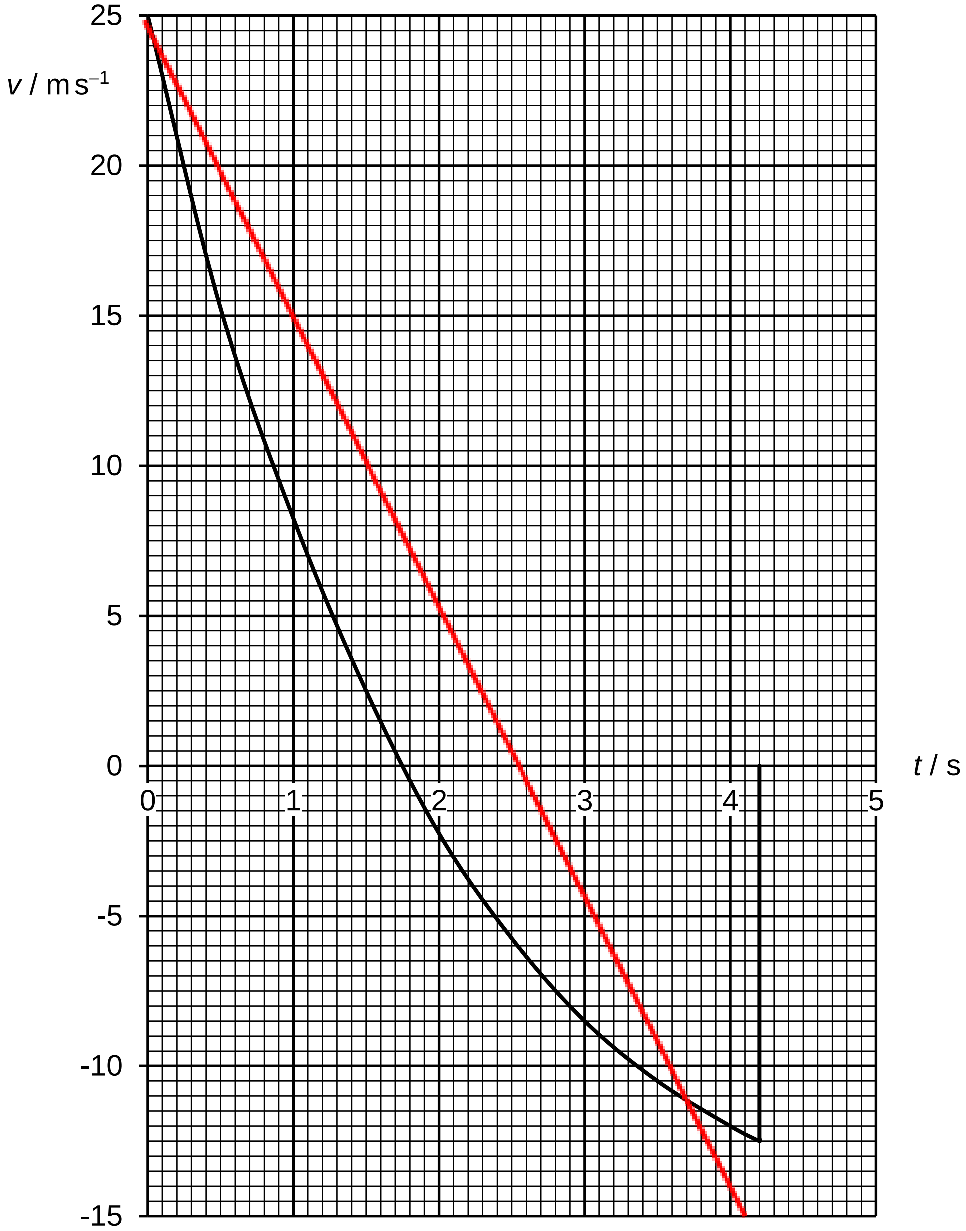
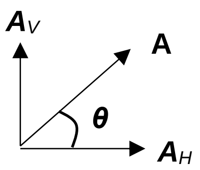
2023 YIJC JC2 H2 Preliminary Examination Paper 2 Suggested Solutions

