2003
Assessment
Report

VICTORIAN CURRICULUM AND ASSESSMENT AUTHORITY

2003 Physics GA 3: Written examination 2

GENERAL COMMENTS

Teachers should note that the comments made in this report are based on the *Physics Study Design* 2000–2003. A reaccredited study design has been implemented in 2004 for Units 1 and 2 only.

This examination provided a fair and reliable test of the material studied in Unit 4. Responses from students and teachers have been quite positive and the context-style, depth and quality of the questions deemed to be both relevant and suitable. The examination was clearly accessible to students as evidenced from the mark distribution (two students scored the full 90 marks). There were students who found the examination long and were pressed for time when completing the later questions on the paper. Some students spent more time than anticipated on the more complex calculations for the ***Structures and materials*** sections of the paper and were then pushed for time when attempting the final section of the examination.

The quality of the upper band of student responses was particularly impressive displaying not only a good understanding of physics concepts, but with an ability to express these ideas via explanations, diagrams and numerical calculations.

The cut-off score for a grade of A+ was 73/90, compared with 75/90 in 2002, 80/90 in 2001, 75/90 in 2000 and 82/90 in 1999. Even though students emerged from the examination with a positive attitude, it was clearly a more probing examination than they were aware. This examination was one that, although reasonably difficult, provided good discrimination at the upper end of the scale.

Some concerns to note:

- students using radian mode of their calculator rather than degree mode for calculations involving angles in degrees
- students experiencing problems when using their calculators to evaluate some of the more complex calculations not understanding the use of brackets or the order of multiplication and division operations when entering numerical data into their calculators
- forgetting to convert cm or km into m, or convert tonnes into kg
- neglecting to show working when part marks may be awarded
- written explanations of poor quality, or simply lacking sufficient detail in cases where 2 or more marks were available
- free-body force diagrams were poorly drawn, with forces and their point of application requiring greater attention in the future
- the concepts of weightlessness and gravitational forces continue to confuse
- the setting out and working shown for the torque problems of the structures and materials section was frequently of poor quality and students should be encouraged to indicate the points about which they are taking torques.

SPECIFIC INFORMATION

Area 1 – Motion

Question 1

Marks	0	1	2	Average
%	25	12	63	**1.38**

The distance was determined by calculating the area under the graph over the first 4.0 seconds of the motion. This area worked out to be 115 m. The most common errors were to calculate the area incorrectly or to try and use the equations for uniformly accelerated motion. Because of the change in acceleration the use of the equations of uniformly accelerated motion was not the ideal method for trying to answer this question.

Question 2

Marks	0	1	2	Average
%	30	8	62	**1.31**

The acceleration was determined by calculating the gradient of the speed-time graph at t = 3.0 s. The gradient worked out to be 10 m s^{-2}.

The most common errors involved either calculating the average gradient over the three seconds (40/3 = 13.3 m $^{-2}$) or trying to solve using the equations for uniformly accelerated motion.

Question 3

Marks	0	1	2	3	Average
%	34	9	9	48	**1.70**

The average speed was determined by dividing the total distance by the time. The total distance involved calculating the total area under the graph for the 12 seconds of the motion, resulting in a distance of 625 m. The average speed was 625/12 = 52.1 m s^{-1}. Most students understood the method of determining the average speed but far the most common problem involved errors when calculating the area under the speed-time graph.

Question 4

Marks	0	1	2	3	Average
%	31	9	7	53	**1.81**

The solution of this question was a two-stage process. The first stage involved calculating the time for car B to reach Y, using the equations for uniformly accelerated motion. This time worked out to be 0.01 hour (36 s). Car A was travelling at a constant speed of 80 km h^{-1} and so travelled 800 m in this time. The main difficulties were in interpreting the written information and setting up the appropriate mathematical equations in order to solve.

Question 5

Marks	0	1	2	Average
%	20	0	80	**1.60**

Graph C best described the motion of car B.

