A Level

Physics

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PHYSICS
ELECTRONICS

Report on the June 1994 Examination

PHYSICS

ADVANCED LEVEL

Subject 9240

Paper 9240/1 (Multiple Choice)

Correct Answers

Question Number	*Key*	*Question Number*	*Key*
1	**D**	16	**D**
2	**B**	17	**A**
3	**D**	18	**A**
4	**C**	19	**A**
5	**D**	20	**B**
6	**C**	21	**C**
7	**A**	22	**C**
8	**D**	23	**B**
9	**C**	24	**B**
10	**D**	25	**A**
11	**B**	26	**C**
12	**C**	27	**C**
13	**D**	28	**C**
14	**A**	29	**A**
15	**B**	30	**D**

The average score on this paper was 16 out of 30, very similar to last year, but there were more questions which were answered correctly by a high proportion of the candidates; *Qs.5, 8, 10* each had more than 80% of the candidates choosing the correct option. The easiest question was *Q.10* with 88% of the candidates choosing correctly.

The most difficult was *Q.18* with fewer than 15% of the candidates answering correctly, whereas 58% chose option C, probably because the wire 'links' the coil. The question required candidates to use knowledge of the pattern of the magnetic flux due to a current in a wire, and to recall that maximum e.m.f. is caused by maximum rate of change of flux linkage and then to shown an appreciation of the three-dimensional aspect of the situation; this obviously proved to be too much for all but the most able candidates.

The statistics of some questions can be interpreted in a way which illustrates the reasoning by which candidates may arrive at the wrong answer; such questions this year include *Qs.4, 9, 15, 16, 17.*

Q.4 had more candidates choosing the wrong answer A than the correct answer C. This would indicate a failure to take the weight of the child into account.

Q.9 required candidates to decide whether the periods of each of three oscillators increased when the mass was increased. The decision for more than 80% of the candidates was B or C. This would seem to indicate that they were sure that the statement was true for a mass on the end of a vertical spring but not true for a simple pendulum; the doubt would seem to be about the mass tethered between two horizontal springs.

Q.15 had more candidates choosing the incorrect answer A than the correct answer B; this may have been due in many cases to a blind quoting of a known formula.

Q.16 first required the candidates to decide whether the charge on each capacitor was the same (A and D) or in a 2:1 ratio (B and C). This choice divided the candidates into two almost equal groups with the better candidates tending to choose equal charges. However more than a third of this group then chose the incorrect answer A, presumably by taking the effective capacitance to be 3.0 μF.

Q.17 was answered correctly by only 28% of the candidates. A total of 60% chose A or C, but surprisingly more chose C than A. Could it be that many candidates failed to appreciate that the direction of the current was stated.

In last year's Report there was a comment that a recall question involving the ideal gas equation was not well known; this year *Q.25*, which was a recall question on the kinetic theory pressure equation, produced only 54% correct answers. *Q.21* was also a recall question from a similar area of the syllabus and this achieved only 47% correct responses. Most other recall questions in the paper produced much higher figures so perhaps this is further indication of an area of the syllabus that would merit more attention.

Paper 9240/2

General Comments

Most candidates were able to find some questions where they were able to score marks, and totals fewer than 30 out of 80 were rare. Most were able to complete the paper within the allotted time. A small proportion of candidates who allocated their time poorly did not have time to complete question eight. These are often candidates who over answer questions, giving several answers where only one is required and writing, say, six lines of answer where only three lines are drawn. It is important that candidates should practise answering papers to time. For this paper a mark a minute is a sensible guide. There is no point in spending ten minutes on a question for which there are only two marks. The first seven questions of this paper discriminated well between the candidates who understand their physics and those who merely try to memorise it. *Q.8* did not prove to be a good discriminator as the vast majority of candidates were able to answer most parts of the question accurately. There were several occasions when a candidate doubled his or her total mark by scoring well on question eight. Still too many candidates lose marks because of carelessness rather than ignorance. The commonest faults which result in unnecessarily lost marks are – 1) omission of units, 2) calculator errors, especially power of ten, 3) $1/R$ given in place of R, or similar, 4) too many or too few significant figures being given, (this is only penalised by one mark in total) 5) leaving blank spaces when an intelligent guess would probably score some marks. A blank space always scores zero; a guess may score something – it will never score less than zero, 6) slip-shod wording e.g. writing 'energy' when clearly 'kinetic energy' is required. This last error is probably the most important of the six. In general candidates score more highly on calculation questions than on descriptive ones. The quality of reasoning sometimes leaves a lot to be desired.

