GENERAL COMMENTS

The examination provided a fair and reliable test of the material studied in Unit 4, with both students and teachers alike being positive about the style, depth and quality of the questions. The examination was clearly accessible to most students as evidenced by the mark distribution, with 23 students able to score the full 90 available marks. The mean score was 54/90 (60%).

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

The cut-off score for a grade of A+ was 80/90 (compared with 75/90 in 2000 and 82/90 in 1999).

A few concerns to note:

- the use of the radian mode of calculators rather than the degree mode for calculations involving angles in degrees, probably resulting from radian as the default mode for graphics calculators
- the absence of working in questions when marks are often awarded for such working
- the calculation of answers arising from simple equations is not of a high enough standard and more practice in calculating numerical answers is required
- written explanations are often of poor quality, or simply lack sufficient detail particularly in cases where two or more marks are to be awarded
- the difficulty in answering the specific question asked, giving instead a broad explanation suggesting that students are grasping at pre-prepared material from the A4 sheet that they bring with them to the examination. Teaching students to use this A4 sheet as a resource, particularly in the early stages of revising for the examination, rather than for direct application may be an issue that teachers need to address (with an emphasis on the value of the preparation process for the A4 sheet, rather than the end product).

SPECIFIC INFORMATION

Area 1 – Motion

Question 1 (Average Mark 0.91/ Available marks 2)

The rider and bicycle were travelling at constant velocity and so the net force is zero.

This question proved to be moderately difficult for such a straightforward question. The most common error was to give the net force as the weight force. This was often accompanied by working showing the net force as being equal to ***ma***, as per Newton’s Second Law, and then setting ***a*** equal to 9.8 m s^{-2}.

Question 2 (1.67/3)

It was necessary to resolve forces perpendicular to the plane and to equate the normal reaction force to the perpendicular component of the weight force. This resulted in the equation: $N = mg \cos 15^0$ **= 947 N**.

The question was moderately well done. The most common errors were interchanging cosθ with sinθ, failing to separate the weight force into components perpendicular and parallel to the plane, and the use of radian mode.

Question 3 (0.93/2)

Students needed to resolve forces parallel to the plane and then equate friction acting up the plane with the component of the weight force down the plane. This resulted in the equation: $F = mg \sin 15^0$ **= 254 N**.

Students experienced some difficulty with this concept with the most common errors being similar to that noted in the previous question.

Question 4 (0.32/2)

This question could have been solved algebraically using the distance of each half of the journey as the variable or simply by assuming an arbitrary numerical value for the distance and calculating the average speed. Either way resulted in an average speed of 5.3 m s^{-1} (answer A).

This proved to be quite a difficult question, with only 15% of students answering correctly. The most common incorrect answer was 6.0 m s^{-1}, that is, the average of the upward and downward speeds. Many students who correctly chose **A** made up an arbitrary distance and calculated the answer for this.

Question 5 (2.6/4)

The force at a compression of 50 mm is 550 N, corresponding to a mass of 56 kg.

Most students correctly equated the weight of the rider to the spring force. The most common errors were in either misreading the graph or in failing to convert from weight force to mass.

Question 6 (2.6/4)

The potential energy is determined from the area under the graph and calculates to 14 J.

Most students calculated the potential energy from the area under the graph. The most common error was to equate the gain in spring potential energy to the loss in gravitational potential energy and to then use the relation ***mgh*** to calculate the spring potential energy. A few students forgot to convert the distance into metres when calculating the area under the graph.

Question 7 (1.55/2)

Graph **A** best shows the gravitational potential energy against horizontal distance.

This question was well answered.

Question 8 (1.41/2)

Graph **B** best shows the kinetic energy against horizontal distance.

The requirements of this question were well understood by most students.

Question 9 (0.77/1)

Graph **E** best shows the total energy against horizontal distance.

This question was well understood.

Question 10 (0.69/2)

Arrow **E** best indicates the direction of the net force on the roller coaster car. The motion of the car at this point can be considered to be made up of both a uniform circular motion component (force towards the centre of the circle) and a friction component (force in the opposite direction to the motion).