Question 6

Marks	0	1	2	3	Average
%	60	5	4	31	**1.06**

Calculating the maximum compression of the bumper spring involved understanding that at maximum compression all of the initial kinetic energy was converted to spring potential energy. This resulted in the following set of calculations:

$$E_{k\ (initial)} = U_{spring}$$
$$½\ m\ v^2 = ½\ k\ x^2$$
$$½.200.2^2 = ½.3.2\ 10^5\ x^2$$

resulting in an answer for the maximum compression distance of x = 0.05 m.

Students found this to be a difficult question. A very common error was made by students calculating the work done on the spring as Fx, that is, assuming a constant spring force rather than the Hooke’s Law variation (F = kx).

Question 7

Marks	0	1	2	3	4	Average
%	32	35	25	4	4	**1.13**

There were three parts when answering this question and they needed to be addressed in the following way:

- initial momentum of the dodgem car was 400 kg m s^{-1} to the left
- final momentum of the dodgem car was 400 kg m s^{-1} to the right
- change in momentum of the dodgem car was 800 kg m s^{-1} to the right
- in order to conserve momentum the guardrail/earth system must have experienced a change in momentum of 800 kg m s^{-1} to the left.

This proved to be an extremely difficult question. Most students failed to realise that momentum is a vector quantity and so they simply addressed the magnitudes of the momentum of the dodgem car before and afterwards and incorrectly asserted that because they were of equal magnitude then momentum was conserved. Very few students considered the total system of the dodgem car, spring and Earth, choosing to concentrate on the dodgem car only. A number of students inappropriately felt that the concept of an elastic collision was enough to prove that momentum was conserved.

Question 8 and 9

Marks	0	1	2	3	4	Average
%	25	3	28	4	40	**2.30**

Question 8

At constant velocity the net force on the train is zero. The driving force provided by the engine must equal the sum of all the resistance forces. The resistance forces total 11 000 N and so the driving force must also equal 11 000 N.

The most common error was to confuse the driving force with the net force resulting in a value of zero for the driving force. Another common error was a failure to include all of the carriages when determining the total resistance force.

Question 9

The solution for this question involved firstly a calculation of the net force and then application of Newton's Second Law to calculate the acceleration, as follows:

$F_{net} = F_{driving} - F_{resistance}$

$= 4.6 \times 10^4 – 1.1 \times 10^4$

$= 3.5 \times 10^4$ N

$ma = 3.5 \times 10^4$

$100 \times 10^3\ a = 3.5 \times 10^4$

and so the acceleration, $a = 0.35$ m s^{-2}

This question was not well answered. A very common mistake was to neglect the resistance forces all together and simply use the driving force as the net force. Another error was neglecting to convert tonnes into kg when applying Newton's second law.

Question 10

Marks	**0**	**1**	**2**	**3**	**4**	**Average**
%	49	15	6	3	27	**1.43**

The key to this question was realising that tension in the coupling provides the driving force for the carriage. The forces on the carriage were simply a tension force forwards and a resistance force of 2000 N opposing the motion. This resulted in the equation:

$T – 2000 = ma$

$T – 2000 = 20 \times 10^3 \times 0.2$

Resulting in an answer for the tension of T = 6000 N.

Students found this to be quite a difficult question. The most common problem was a poor understanding of the tension force, (i.e. not understanding the location or direction of the tension force). As a result many students could not draw a correct force diagram for the last carriage and so could not get started on this question.

Question 11

Marks	**0**	**1**	**2**	**Average**
%	24	0	76	**1.51**

Arrow C best showed the direction of the net force on the car at the position X.

Most students understood the net force direction for uniform circular motion. The common incorrect answer was G, probably arising for students working from figure 5b rather than 5a.

Question 12

Marks	**0**	**1**	**2**	**Average**
%	53	33	14	**0.60**

Students needed to show arrows indicating normal contact forces upwards from the tyre-road interface, friction forces inwards from the tyre-road interface and a weight force at the center of mass of the car.

This was a difficult concept for students and many errors were noted such as:

- incorrect point of application of forces
- showing the friction force acting outwards rather than inwards
- a failure to put all three forces on the diagram.