1	**(a)**	The gradient of the graph represents the acceleration of the ball, which is changing with speed. This suggests that the resultant force acting on the ball (which is proportional to the acceleration by Newton's second law) is changing with speed. When the ball is rising, the resultant force is given by weight and viscous force. Since its weight is constant, a changing resultant force implies that air resistance acting on the ball must vary with speed. OR when the ball is falling, the resultant force = weight – viscous force. A decreasing resultant force will imply that the viscous force is increasing with increase in speed.		**B1** **B1**
		Marker's comment Students should start the explanation by connecting the gradient of v-t graph to acceleration. This will allow the examiner to better follow the discussion. Students tend to be unclear in which part of the motion they were describing. The students did not seem to recognise that while the gradient is decreasing and hence the acceleration is decreasing, the implication is different when the ball is rising compared to the case when the ball is falling. Some answers are rather convoluted and answering directly to the question. Students should state clearly		
	(b)	**(i)**	time = 1.75 s	**A1**
		Marker's comment Some students did not understand at the highest point, the resultant force is the weight and thus this is the time at which the acceleration of the ball is *g*. There were several students who gave the answers as 4.2 s.		

		(ii)	 **[B1]** – Straight line graph starting from (0, 25) with negative gradient. **[B1]** – Cuts time axis at t = 2.55 s (so that the gradient of graph is –9.81 m s^{-2})	**B2**
		Marker's comment Students need to plot the graph to half a small square. It should be shown clearly that the line cuts in between 2.5 and 2.6 s. Students do not gain credit if the graph is not plotted to half a small square. This part was poorly done as students did not show understanding that the gradient of graph needs to be 9.81 m s^{-2}. Most students understood that the ball starts with a speed of 25. m s^{-1}		

	(c)	For the upward motion, energy lost = loss in KE - gain in GPE energy lost $= \frac{1}{2} \times 0.350 \times 25^2 - (0.350 \times 9.81 \times 19)$ = 44.14 J	**C1**
		For the downward motion, energy lost = loss in GPE - gain in KE energy lost $= 0.350 \times 9.81 \times 19 - \left(\frac{1}{2} \times 0.350 \times 12.5^2\right)$ = 37.89 J	**C1**
		Therefore, ratio $= \frac{44.14}{37.89}$ ≈ 1.16	**A1**
		Marker's comment Not well done. Students did not make sense of the given data from the graph. Also, some students tried to find the acceleration from the graph which would only be useful if the question assesses on the concepts of dynamics. Students need to connect the graph to the physical motion of the ball to better solve the question.	

2	(a)	Moment of a force is the product of the force and the perpendicular distance to a pivot.		B1
		Marker's comment Students need to learn the definition and follow the definition closely. Simply saying that it is the product of force and perpendicular distance is not sufficient. Students need to state clearly the perpendicular distance is from the line of action of the force to the pivot. Saying "perpendicular distance from the pivot" is not clear enough. There was also some students who mentioned "perpendicular distance from the point the force acts to the pivot" which was incorrect.		
	(b)	(i)	Taking moments about A, $T(2.8) = 500(1.4 \sin 30°) + 4000(2.8 \sin 30°)$ $T = 2125$ N $T = 2.1$ kN (shown)	 M1 A0
		Marker's comment Most students were able to show the tension by taking moments about point A. There were a handful who were unable to find moment of forces correctly.		
		(ii)	$T_v = T \cos 60°$ $= 2100 \cos 60°$ $= 1050$ N	 A1
		Marker's comment Most students were able to resolve the tension correctly.		
		(iii)	There is an upward vertical component of force acting on the beam at A such that upward force at A + T_v = sum of downward forces of weight of beam and load.	B1
		Marker's comment Not well done. The key idea that there is an "upward vertical component of the force acting on the beam" was not clearly brought across. Also, there were several students who incorrectly used the term "normal contact force" from the wall. Normal contact force acts perpendicular to the vertical wall and thus would have been acting horizontally and hence not awarded credit.		

		(iv)	<u>Vertical equilibrium</u>: $A_v + T_v = 500 + 4000$ $A_v = 4500 - 1050$ $= 3450$ N <u>Horizontal equilibrium:</u> $A_H = T \sin 60 = 2100 \sin 60$ $= 1820$ N Hence magnitude of force at A = $(1820^2 + 3450^2)^{1/2}$ $= 3900$ N  $\tan\theta = 3450 / 1820$ $\theta = 62°$ Direction is 62° above the positive horizontal.	 C1 C1 A1 A1
		Marker's comment Poorly done. Many students were not able to recall the steps to solve this kind of question. The angle was poorly expressed. Students should draw diagram to show clearly the angle they were determining. Use of scale diagram to solve this question is not encouraged.		