Comments on Individual Questions

Q.1 This question was answered well by many candidates. *(a)* posed few problems but it was all too common in *(b)* to omit the condition 'if no external force acts'. It was deemed insufficient to write 'the momentum before equals the momentum after'. In part *(c)* there was wide evidence of confusion between kinetic energy and momentum. 'Kinetic energy and momentum are converted into sound and heat' being a typical answer to part *(i)*. The numerical answer to part *(i)* was usually correct but the unit was often incorrect. The calculation in *(ii)* was tackled well by most but omission of the minus sign and solution of the equation by division rather than subtraction (to get $v = 0.54\,\mathrm{m\,s^{-1}}$) were common errors. Part *(iii)* was poorly done by many, who, despite being asked to deal with the conservation of momentum, insisted on giving their answer in terms of the conservation of energy.

Answers: *(c) (i)* 1.6 N s, *(ii)* $-5.5 \times 10^5\,\mathrm{m\,s^{-1}}$.

Q.2 Most candidates were able to answer parts *(a), (b)* and *(c)* correctly but it is disappointing that so few candidates used the words 'force per unit mass' in *(a)* and that there were so many who thought that G was the gravitational field strength of the Earth. Answers for part *(c)* were interesting – especially from those who always call '*g*' gravity. Part *(d)* was mostly well answered but incorrect answers which were common were, for *(i)*, speed = radius/time, and speed = angular velocity (ω), for *(ii)*, $s = \frac{1}{2}at^2$, and $a = mv^2/r$ and for *(iii)*, an expression involving the mass of the Earth in place of $F = ma$. Part *(iv)* was often left blank despite just having defined gravitational field strength as force on a kilogram. Many failed to realise that the answers to *(ii)* and *(iv)* should have been numerically equal. There were the usual crop of non-sensical answer to this question. Answers such as 'the speed of the Moon equals $1.6 \times 10^{-6}\,\mathrm{m\,s^{-1}}$, or 'the acceleration of the Moon equals $6.4 \times 10^{16}\,\mathrm{m\,s^{-2}}$, ought to sound alarm bells in candidates' minds. If they did, candidates would often be able to find their own mistakes instead of letting examiners find them.

Answers: *(d) (i)* $1020\,\mathrm{m\,s^{-1}}$, *(ii)* $2.72 \times 10^{-3}\,\mathrm{m\,s^{-2}}$, *(iii)* $2.00 \times 10^{20}\,\mathrm{N}$, *(iv)* $2.72 \times 10^{-3}\,\mathrm{N\,kg^{-1}}$.

Q.3 *(a)* Parts *(i)* and *(ii)* were fine, but a very large number of candidates then drew graphs which did not pass through the point 0.25 A, 240 V. Many graphs were straight lines. Answers to part *(b)* varied enormously. Some answers easily scored full marks but there were also many blank spaces. Apart from the answer 1/30 Ω for *(i)* this part of the question was answered well. There was much vague guesswork for parts *(ii)* and *(iii)* however (this is preferable to blank spaces nevertheless).

Answers: *(a) (i)* 0.25 A, *(ii)* 960 Ω, *(b) (i)* 30 Ω.

Q.4 This question was generally well answered. The common error from the candidates who knew what they were doing in part *(c)* was to neglect the conversion to S.I. They ended up with answers 1000 times too large.

Answers: *(c) (i)* 0.030 J, *(ii)* 0.6 (±0.1) J.

Q.5 Candidates generally could not do this question. Many pages were left entirely blank and many, who often correctly started by writing down the algebraic statement of the first law of thermodynamics could not use it. Words are much more reliable than symbols for this topic. The question is really very straightforward and some candidates were able to score full marks in a very short space of time but three common stumbling blocks were noted. 1) Candidates are very unsure about the sign of any term. As far as any question set on this syllabus is concerned the sign convention of the syllabus will be followed. 2) Candidates do not seem to be aware of the fact that if the volume is constant no work will be done. 3) Candidates need to register the fact that for a closed loop the change in the internal energy around the loop is zero.