Question 13

Marks	**0**	**1**	**2**	**Average**
%	79	0	21	**0.41**

The road exerts a force on the tyre both upwards and inwards, and Newton's Third Law requires that the tyre exerts a force on the road downward and outwards. Arrow G represents a force vector with both a downward and outward component.

This was a question with a high degree of difficulty. The most common incorrect answers were arrows E and B, which represent the two separate components of the final answer. Students were not aware that when cornering the force that the tyre exerts on the road is composed of both a normal and horizontal component.

Question 14

Marks	0	1	2	3	Average
%	35	23	21	21	**1.27**

The wheels of the car rotate in a clockwise direction. The wheels tend to rotate backwards relative to the ground and as a result of friction will push backwards against the ground. According to Newton's Third Law the ground pushes in the opposite direction (forwards) on the tyre and this results in a net force forwards on the car wheels and so it accelerates forwards. Students needed to address the key points of:

- the wheels rotate in a clockwise direction
- friction between the tyre and road surfaces results in the tyres pushing backwards against the road surface
- the road surface exerts an equal and opposite force, that is forwards, on the tyres
- there is a net force forwards on the car wheels and so the car accelerates forwards
- a force diagram was useful, clearly showing frictional forces acting forwards on the tyre surfaces in contact with the road.

This was a demanding question and the role of friction as a driving force is not well understood by students. Many mentioned the wheels turning in a clockwise direction and were able to discuss the action-reaction concept related to this question. They discussed friction but gave the incorrect direction for the friction force, showing a poor understanding of the way that the friction force opposes the 'intended' motion. Very few students mentioned the role of the normal contact force in relation to friction.

Area 2 – Gravity

Question 1

Marks	0	1	2	3	4	Average
%	23	10	9	11	47	**2.48**

The period of Odyssey's orbit was obtained from combining the equations for universal gravitation and uniform circular motion as follows:

$$GMm/R^2 = m4\pi^2R/T^2$$

followed by substituting in the given values for G, M and R and solving for the period T.

This resulted in a period of 7.1×10^3 s or 1.98 h, that is, approximately 2 hours.

Students had a reasonable understanding of this concept, combined with the ability to perform a complicated calculation using their calculator. The main error was due to substituting an incorrect value for the radius of the orbit. Many students forgot to combine both the radius of Mars and the altitude of the orbit when calculating the radius of the orbit. Other common errors were either arithmetic errors when using the calculator or forgetting to take the square root when calculating T via the formula.

Question 2

Marks	0	1	2	3	4	Average
%	63	9	9	6	13	**0.98**

Students needed to follow a logical sequence of steps in order to determine the speed of Odyssey. The steps were as follows:

- the gain in kinetic energy of Odyssey was equal to the area under the force-distance graph between 3200 km and 1200 km
- this results in the equation $E_{Kf} – E_{Ki}$ = area under the graph
- this equation can be rewritten as $½\, mv_f^2 – 1/2\, mv_i^2$ = area under graph
- substitution of given values, along with the area calculation will result in a value for v_f.

This was a difficult question. The style may have surprised many students because the examiners suspect that if students had actually been asked to calculate the speed they would have made a better attempt. That is, students have an understanding of the steps needed to perform the calculation but cannot express this in written form.

Question 3

Marks	0	1	2	3	Average
%	28	4	6	62	**2.03**

The speed of Quaoar was calculated by combining the equations for universal gravitation and uniform circular motion as follows:

$GMm/R^2 = mv^2/R$

Substitution of the relevant values resulted in a value for the speed of 4.5×10^3 m s^{-1}.

The major error was in neglecting to take the square root when solving the above equation for the speed, v.

Question 4

Marks	0	1	2	3	4	Average
%	38	17	17	13	15	**1.50**

Students needed to address the following key points when considering whether Kiera was correct or incorrect:

- Kiera was in fact incorrect
- at the surface of Quaoar a person would be subject to the combined gravitational force of the sun and that of Quaoar itself
- because both the person and Quaoar were in orbit around the sun then this part of Keira's explanation was correct but she has neglected the gravitational field due to the mass of Quaoar itself
- a person on the surface of Quaoar would feel a contact force between themselves and the surface and hence would not feel weightless.