This question proved to be a little more difficult.

Question 11 (0.92/4)

This question could have been answered using a conservation of momentum approach or by application of Newton's Second Law. Either way this will not be a successful way for Jack to win the race because it does not change the forward momentum of the box or toboggan.

This proved to be quite a difficult question with very few students scoring full marks (only about 7% of students scored the full 4 marks). It was anticipated that students would use conservation of momentum to address this question, but very few did. Most students attempted to answer using $\boldsymbol{F = ma}$. Many students incorrectly thought that mass affected the acceleration – stating either that less mass will allow the toboggan to go faster or conversely that greater mass will result in greater acceleration. Some even suggested that lighter objects accelerate at a greater rate.

Question 12

Application of the equations for uniform acceleration resulted in an answer of either 4.7 m s^{-2} or 16.9 km h^{-1} s^{-1}.

This question was done quite well with most students obtaining the correct magnitude, but with less giving the correct unit for acceleration. The most common error was in giving the magnitude answer of **16.9** with the corresponding incorrect unit of $\boldsymbol{m\ s^{-2}}$.

Question 13 (3.7/5)

Application of the equations for uniform acceleration, using the acceleration value of 4.7 m s^{-2}, resulted in an answer of 82 m.

This question was reasonably well done with most students using the correct equation for uniform acceleration to calculate the distance travelled. The most common error arose as a result of mixing up the magnitude and unit for acceleration.

Question 14 (1.89/3)

Application of Newton's second law resulted in an acceleration of negative 10 m s^{-2}. Substituting into the equations for uniform acceleration gave a speed of 32 m s^{-1} (114 km h^{-1}).

A number of students did not attempt this question (30% scored zero). Common mistakes included some simple arithmetic errors along with a failure to convert tonnes to kilograms.

Question 15 (2.16/4)

The motion of the car was an example of projectile motion. This required students to separate the launch velocity into horizontal and vertical components, treating the vertical motion as constant acceleration under gravity and the horizontal motion as uniform speed. This resulted in a time for flight of 2.1 s and a corresponding range of 59 m.

Question 15 was moderately well done, (but 35% scored zero) with the most common incorrect approach being to confuse the horizontal and vertical components of the initial velocity. The problem of using radian mode of the calculator was evident in this question.

Area 2 – Gravity

Question 1 (1.65/3)

The period of Mir's orbit was 5.5 x 10^3 m s^{-1}.

This was a relatively simple question and the most common problems were either due to simple arithmetic mistakes or to substituting of incorrect numerical values when converting 14.6 years into seconds. Some students took a 'round-about' approach and went back to the equations for Universal Gravitation and circular motion, often making arithmetic errors when doing so.

Question 2 (1.65/3)

The speed of Mir while in orbit was 7.7 x 10^3 m s^{-1}.

This question was reasonably well answered, particularly by those students who worked with the given data rather than trying to work with equations from the data booklet or their A4 sheet. Common errors resulted from failing to include the altitude when determining the radius of the orbit and the usual problem of calculating arithmetic expressions involving powers of 10.

Question 3 (2.6/5)

For uniform circular motion the acceleration can be calculated via application of the equation $a = v^2/r$, using the speed calculated in Question 2 and the radius of the orbit as the radius of the earth plus the altitude. This resulted in a gravitational field value of 8.8 N kg^{-1}.

The question itself was reasonably well understood by most students. The two most common errors were in failing to include the altitude when determining the orbit radius and using the mass of Mir rather than Earth for the calculation. Students need to be aware that it is the central mass, not that of the orbiting body, that determines gravitational field strength and they need to be reminded to think more carefully when choosing values to substitute into formulas.

Question 4 (2.6/5)

This question was testing the concept of apparent weightlessness in a slightly different format than in previous examinations. Both the spring and the mass are accelerating at the same rate and hence the reading of the spring balance will be zero.