Answers: *(a) (i)* 1200 J: –600 J, *(ii)* zero: zero, *(iii)* –1350 J, *(iv)* 750 J, *(v)* 750 J, *(b)* 2.25

Q.6 This was another poorly answered question. Too many candidates were unsure of the difference between conduction and convection and phrases like 'hot molecules rise …' should not appear on A level papers. It appears that when faced with answering a descriptive question candidates give too little thought to structuring an answer in a logical manner. Instead they simply write down a series of facts and hope that some of them are relevant. Common misconceptions were that the floor provides insulation, that the bottom has to be kept cool or convection will not be able to take place and that convection is necessary to make the temperature throughout the tank constant. In part *(c)* it was very common to show a large temperature drop across the copper and a small temperature drop across the lagging. Most showed the temperature at C equal to room temperature and some even had a temperature rise taking place from A to C.

Q.7 *(a)* Disappointing answers were often given to routine bookwork. Many candidates had no idea what was meant by 'decay constant' yet they knew the equation $A = \lambda N$. Definitions of half life too were often inaccurate. It was common to find candidates writing that the mass became half in one half life. Candidates would be well advised to express half-life as the average time taken for the *activity* of a particular radioactive nuclide to fall to half its initial value. This gets over the problem of whether it is the amount, or the mass or the number of atoms or the quantity, which is reduced to half.

(b) Answers here were better but units were often muddled. Any correct value was acceptable whether time units were seconds or years.

Answers: *(b) (ii)* $4.18 \times 10^{-9}\,s^{-1}$, *(iii)* $4.19 \times 10^{13}\,Bq$.

Q.8 This question was answered well by nearly all candidates. Parts *(a)* to *(e)* proved to be very straightforward with most candidates being able to use the unfamiliar nomogram very readily. Part *(f)* was poorly done however. A huge majority could not see that with 'efficiency' defined the way it is an 'efficiency' of more than 100% is possible. Most stated that an efficiency of 100% is impossible in practice. Their reasoning from this statement onwards was often revealing. Many said that an efficiency of 100% cannot be achieved because some energy will be lost as heat, many assumed that an efficiency of 100% means stopping instantly while many more stated that a deceleration of anything greater than *g* (often called gravity!) will cause injury. It was strange the way that many found the stopping distance rather than the efficiency, as requested, and also that many did not use the chart but calculated the stopping distance.

Answers: *(a)* 75% (±1%), *(b)* $7.35\,m\,s^{-2}$, *(d) (ii)* 90 (±2) m: 22% (±1%), *(f)* 105% (±3%).

Paper 9240/3

General Comments

The paper produced a wide distribution of marks, with a fairly even choice of questions from Section A. In Section B, the majority of answers were, as usual, drawn from the *Physics of Transport* option but there was a significant and welcome increase in the number of attempts at questions from the *Communications* and the *Medical Physics* options.

A pleasing trend over the last few years has been a slow but steady improvement in the standard of presentation. There are still too many scripts wherein sentence construction is very poor and where some of what is written is quite meaningless if taken literally. However, there appears to be more awareness of the need for effective communication and, apart from the improvement in the clarity of prose, fewer numerical answers consist solely of a jumble of figures and more sketch diagrams show accurately the important features which are being considered.

In a disappointingly large number of scripts, candidates who scored good marks on the paper as a whole revealed in their answers to the 'comment' and 'discuss' parts of questions the superficial nature of their knowledge and understanding of the subject.

Most candidates appeared to have allocated their time satisfactorily and few appeared to have been prevented from completing their answers by a lack of time. There were a few rubric infringements, mainly by weaker candidates who appeared misguidedly to think that it would be beneficial to answer as many bits of questions as possible, regardless of where they were located.

Comments on Individual Questions

Section A

Q.1 Answers: *(c) (i)* 20.6 m s^{-2}, 648 N; *(ii)* 8230 J, 20.5 m s^{-1}

(a) Angular velocity was often loosely defined in terms such as 'the velocity in a circular path' or 'the velocity measured in radians per second'. Of those candidates who did give some sort of definition by reference to rate of change of angular displacement, very few indicated that angular velocity is a vector quantity.