Students found this a difficult concept and apparent weightlessness is still not well understood. Of concern were those students who felt that because Quaoar was so far from the sun that this gravity force would have been negligible – one wonders how the outer planets remain in orbit if this is the case. Also, many students did not address the idea of the surface contact force when discussing apparent weightlessness. However, it was pleasing to note that a number of students addressed this question by drawing an analogue with a person standing on the surface of Earth and arguing that we on the surface of Earth do not feel weightless.

Area 3 – Structures and materials

Question 1

Marks	0	1	2	3	Average
%	24	21	41	14	**1.42**

The explanation of the features of the bridge that ensure that it is a strong, safe and stable structure needed to cover the following points:

- brick and stone are much stronger under compression than tension
- the arch structure is such that it places the brick and stone materials on the lower surface of the arch under compression
- the arch is also a structure that has the property that it transfers the arch forces into nearly vertical components at the support pillars
- however, while arches need buttressing at the ends in order to balance any horizontal force components; the banks of the river may well provide this buttressing.

Students were generally able to address the first two points, but struggled to gain the third mark by mentioning one of the latter two points. Many gave explanations that lacked sufficient detail in order to gain full marks.

Question 2

Marks	0	1	2	Average
%	52	2	46	**0.94**

At the point P the net force on the pin is zero. The tension force must balance the weight of the upper walkway. Thus, the tension in the rod must be 5000 N. The most common incorrect answers were forces of zero and 10 000 N respectively.

Question 3

Marks	0	1	2	Average
%	71	0	29	**0.58**

The description A best describes the force exerted by the two separate rods on pins P and Q. The force exerted by the rod on pin P (5000 N) is half that exerted on pin Q (10 000 N). As a multiple-choice question this was difficult.

Question 4

Marks	0	1	2	3	4	Average
%	59	15	7	5	14	**1.01**

In order to decide whether or not the cable will break it was necessary to calculate the actual tension in the cable. This required students to take torques about the base of the walkway. The equilibrium torque equation for this was:
$10.7 \times 10^3 \times 9.8 \times 1.2 = T \sin 50^o \times 16$ resulting in a value for the tension in the cable of $T = 1.03 \times 10^5$ N. This is below the maximum breaking tension of 1.5×10^5 N and so the cable will hold.

Students experienced difficulty with this concept. Some students tried to solve this question by simply resolving forces, but neglected the reaction force at the base of the walkway. Others used the torque method did not take the vertical component of the tension force and were in error. Common problems were leaving out the gravitational field strength ***g*** when using the masses of the walkway and maximum load, forgetting to convert tonnes to kilograms and leaving out either the weight of the walkway or the load.

Question 5

Marks	0	1	2	3	4	Average
%	37	8	14	10	31	**1.89**

The diameter of the cable was calculated via the following method:

Young's Modulus = stress/strain = FL/AΔL
$3.4 \times 10^{11} = 1.5 \times 10^5 \times 25/\pi r^2 \times 0.010$

Solving for the radius gave $r = 1.873 \times 10^{-2}$ m and so the diameter of the cable was 0.037 m.

Most students knew how to get started on this question in terms of Young's Modulus equal to stress/strain. Many could not take it further to derive the expression in terms of FL/AΔL. Others could not put the area in terms of πr^2 or forgot to convert from the radius into the diameter for the final answer.

Question 6

Marks	0	1	2	3	Average
%	39	11	10	40	**1.52**

This question was similar to Question 4, although more straightforward because all contact forces were more obvious. The method of solution involved equating torques, resulting in contact forces of 1.8×10^6 N and 1.63×10^6 N respectively.

Most students were able to get started and understand the concept of torques. Of concern was the number of students who did not begin with a clearly labelled force diagram. Force diagrams are essential and this should be stressed. Problems occurred when students neglected to convert from tonnes into kilograms or include the gravitational field strength ***g*** when converting from mass to weight force.

