being 10 mW, the current in the photodiode circuit was 4 mA. With the resistance of the resistor being 2 kΩ, the voltage across the resistor was 8.0 V. Most students were able to successfully attain this voltage. The main source of error was in using the light power of 10 mW and dividing by the current of 4 mA to calculate a voltage of 2.5 V.

Question 9

Marks	0	1	2	Average
%	36	40	24	0.9



The variation should match the resistance variation for timing and shape, even with some 'curving'. The brightness variation would be inverted in comparison to the variation in resistance. The question stated that the LED stays on so the brightness variation should never drop to zero.

Most students were able to appropriately illustrate the variation, but some had the brightness dropping to zero.

Question 10

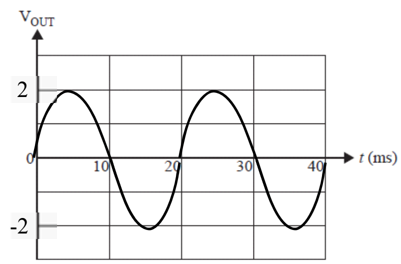
Marks	0	1	2	Average
%	58	28	14	**0.6**

The light signal was easily identified as the carrier wave. However, many students gave a generic definition of modulation without actually answering the question. In applying an understanding of modulation to the specific situation, students were expected to indicate that a variation in the electrical signal/current/voltage/resistance was converted into a variation in light brightness/intensity/amplitude.

Question 11

Marks	0	1	2	Average
%	31	11	58	**1.3**

An input of amplitude 5 mV would not be inverted or clipped. The output will have amplitude of 2 V, as illustrated below:



Most students handled this question well, with some students inverting the signal or getting the incorrect amplitude.

Question 12

Marks	0	1	2	Average
%	47	35	18	**0.7**

The most common weakness in students' responses was to favour a generic description of 'clipping' rather than referring directly to the amplifier being addressed. Students should be confident when describing a situation quantitatively. In this case, any input of greater than 10 mV in amplitude would result in the output signal being 'cut off' or flattened with maximum amplitude of 4 V.

Section B – Detailed studies

Detailed Study 1 – Einstein's relativity

Question	% A	% B	% C	% D	% No Answer	Comments
1	20	39	29	10	2	Some students found this question difficult. Working with one proton, the kinetic energy (E_k) and rest mass (m_0) were given. $E_k = (\gamma - 1)m_o c^2$ gives γ = 7308.32. This gives $m = m_o\gamma = 1.222\times10^{-23}$ kg. This is doubled for the best estimate of the mass of the Higgs particle: m = 2.44×10^{-23} kg.
2	5	19	14	62	1	
3	18	26	47	5	3	It is important that students understand the physics behind these formulas. Work done = $\Delta E_k = \Delta\gamma m_o c^2 = \Delta\gamma \times$ rest mass energy = $0.05 \times 1.50 \times 10^{-10} = 7.5 \times 10^{-12}$ J.
4	10	16	64	8	2	
5	60	25	4	9	1	
6	77	5	13	3	1	
7	21	9	5	64	1	
8	20	64	9	5	2	
9	8	19	26	42	5	Using the stated distance and speed of the particle, the relativistic lifetime for the travel could be calculated as: $t = \frac{d}{v} = 2.16\times10^{-11}$ s, and hence the proper lifetime of the particle could be calculated as: $t_0 = \frac{t}{\gamma} = \frac{2.16\times10^{-11}}{1.81} = 1.19\times10^{-11} \cong 1.2\times10^{-11} s$ Some students struggled with the time required to work through the calculations.
10	5	46	41	6	2	Option B was a correct statement but did not answer the question. It is impossible to provide the infinite energy required to increase the kinetic energy to the value required for a particle to travel at the speed of light.
11	43	11	9	34	3	
12	15	12	19	50	4	

Detailed Study 2 – Investigating materials and their use in structures

Question	% A	% B	% C	% D	% No Answer	Comments
1	7	5	85	3	0	
2	2	21	75	2	0	
3	7	71	7	14	1	
4	9	62	15	12	2	
5	14	13	34	37	3	Most students were able to give a definition for toughness, but the provision of a force-extension graph rather than a stress-strain graph contributed to this being a difficult question. Counting the squares found approximately 14 squares; each representing one joule of energy. The volume of sample P = cross-sectional area × length = 2×10^{-6} m^3. Therefore the 'toughness' = energy absorbed per volume = $(14) \div (2 \times 10^{-6}) \cong 7 \times 10^{6}$ J m^{-3}.
6	11	73	6	9	1	
7	8	4	8	78	1	
8	7	14	64	12	2	
9	10	24	59	3	3	
10	26	9	14	48	2	The diving board would experience tensile force through its upper region. Hence the need for reinforcing. Many students chose option D, seemingly believing that the board would sag between A and B.
11	61	8	26	3	2	
12	25	59	5	9	2	

Detailed Study 3 – Further electronics

Question	% A	% B	% C	% D	% No Answer	Comments
1	6	6	7	81	0	
2	7	75	6	11	0	The lengthy time constant results in a very smooth, near linear output at a peak voltage of $3600\sqrt{2} = 5091$ V $\cong 5000$ V.
3	13	45	33	7	2	The power delivered to the cathode-ray tube can be found to peak at about 5 W, so a 2 W transformer (option A) will not be adequate. The 10 W transformer (option B) is the minimum power rating transformer.
4	40	7	41	12	0	Given the time constant for the system, the frequency is irrelevant. The different input (primary) voltage will require a different transformer if the voltage output is to remain at 3600 V_{RMS}.
5	52	23	8	15	1	
6	3	87	5	5	0	
7	16	62	7	15	1	
8	54	7	32	6	1	
9	8	45	12	35	1	Both options C and D were accepted as correct given the placement of the Zener diode in the incorrect bias in Figure 4.
10	51	23	12	13	1	

11	10	66	17	5	2	
12	12	19	36	30	3	The time constant could be estimated to be 26 s. The capacitance of the capacitor was estimated as 10 µF from the previous question. The total resistance of the discharging circuit would be $R_R + R_E = 1$ MΩ + R_E. This provided a time constant equation of: $26 = (10 \times 10^{-6})(R_E + 1 \times 10^6)$, and hence $R_E = 1.6 \times 10^6 = 1.6$ MΩ.