This proved to a reasonably demanding question and certainly highlighted just how poorly students understand the concept of apparent weightlessness. The most common error was to give the answer as the weight force ***mg*** (22 N). Very few students mentioned that the net force on the mass was ***mg*** and hence the spring force was zero. Very few chose to draw a force diagram and use this to calculate the spring force as zero. Many answers referred to 'freefall' or 'apparent weightlessness' but without using this to really address the question asked. Many students inappropriately used the term 'normal reaction' rather than 'tension' when referring to the force exerted by the spring.

Question 5 (1.68/2)

The weight of the spacecraft on the surface of Earth was 4.4×10^3 N.

This question was quite well understood by most students. A small number of students misread the question and calculated ***g*** for the surface of Eros.

The average score for Questions 6 and 7 was a combined 2.1/4 indicating this was a moderately demanding group of questions (30% scored the full 4 marks).

Question 6

Application of the equations for universal gravitation and uniform circular motion resulted in a mass for Eros of 2.1×10^{16} kg.

This question was not well done and the errors were many and varied, with a number of incorrect formulas. Students also made some simple errors, such as forgetting to convert 50 km into metres or using the value of ***g*** for the surface of Eros rather than at the radius of the orbit. Many students experienced difficulty using powers of 10 in their calculations and/or forgot to cube or square the numbers.

Question 7

There is only one force acting, that of the gravitational force that Eros exerts on the spacecraft. Hence, an arrow pointing inwards from the spacecraft towards Eros was expected.

This was reasonably well done with most common errors being:

- drawing two arrows, one toward and one away from Eros
- drawing an arrow vertically down to represent the weight force and drawing a tangential arrow and then omitting to label this as representing the direction of motion.

Area 3 – Structures and materials

Question 1 (1.66/2)

The calculated torque was 240 N m.

This question was very well done.

Question 2 (2.03/3)

Region **A** was under tension and both regions **B** and **C** under compression.

This question was also well done with most students quite clear that points **A** and **B** were under tension and compression respectively. A number were confused about point **C**, choosing it as a neutral point.

Question 3 (1.93/3)

Wood is a good building material because it is strong under both compression and tension. It also is tough, possesses a good strength to weight ratio, is not brittle and is not too elastic.

This question was quite well understood with most students clear that wood needed to be strong under both tension and compression. They were usually also able to point out one other structural property of wood that made it a good building material.

Question 4 (1.5/3)

Students needed to equate the vertical components of the tension in the two wires to the weight force of the mirror. This resulted in a tension of 128 N in each wire supporting the mirror.

Students found this to be a moderately difficult question (38% of students scored zero). The concept of a component of a force was not at all well understood and nor was the ability to then express the components in terms of the correct algebraic expression. There were a variety of equations involving permutations on sin, cos and tan. Some students forgot to account for the two wires and obtained an answer that was twice as large. The problem of using the calculator in radian mode was evident in this question.

Question 5 (1.56/2)

Young's Modulus was calculated from the gradient of the graph to be 6×10^{10} N m^{-2}.

This was a straightforward question and was well answered with most quite clear about calculating Young's Modulus. The most common mistake was usually due to a power of 10 error.

Question 6 (1.72/3)

The energy per unit volume was calculated by estimating the area under the curve. This area was determined by either counting squares or dividing the area up into rectangles and triangles. This resulted in an area of 1.4×10^5 J m^{-3} (a range of values between 1.3×10^5 to 1.5×10^5 was accepted as correct).

Most students were able to identify that the answer was calculated from the area under the stress-strain graph. Some students determined the area by counting squares or by dividing up into rectangles and triangles. A common error was to determine the area under the linear section only. Although students clearly knew that they needed to estimate the area under the graph, of concern was that they were not able to do so within the acceptable range of values.

The average score for Questions 7 and 8 was a low 2.5/4, for what was expected to be a straightforward group of questions.

Question 7

The prize is hanging at rest and so the net force on it is clearly zero.

Many students found this to be a moderately difficult question. The most common incorrect answer was 9.8 N, suggesting that there were students who were not quite clear as to what the question required.

Question 8

Since the net force on the prize is zero, the tension in the string balances the weight force of the prize. Hence, the tension equals 9.8 N.

Most students understood this question and obtained the correct answer.