3	(a)	Work done is the product of the force and the displacement moved in the direction of the force		B1
		Marker's comment Many students left out the "in the direction of the force".		
	(b)	(i)	Displacement = Area of $v - t$ graph = ½ (1.0 + 4.0) × 2.4 = 6.0 m	M1 A1
		Marker's comment Many students left the answer in 1 sf. Students should know that the readings should be read to half of the smallest division, and hence to 1 d.p. Therefore, the displacement should be calculated to 2 s.f. BOD is given. The marking of this question is quite lenient. Students who showed workings to find area under the graph, 1 mark is given, although the range could be incorrect.		
		(ii)	Increase in GPE = mgΔh = 13000 × 6.0 = 7.8×10^4 J Increase in KE = ½mΔv^2 $= \frac{1}{2} \times \frac{13000}{9.81} \times (2.4^2 - 0^2)$ = 3817 J Work done against friction = $F \times s$ = 2000 × 6.0 = 1.2×10^4 Work done by motor = Increase in energy of the lift + Work done against friction = ΔGPE + ΔKE + W = 78000 + 3817 + 12000 = $9.38 \times 10^4 \approx 9.4 \times 10^4$ J	C1 C1 C1 A1
		Marker's comment Very poorly done. Many students attempted to use the approach of determining the work done by the forces instead of energy approach. However, many considered work done by the net force rather than work done by the tension. For those who considered work done by tension, many did not realise that the tension from t=0 to t=3 is different from t=3 to t=4.		

		(iii)	Output power = $F v$	
			$= 1.6 \times 10^4 \times 2.0$	**C1**
			$= 3.2 \times 10^4$ W	
			$\text{Efficiency} = \frac{\text{Output Power}}{\text{Input Power}}$	
			$0.67 = \frac{3.2 \times 10^4}{\text{Input Power}}$	**C1**
			Input Power = $4.78 \times 10^4 \approx 4.8 \times 10^4$ W	**A1**
		Marker's comment Very poorly done as well. Some students found the work done from t=0 to t=2.5s and then divided by the time. These students have used the concept of average power instead of instantaneous power. The way to obtain instantaneous power is to use P = Fv where F and v are the force and velocity at that point in time. A few students thought that efficiency is input/output power instead.		

4	**(a)**	**(i)**	Resultant force acts perpendicular to the velocity of the object. / Centripetal force is constant in magnitude	**B1**
		Marker's comment Generally well done. Some students were vague when referring to "the centre" without specifying whether it is the centre of the circular motion or the centre of the object.		
		(ii)	The velocity of the object is always changing as the <u>direction</u> of the motion is always <u>changing</u>. Thus the object experiences a rate of change of velocity. Acceleration is in the direction of the resultant force / perpendicular to the velocity / towards the centre of the circular path.	**B1** **B1**
	(b)	**(i)**	The gravitational force provides the centripetal force to keep the satellite in circular motion. Thus, gravitational force = mv^2/r $GMm/r^2 = mv^2/r$ $r = \frac{GM}{v^2} = \frac{(6.67\times10^{-11})(6.0\times10^{24})}{3700^2}$ $r = 2.92 \times 10^7$ m	**B1** **C1** **A1**
		Marker's comment For **(i)**, students should explain that the direction of velocity changes which leads to a change in velocity which means that there is acceleration. For **(ii)**, the majority could obtain the correct answer.		
		(ii)	$v = r\omega = r\frac{2\pi}{T}$ $T = \frac{2\pi r}{v} = 4.96\times10^5$ s = 13.8 h Since the time is not the same period as the rotation of the Earth (24 h), the satellite is not a geostationary satellite	**M1** **A1**
		Marker's comment Students who obtained full credit presented a systematic presentation of steps - find the period of the given satellite - comparing this period with **24 hours** (the period of a geostationary satellite) - making a conclusion ECF would have been given to those who used their value of *r* in (i), even though is was incorrect. However, credit could not be given to answers that stated the period of a geostationary satellite to be 1 year.		