Question 7

Marks	0	1	Average
%	28	72	**0.72**

Students were expected to describe that brittle materials either fracture in the elastic region or have a small (or no) plastic region. There was a clear understanding of this aspect of a brittle material.

Question 8

Marks	0	1	2	3	Average
%	54	11	12	23	**1.04**

The answer to this question involved students understanding that the area under the stress-strain graph represented the energy per unit volume stored in the material. For this question this area was calculated to be 1.125×10^5 J m^{-3}. The total energy could be obtained by multiplying this by the volume of the material.

Thus, the total energy was $1.125 \times 10^5 \times 0.10 \times 0.05 \times 10 = 5.6 \times 10^3$ J.

This concept was not well understood. The most common error was in forgetting to multiply by the volume. Some students did not read the scales on the graph carefully and omitted to include the 10^{-3} or 10^6 factor associated with the scales.

Area 4 – Ideas about light and matter

Question 1

Marks	0	1	2	Average
%	39	0	61	**1.22**

Transition A shows the change in atomic energy levels for the emission of a photon of energy 1.65 eV.

Question 2

Marks	0	1	2	3	Average
%	39	7	19	35	**1.50**

The energy of a photon is determined from the change in energy levels to be 2.10 eV. Photon energy is given by the equation $E = hc/\lambda$ and substitution into this equation resulted in a wavelength of 5.9×10^{-7} m.

Most students were able to get started because they were aware of the equation that they needed to use. However, a significant number of students used the 1.65 eV value for the photon energy from Question 1 rather than the 2.10 eV value. When students are in a rush towards the end of the examination they tend not to read the information carefully enough.

Question 3

Marks	0	1	2	3	4	Average
%	51	3	2	4	40	**1.79**

The final kinetic energy (1/2 mv^2) of the electrons will be 2500 eV. Substitution of the relevant values resulted in the equation: $\frac{1}{2} \times 9.1 \times 10^{-31} \times v^2 = 2500 \times 1.6 \times 10^{-19}$ resulting in a value for the speed of the electrons, $v = 2.96 \times 10^7$ m s^{-1}, which is approximately 10% of the speed of light (3×10^8 m s^{-1}).

Students either clearly understood how to tackle this question or had little idea. Many did not attempt this question, possibly due to running out of time towards the end of the examination.

Question 4

Marks	0	1	2	3	Average
%	41	10	20	29	**1.36**

Students needed to address the following points in their explanation of why Jane would be unable to see the wave nature of a moving softball.

- the deBroglie wavelength of the softball needed to be calculated
- this calculation resulted in a deBroglie wavelength value of 1.1×10^{-34} m
- this value for the wavelength is much smaller than the size of the bat and so diffraction would not be significant.

Students understood how to work out the deBroglie wavelength using the correct formula. The main stumbling block was relating this value for wavelength with the concept of diffraction. Many students mentioned that because the deBroglie wavelength was less than 10^{-10} m then it would not be visible. This strange statement indicated students were confused about values they had met when discussing X-rays or atomic lattice spacing or were simply confused about visible light wavelengths.

Question 5

Marks	0	1	2	Average
%	41	24	35	**0.94**

Extrapolating the graph and determining the V-axis intercept determined the magnitude of the work function. This was approximately 2 eV. Another way of calculating the work function was to determine the threshold frequency and convert this to a photon energy. Either method was acceptable. The examiners accepted a range of values between 1.6 eV to 2.2 eV to allow for differing lines of best fit when answering this question. A number of students calculated the correct value for the work function but then included an incorrect unit corresponding to this value. For example, some students gave answers of 2.0 J. Some students even went to the trouble of converting a value of 2.0 eV into the corresponding value in joule – which was quite acceptable, but unnecessary.

Question 6

Marks	0	1	2	3	Average
%	42	15	6	37	**1.36**

Application of Einstein's equation $\boldsymbol{E_{Kmax} = hf - W}$ results in a maximum kinetic energy for the photoelectrons of 77.9 eV.

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