Question 9 (1.45/4)

Students needed to take torques about the edge of the bank, equating the clockwise and anticlockwise torques. This resulted in an equation involving only the distance that Chris is from the bank of the river. Solving this equation gave an answer of 0.88 m for this distance.

This proved to be a reasonably difficult question with quite a few students not attempting it, suggesting that the concept of equating clockwise and anticlockwise torques for the case when the net torque is zero is poorly understood. Common errors were to calculate torques about different points along the beam rather than a consistent point, and to neglect the mass of the beam.

Students can gain some marks, even though they obtain the incorrect answer, provided that their working is shown. However, it was often difficult to award any marks in questions such as this because of messy and confused working or because no working at all was shown.

Area 4 – Ideas about Light and Matter

Question 1 (1.4/2)

The kinetic energy was equal to the stored potential energy (***qV***). This calculated to a value of 1.6×10^{-15} J.

This question was generally well understood. Common errors were incorrect calculations or forgetting to convert 10 kV to 10 000 V.

Question 2 (1.34/3)

This was a two-stage question. Students needed to determine the speed by using their answer for the kinetic energy obtained in Question 1. This gave a speed for the electron of 5.93×10^7 m s^{-1}. This speed value needed to be substituted into the expression for the de Broglie wavelength resulting in an answer of 1.2×10^{-11} m.

This was expected to be a difficult question and students did find it challenging. Two errors of concern were:

- taking the speed of the electrons as the speed of light (3×10^8 m s^{-1})

- taking the speed of the electrons as 10 000 m s^{-1}; confusing v in the expression for de Broglie wavelength with V, the accelerating voltage.

This was a case of students 'blindly' substituting values into an expression without paying attention to the meaning of the symbols in the expression.

Question 3 (0.52/3)

Students needed to be comfortable with the orders of magnitude of the wavelengths relating to electrons and visible light. That is, the electrons have a deBroglie wavelength of 1.2 x 10^{-11} m and visible light has a wavelength of about 5 x 10^{-7} m. This means that the wavelength relating to the electrons is very much smaller than that for visible light. Students also needed to realise that the blurred image in the second picture was due to diffraction effects and that a sharper image required less diffraction and hence a shorter wavelength.

This proved to be a demanding and challenging question and it highlighted a number of student misconceptions about wave-particle duality and diffraction. The context itself confused some students who did not recognise this as relating to the concept of diffraction and the effect of wavelength on the diffraction pattern. Of concern was the number of students who correctly noted that the clarity of the image was related to diffraction but then went on to state that greater diffraction actually led to a clearer image (possibly believing that greater diffraction effects are desirable in any situation). Very few students were able to compare the wavelength of visible light with that calculated for the electron.

Question 4 (1.31/2)

The work function of the metal could be calculated either by extrapolating the graph or from the cut-off frequency. This resulted in a value of 3.7 x 10^{-19} J (a range of values between 3.5 x 10^{-19} to 3.9 x 10^{-19} J was scored as correct).

This question was reasonably well answered. Students either calculated the value from the horizontal intercept or by extrapolation to the vertical axis. Others tried to find the value from application of the equation $E_{Kmax} = hf - W$, but were generally unsuccessful.

Question 5 (1.2/2)

Students needed to determine the wavelength from the cut-off frequency and this calculated out to a value of 545 nm. This corresponded to the value for the metal sodium.

Most students were able to use the frequency to calculate the wavelength and then show that this corresponded to the metal sodium.

The average combined score for Questions 6 and 7 was 2.0/4, indicating that students found this group of questions either reasonably challenging or that they were rushing due to poor time planning.

Question 6

The photon energy corresponding to a wavelength of 497 nm calculates to a value of 2.5 eV.

Students generally understood the concept and any errors were due to mistakes in calculations.

Question 7

The transition required to emit a photon of energy 2.5 eV was between the –0.9 eV and –3.4 eV energy levels.

This proved to be a difficult question and quite a large number of students did not make a link between the energy levels in Question 7 and their answer to Question 6. About 20% of students answered Question 6 correctly but did not attempt Question 7. Some students drew the arrow in the wrong direction and others drew in all possible energy level transitions. A significant number of students did not answer this question.