		(iii)	GPE = $-GMm/r = -2.74 \times 10^7$ J KE = $\frac{1}{2}mv^2 = 1.37 \times 10^7$ J Total energy = GPE + KE = -1.37×10^7 J	**C1** **C1** **A1**
		Marker's comment Many students mistakenly ignored the negative sign in the GPE expression. There were also students who merely used the expression $-GMm/2r$ to obtain the correct answer. They received partial credit. Students are reminded that this expression has to be derived before use.		
	(c)	**(i)**	Any mass ejected in the same direction as the satellite. (Idea of rocket motor pushing against direction of motion of satellite.	**B1**
		Marker's comment This question was poorly done. The force in question has to slow down the satellite and thus must acting against its instantaneous velocity.		
		(ii)	Kinetic energy of the satellite in a circular orbit is inversely proportional to the radius of the circular orbit. (KE = $GMm/2r$) With a smaller orbital radius, kinetic energy of the satellite increases.	**C1** **A1**
		Marker's comment There were many wrong concepts found in students' answers here. Many believed that total energy remained the same despite r decreasing and so mistakenly quoted conservation of mechanical energy. Others believed that the centripetal force remained constant in different orbits. Correct responses relied on the expression KE = $GMm/2r$ or $v^2 = GM/r$ to determine the dependence of KE with r. If faced with similar questions in future, students are advised to look for a mathematical expression to guide their thinking.		

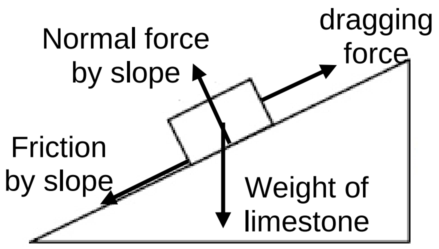
5	**(a)**	$\frac{n_S}{n_P} = \frac{V_S}{V_P}$ $\frac{n_S}{4200} = \frac{12}{230}$ The number of turns in the secondary coil = 220		**C1** **A1**
		Marker's comment Generally well done. A few students wrongly use the wrong formula $\frac{n_S}{n_P} = \frac{V_P}{V_S}$ or wrongly thought that one of the voltage given is the peak value.		
	(b)	**(i)**	p.d. across the leads = e.m.f. across the output – p.d. across the lamp V_{lead} = 12 – 11.8 = 0.2 V $V_{lead} = I_{lead} \times R_{lead}$ 0.2 = I_{lead} × 0.35 I_{lead} = 0.57 A	**C1** **A1**
		Marker's comment Poorly done. Many did not realise that the resistance 0.35 Ω given is the resistance of the leads while the voltage 11.8 V is the p.d. across the lamp and they wrongly use them to find r.m.s. current. Another common error is that many failed to realise that the values given in the question are already the r.m.s. values and wrongly divide the values by $\sqrt{2}$ to "find" the r.m.s. values.		
		(ii)	Mean power dissipated in leads = $i_{rms}^2 R = 0.571^2 \times 0.35$ = 0.114 W Maximum power = $2P_{mean}$ = 2 × 0.114 = 0.23 W	**C1** **A1**
		Marker's comment Below satisfactory. Given that the r.m.s. current is computed in (b)(i), many did not realise or know how to use it to compute peak power, instead they compute average power. Some are carelessly use either wrong formula (e.g. $P = V^2R$) or substitute the e.m.f. across the secondary coil into the formula.		

6	(a)	A photon is a discrete amount/quantum/packet of energy of electromagnetic radiation.		B1
		Marker's comment Poorly done. Many did not show the basic understanding of what a photon is. Some failed by only relating photon to the energy needed in photoelectric effect or line spectra. Students need to understand the fundamental concepts, revolving around the energy that the light provides.		
	(b)	The electrons in the gas atoms/molecules (interacts and) absorbs photons and their energy, causing electrons in the gas atoms/molecules to move to a higher energy level or to be excited. (For the excitation to occurs,) the energy of the photons must be the difference in the energy of the electron energy levels of the gas atoms/molecules. When the electrons de-excite (after a random short interval), photons are emitted in all directions. Since the intensity of such re-emitted photons in the original direction are lower than that of the other incoming photons, the spectrum consists of a number of dark lines in coloured spectrum.		B1 B1 B1 B1 A0
		Marker's comment Below satisfactory. Some are mistaken that the diffraction grating is the source of the dark lines and went on to use destructive interference to explain. A few uses the concept of X-ray spectrum to explain but unable to come up with any explanation. Several understand the dark lines are due to the light interacting with the gas molecules. Details may be lacking, e.g. some failed to include the existence of photons to explain while other did not mention how the re-emitted of the photons results in all directions lead to the dark lines in the continuous spectrum.		
	(c)	(i)	$E_p = \frac{hc}{\lambda}$ $= \frac{6.63 \times 10^{-34} \times 3.0 \times 10^{8}}{420 \times 10^{-9}}$ $= 4.736 \times 10^{-19}$ J = 2.96 eV $E_p = \frac{6.63 \times 10^{-34} \times 3.0 \times 10^{8}}{740 \times 10^{-9}}$ $= 2.688 \times 10^{-19}$ J = 1.68 eV	M1 A0 M1 A0
		Marker's comment Average. It was surprising that some left this questions unattempted, suggesting that they did not know or understand how to compute energy of photon using wavelength. Additionally, since this is a "show" question, students need to show the full working and subtraction that results in the energy computed in eV.		