(b) In *(i)*, almost all candidates gave a correct relationship between the given quantities. Although v was clearly defined in the question as speed, in *(ii)* it was common to find an argument based on v changing due to a change in direction. In part *(iii)*, many answers merely made reference to a tension in the cord providing the centripetal force although the question did ask for an explanation as to why such a force is needed. Part *(iv)* presented very few difficulties although some arguments were not very convincing as to the step from mv^2/r to $mv\omega$.

(c) *(i)* Most candidates correctly calculated the acceleration although it was common to find the answer given to an unjustifiable number of significant figures. The associated centripetal force was then calculated but rarely was any account taken of the weight of the passenger when determining the force of the seat on the passenger. In part *(ii)*, the calculation of the change in potential energy presented very few problems. However, when calculating the speed at the bottom of the loop, most candidates ignored the kinetic energy of the passenger when at the top of the loop. Some added the speed at the top of the loop to a speed which had been calculated by considering only the change in potential energy. In part *(iii)*, almost all candidates indicated in some way that the passengers and/or cart might fall off the track or roll back if the speed at entry was too low. Many dwelt at unnecessary length on commercial or personal consequences but comparatively few explained the limiting condition occurs at the top of the loop when weight is numerically equal to centripetal force. A common misunderstanding was to assume that the limiting condition would occur when the kinetic energy at the top of the loop was equal to the increase in potential energy in reaching the top.

Q.2 Answers: *(b) (i)* 1.46 mA, 0.78 mA; *(ii)* 29.2 V, 15.6 V; *(iii)* 22.4 mC; *(iv)* 1650 μF.
(d) (i) 33 s; *(ii)* 0.27 mA.
(e) (i) 31.5 s.

(a) Capacitance was defined in terms of charge and potential difference but the essential 'ratio' was not always made clear. Capacitance should not be defined as 'the charge required to raise the potential by unity'. Very few errors were made as regards units. Some referred to a charge of 1 coulomb flowing under a potential difference of 1 volt.

(b) *(i)* There were very few problems associated with the reading of the graph. In *(ii)*, most calculated the potential difference across the capacitor as being equal to that across the resistor but explanation was sadly lacking. Part *(iii)* was not understood. The majority of candidates used the formula $Q = It$, substituting the values of I at $t = 10$ s and $t = 30$ s then subtracting the two values of Q, without any consideration of the meaning, if any, of the answer. In *(iv)*, most candidates correctly used their results from *(iii)* in order to determine a value for the capacitance. It was surprising that a significant minority of answers involved using an average value of the voltage although an average value for current had not been considered when calculating the charge.

(c) It was disappointing to find so few candidates who said they would plot a graph of ln*I* against *t* and would draw appropriate conclusions from the resulting straight line. Some candidates decided to investigate the 'half-life' of the given curve, thereby establishing satisfactorily that the curve is exponential but not necessarily relating their findings to the value *RC*. Many stated with varying degrees of justification, that they would substitute values read from the graph into the equation.

(d) *(i)* This presented very few problems although in *(ii)*, many were defeated by the mathematics or compounded earlier errors by reading a value for *i* from the graph.

(e) The reading of the graph was usually quite satisfactory but comparatively few realised and clearly explained that the two times to be compared should have been the same. Where candidates did not have similar values due to earlier errors, many did their best to explain the difference and some, to their credit, doubted the validity of their calculations.

Q.3 *(a)* The vast majority of candidates were able to interpret the curve and give correct times.

(b) *(i)* Almost all candidates sketched a sinusoidal curve of constant amplitude and having the correct frequency. The phase of the curve did present some difficulty. In part *(ii)*, it was pleasing to observe that many candidates explained the shape of their sketch clearly and succinctly by reference to the laws of electromagnetic induction and the speed and direction of motion of the magnet. However, a significant number did attempt an explanation in terms of the magnet entering and leaving the coil, although the graph drawn in *(i)* was appropriate only to oscillations wholly within the coil.

(c) This part of the question was poorly answered. Very few candidates sketched a damped oscillation and often these showed erratic variations in amplitude and/or large variations in the period of oscillation. In many cases, a sketch was drawn which was similar to that in *(b)* *(i)* but of a smaller constant amplitude. Most candidates stated that thermal energy would be dissipated in the resistor but few explained the essential difference between the two cases, i.e. that in the second case, there is a current through the resistor which dissipates energy as thermal energy at the expense of the energy of the magnet. A correct answer to part *(iii)*, involving a heavy or critical damping, was rarely seen. The usual answer involved an assumption that, for small values of resistance, the situation would approximate to the original open circuit state, with a curve similar to that drawn in *(b)* *(i)*.