		(ii)	- 3.4 eV → - 1.5 eV - 3.4 eV → - 0.85 eV - 3.4 eV → - 0.54 eV All correct and none incorrect 2/2 2 correct and 1 incorrent **or** only 2 correct ½ **or** 3 correct ΔE but de-excitation	**B2**
		Marker's comment Below satisfactory. Many did not know that it is possible for gas molecules to be at higher energy levels due to thermal energy. They wrongly thought that the absorption of the photons must occur from the ground state. Some did not understand that the absorption of the photons, hence removal of such photons at these wavelengths, is the cause of the dark lines in the continuous spectrum. Students need to understand that the electrons will only transits from one energy level to another, and not in between.		
	(d)	$p = \frac{h}{\lambda}$ $9.11 \times 10^{-31} \times v = \frac{6.63 \times 10^{-34}}{420 \times 10^{-9}}$ v = 1730 ≈ 1700 m s^{-1}		**C1** **A1**
		Marker's comment Below satisfactory. Many either leave this unattempted or wrongly use the equation $E_P = \frac{hc}{\lambda}$ and then use the energy of the photon to equate to the kinetic energy of the electrons. Some did not use the shortest wavelength of the light beam in the question.		

7	(a)	(i)	LEDs, which is a type of diode, will only produce light when it is forward biased with the A.C. power supply.	B1
		Marker's comment Many answers did not address the reverse-biasedness of the LED when an a.c. voltage is applied across the LED. This is the key to why the LED cannot operate at full power. There were many answers with correct Physics but inevitably did not directly address the question e.g. "the r.m.s. value of the a.c. is less than the maximum value", "the a.c. causes the direction of the current to change", etc. No credit was given to such responses.		
		(ii)	A milliammeter can be connected in series to the e.m.f. / LED to determine the threshold potential difference when the current first become non-zero when the resistance of the variable resistor is varied.	B1
		Marker's comment A vast majority of answers suggested the use of a voltmeter in the circuit. No credit is given here. The question is not asking how to measure p.d. Rather it is how to determine the threshold p.d. as a visual observation of light emitted by LED may be inaccurate/difficult. Thus we require a current-measuring device in the circuit to determine whether current flows through the LED.		
		(iii)	$V = \frac{R}{R_{total}} \times E$ $1.66 = \frac{R}{500 + R} \times 9.0$ $R = 113 \approx 110\ \Omega$	C1 A1
		Marker's comment Generally well done although there were some students who wrongly thought the entire 9 V p.d. appears across the 500 Ω resistor		
	(b)	Energy released by electron = Energy of photon Since $V = \frac{\text{Work done}}{\text{charge}}$, Energy released by electron = $qV = eV$ $eV = \frac{hc}{\lambda}$ $V = \frac{hc}{e} \times \frac{1}{\lambda}$		B1 B1 A0
		Marker's comment This was very poorly done. Many students did not provide the definition of p.d. For those that did, they did not explain how work done/energy change is related to the energy of the photon. Students should take cue from the question stem which states that "*During the recombination process, the energy that the electron had previously gained is released in the form of a photon*" to then state that the energy change is from electrical energy (electron's) to photon energy.		

	(c)	**(i)**	gradient $= \dfrac{y_2 - y_1}{x_2 - x_1}$ $= \dfrac{2.40 - 1.42}{2.31 \times 10^6 - 1.60 \times 10^6}$ $= 1.38 \times 10^{-6}$ V m	**C1** **A1**
		Marker's comment Many students correctly avoided the use of data points in determining the gradient. However, many ignored the 10^6 order of magnitude for the $\dfrac{1}{\lambda}$-axis. Furthermore, many answers did not contain units.		
		(ii)	gradient $= \dfrac{hc}{e}$ $1.38 \times 10^{-6} = \dfrac{h \times 3.0 \times 10^8}{1.60 \times 10^{-19}}$ $h = 7.47 \times 10^{-34}$ J s	**A1**
		Marker's comment A significant number of students did not use the gradient from the earlier part to answer this part.		
	(d)	There are some (small) energy losses in the LEDs due to its resistance.		**B1**
		Marker's comment This was poorly done. The answer is derived from the possibility that the electron did not lose all its energy to form a photon. Some of the electron energy could have gone to making the LED hotter.		