Q.4 Answers: *(b)* *(i)* 6.45×10^{-10} s; *(ii)* 1.6×10^{4} V m^{-1}; *(iii)* 2.56×10^{-15} N; *(iv)* 2.81×10^{15} m s^{-2};
(v) 1.81×10^{6} m s^{-1}
(c) 0.88 cm

(a) For the description of the c.r.o., most candidates did include some form of electron gun, two sets of deflecting plates and a screen. Very many omitted to make reference to an evacuated enclosure, and there were some odd descriptions of the phosphor coating on the screen, including 'a coating of phosphorus'.

(b) The calculations were completed satisfactorily by many candidates. The most common error (apart from arithmetical errors) was in *(v)* where the speed in the direction of the electric field was found using an equation for uniformly accelerated motion, assuming an initial speed of 3.1×10^{7} m s^{-1} in the direction of the electric field.

(c) Most candidates who had calculated a realistic value for the speed in *(b)* were able to determine the deflection although many used highly involved calculations. Some left the deflection in angular form.

(d) The correct plotting of the deflection from the previous calculations presented few difficulties. However, in *(ii)*, a large proportion of candidates appeared to think that it was necessary to assume that a time-base was being used on the c.r.o. when a sinusoidal signal was applied to the Y-plates. Regardless of this, the amplitude of the trace was often wrongly shown. There was confusion between the r.m.s., peak and peak-to-peak values. In (2), most candidates' answers were consistent with that shown for the sinusoidal wave.

Q.5 Answer: *(c)* 6.4 s

(a) Most candidates were familiar with the Young's double slit experiment and satisfactorily described the lay-out and the measurements to be made, and gave a relevant formula. The most common omission was the single slit, with the light source merely labelled as 'lamp'. A minority of candidates confused the double slit with a grating. Values given for the dimensions of the slits varied from centimetres to nanometers. It was not uncommon to find slit width greater than separation. Answers to part *(iii)* were generally poorly composed. Most candidates made reference to diffraction at the slits and that interference was responsible for the fringe pattern but clear reference was not made to superposition and constructive/destructive interference.

(b) Apart from some confusion between photons and photoelectrons, most candidates gave a satisfactory statement of the photoelectric effect. The relevant observations were known although often described in very loose terms. For example, the *number* of photoelectrons emitted was said to depend on intensity.

(c) The calculation posed very few problems although some candidates introduced complications and errors by calculating the number of 'circular' atoms which cover unit area and then dividing the power incident on that area between the atoms. Arithmetical errors were not uncommon and the formula for the area of a circle was frequently incorrect. In part *(ii)*, many candidates did realise that the time delay as predicted by wave theory is at variance with experimental observation and that the theory in inappropriate.

Q.6 Answer: *(c)* 79 °C

(a) Many candidates discussed the nature of the variation of a physical property of a substance with temperature rather than explain how this variation could be used to measure temperature. Many said that the property must vary linearly with temperature, though candidates making this assertion often referred later in their answers to the non-linear variation of resistance with temperature. Of those candidates who did consider fixed points and calibration, many quoted a formula using confusing symbols which did not clearly identify the unknown temperature and the value of the property at the fixed points and the unknown temperature.

(b) Most descriptions of a liquid-in-glass thermometer were very superficial. Mercury-in-glass was usually chosen but only very infrequently was reference made to the thin wall of the bulb, the thick wall of the stem of the capillary nature of the bore. Many answers did not make reference to a scale on the stem. In part *(ii)*, few answers dealt with the *relative* advantages and disadvantages in the *same* temperature range. All too often, lists of advantages and disadvantages were given for each type without any attempt to relate one to the other. The type of resistance thermometer being considered was rarely mentioned.

(c) *(i)* Many candidates appeared to be familiar with applying the formula to situations where the value of the property increases with increasing temperature. Consequently, there was much confusion as regards substitution and signs. Candidates who calculated the change in resistance per degree change in temperature often subsequently calculated the temperature

interval but then made no reference to fixed points. In part *(ii),* many answers made reference to non-linearity although a significant proportion of candidates gave an explanation in terms of experimental errors.

(d) *(i)* Most candidates were able to distinguish the absolute scale of temperature from other scales and in *(ii)*, many candidates deduced the correct expression. However, there was much confusion and lack of explanation as regards molar mass and molecular mass, and number of moles and number of molecules.

(e) Most candidates recognised that an increase in total energy without a change in temperature involved a change in phase. Unfortunately, explanations were usually inadequate and merely involved latent heat without reference to change in potential energy associated with change in separation of atoms.

Section B

Sound and Music

Q.7 *(a)* In general, candidates were able to distinguish correctly between intensity and loudness. Most said that the 3 kHz sound would be louder than that at 20 kHz, but relatively few mentioned that the higher frequency sound would be unlikely to be heard.

(b) Most answers made reference to the number and intensity of overtones as the factors governing tone. Many candidates sketched graphs to show differences in waveform but unfortunately little or no thought was given to keeping the predominant frequency the same in each case. They did, however, state that the predominant frequency must be the same in order for the instrument to be tuned to the fork.

(c) There was a general awareness that tuning involved change in length of the air column in the case of the recorder and change in tension for the guitar string. Not many candidates explained why change in these factors affected fundamental frequency and, in the case of the recorder, it was not made clear how the length would be altered.

Q.8 This question was answered by very few candidates.

(a) There were very few answers where a stationary wave was described as the interference of two waves travelling in opposite directions with the resultant pattern of nodes and antinodes. Even fewer answers included a statement that there would be no net transfer of energy along the wave.

(b) Most candidates were familiar with the modes of vibration of a drumskin and were able to identify and illustrate the positions of nodes and antinodes in the waves.

(c) The difference in the overtones present and in the loudness of the sound produced in the two cases were adequately discussed.

(d) Most candidates knew that areas of different shapes and thickness on the top of the drum would produce different frequencies but most were unaware of the fact that the length of the drum also affects the overtones which are most evident.

Q.9 *(a)* Most observations on the acoustic properties of a room amounted to little more than generalisations such as 'how well you can hear the sound'. There were relatively few discussions based on reverberation time and the distribution of sound power. However, in part *(ii)*, most candidates correctly discussed the effect on reverberation time of including absorbing or reflecting materials in a room. Unfortunately, once again, there were very few answers which included any reference to distribution of sound power.

(b) *(i)* The need to maintain constant acoustic properties was widely appreciated and consequently, some good explanations were given. However, in *(ii)*, there was less agreement as to the effect of the panelling. Many stated that the reflecting properties would be enhanced. Relatively few maintained that multiple reflections within the cavities formed by the panelling would absorb sound energy and hence reduce reverberation time. In part *(iii)*, most candidates referred to the difference in thickness of the two sheets and to the varying width of the air gap. Usually, the explanations were plausible.

Communications

Q.10 Answers: *(b) (i)* 7.85 Ω, 1.81 V, 7.32 V; *(ii)* 5.51 V; *(iii)* 503 Hz

(a) Candidates who attempted this question appear to have been attracted by the calculations and were not well-equipped to write brief notes. Consequently, the notes were very brief, rarely going beyond vague statements such as 'opposes direct current' or 'opposes alternating current'. Few candidates made any reference to power dissipation.

(b) The calculations in *(i)* presented very few difficulties. In part *(ii)*, the phase relationships were correct in most cases, but there were far fewer correct deductions of the magnitude of the supply p.d. The most common error was to add the components vectorially as if the phase angle between them was 90°. The formula for resonant frequency was widely known and most made reference to circuit resistance as a limiting factor.

Q.11 *(a)* Most answers included a statement that the carrier wave is a wave on which information to be transmitted is superposed. Very few answers included any further detail.

(b) Almost all candidates stated or implied that, for AM, the frequency of the carrier wave remains constant. Thereafter, answers tended to be muddled. Few candidates gave clear sketches to support vague statements and calculations of the amplitude or frequency variations were often incorrect or non-existent. Very few candidates made it clear that the frequency of the modulation would be 1.0 kHz.