8	**(a)**		Work = Increase in the GPE in raising the mass to ¼ of the height $= mg \times \frac{1}{4}h = \rho \times \frac{1}{3}b^2h \times g \times \frac{1}{4}h$ $= 2600 \times \frac{1}{3} \times 230^2 \times 147 \times 9.81 \times \frac{1}{4} \times 147$ $= 2.4 \times 10^{12}$ J	**C1** **A1**
			Marker's comment Poorly done. Many are not aware that the work done in lifting the limestones is equivalent to the increase in GPE needed. For those who did, many did not understand that the correct height is a quarter of its height of the pyramid, information from the passage. Some also failed to use the volume to determine the mass of the limestones involved.	
	(b)	**(i)**	<u>Negative work is done by friction</u> when dragging the stone up the slope.	**B1**
			Marker's comment Average. Students needed to be clear in their explanation to explain the effect that friction has on the work, instead of merely stating the presence of friction.	
		(ii)	 All correct and none incorrect 2/2 2 correct and 2 incorrect <u>**or**</u> only 2 correct 1/2	**B2**
			Marker's comment Average. Several did not understand that a dragging force is needed to drag the limestone up the ramp while others did not follow the instruction of labelling the forces involved.	
		(iii)	Since the stone is moving up the ramp at constant speed, $N = mg\cos\theta$ $\therefore f = \mu N = \mu mg\cos\theta$ $f = 0.75 \times 2500 \times 9.81 \cos 5°$ $= 1.83 \times 10^4$ N $\approx 1.8 \times 10^4$ N	**M1** **A1**
			Marker's comment Below satisfactory. Many did not use the free-body diagram to find out the relationship between normal force and weight. They wrongly suggest that the two values are the same or they are unable to resolve the component of weight perpendicular to the ramp surface (e.g. W sin θ). Some wrongly use 20° instead of the 5.0° which is stated in question stem of (b).	

		(iv)	$F_{dragging} = f + W_{//}$ $= \mu mg \cos\theta + mg \sin\theta$ $= 1.83 \times 10^4 + 2500 \times 9.81 \sin 5.0°$ $= 2.04 \times 10^4$ N $\approx 2.0 \times 10^4$ N	M1 A0
		Marker's comment Below satisfactory. Since many are unable to find the correct friction in (b)(iii), they fail to show how the friction and component of weight along ramp will add up to equate to the dragging force. Again, some are unable to resolve the component of the weight parallel to the ramp surface.		
		(v)	Pulleys can be placed on the posts so that more people can be pulling downwards.	B1
		Marker's comment Poorly done. A wide variety of answers is seen, with many suggesting that the posts are meant to stabilise the ramp from moving or stop the blocks while the people are resting. Students fail to address how it is easier to drag the blocks up.		
	(c)	(i)	$W = N \times F_{dragging} \times s$ $= 2.7 \times 10^6 \times 2.04 \times 10^4 \times \frac{147}{4 \sin 5.0°}$ $= 2.33 \times 10^{13}$ J $\approx 2.3 \times 10^{13}$ J	C1 A1
		Marker's comment Below satisfactory. Many did not know or calculate the correct displacement undertaken when the blocks are dragged up the ramp, instead they wrongly use the quarter of the pyramid height as the displacement. Again, there are some who are unable to use trigo to find the correct displacement. Additionally, some only find the work done to drag one block instead of all the blockes.		
		(ii)	Work = number of people × work done by 1 man in 20 years $2.33 \times 10^{13} = N \times 0.20 \times 870 \times 4.18 \times 10^3 \times 365 \times 20$ $N = 4390 \approx 4400$	C1 A1
		Marker's comment Poorly done. The answers found in (c)(i) has made it challenging for students to do the next part. Many of the answers found in (c)(i) is too small, making the students doubt their small answer in (c)(ii). Many also have difficulty piecing up all the necessary data to compute. A significant majority of the students only use the energy available by one man in 1 year and fail to recognise that the building of pyramid took 20 years.		