(c) It was widely appreciated that an AM wave is equivalent to a carrier wave plus two sidebands. Bandwidth was usually associated with this range of frequencies but few candidates related bandwidth to the modulation frequency. In part *(ii)*, some candidates related quality of reception to bandwidth and most mentioned the limitation imposed by bandwidth on the number of channels available in a given waveband.

Q.12 Answers: *(b) (ii)* 100 Hz; *(c) (i)* 9.0×10^{-7} W

(a) Most candidates stated that a digital signal can take only set values. Surprisingly few added a simple diagram or emphasised the 'pulse' nature of the signal.

(b) There were very few errors associated with converting the binary numbers to their decimal equivalents. The majority then treated the output as an analogue signal and plotted a smooth curve. A minority drew a stepped graph but equal credit was given for each. Many then simply quoted the sampling frequency as the pulse transmission frequency.

(c) *(i)* A surprising large proportion of candidates muddled P with P_0. In part *(ii)*, sources of power loss which were listed were usually reasonable.

Medical Physics

Q.13 *(a)* As usual, this type of question attracted weaker candidates who were unable to express their ideas succinctly. Some candidates referred to the breaking of bonds in vital molecules in living tissue but most wrote in vague terms about 'cell damage caused by ionisation'. The probable effects of such damage were quite well covered with most candidates mentioning permanent damage, short- and long-term problems associated with cellular reproduction and genetic mutations.

(b) Answers to this section were generally of poor quality. In part *(i)*, entire discussions were concentrated on the relative penetrating properties of the different types of radiation with only passing reference, if any, to density of ionisation. Most candidates failed to distinguish between parts *(ii)* and *(iii)*, effectively saying that 'the more you get, the worse it will be'. A minority of candidates did make reference to repair mechanisms and time for repair.

Q.14 Answer: *(b)* 2.67 D

(a) With very few exceptions, candidates diagnosed long sight and showed that they knew the significance of the near point although the majority defined it as a distance rather than a position.

(b) *(i)* Most diagrams correctly showed rays diverging from the near point and converging after refraction at the cornea to a point behind the retina. Some candidates complicated matters by including an eye lens but then showed all the refraction occurring at the air-cornea boundary or at the lens. In *(ii)*, most diagrams included a convex lens. The most common error was to show the rays converging to a point behind the eye after refraction through the convex lens rather than diverging from the actual near point of the eye. In part *(iii)*, most candidates knew the lens formula and the relation between focal length and power of the lens. Unfortunately, many failed to apply any sign convention when substituting into the lens formula.

(c) There were many good answers to this part of the question but a surprisingly large number of answers did not deal with direction of change and consequently did not arrive at the conclusion that the curvature must be increased, but merely that it must be changed.

Q.15 Answers: *(c)* *(i)* 45.9 kJ, *(ii)* 19.1 g

(a) Basal metabolic rate was understood by almost all candidates although there was confusion between energy and power. The extra requirements for children for growth were also recognised.

(b) Many candidates correctly calculated the output power developed by the man and concluded that 1700 W was unreasonable for a normal person. Others merely stated that the man would be climbing 11 steps per second for both approaches. Several candidates made calculations which purported, with no foundation, to find the speed of the man at the beginning or at the end of the climb.

(c) If they had not already done so, most candidates were now able to calculate the gain in potential energy during the climb. Unfortunately, at this stage, many attempts at finding the wasted energy were failures. In part *(ii)*, most candidates understood how to obtain the mass evaporated but, what with incorrect answers to *(i)* and a general failure to take into account the units, answers varied between 310 kg and 9 μg.

(d) Many candidates realised that thermal energy may be lost by alternative mechanisms and

consequently the mass of sweat would be less. Rather fewer observed that, conversely, the mass required would increase because not all sweat would evaporate.

Physics of Transport

Q.16 Answers: *(c) (ii)* 70.1 m s^{-1}, *(iii)* 8130 N

(a) Most candidates stated that the fluid would experience a change in momentum in passing through the propeller. Many then went on to discuss Newton's laws, making reference to rate of change of momentum, force, action and reaction. A significant minority stated quite wrongly that the vessel would gain momentum equal but opposite to that gained by the fluid (rather disconcerting for a mechanic running up aircraft engines on the ground!).

(b) Many candidates appeared to be familiar with the derivation – so much so that they failed to give explanation such as why the volume of air moved per unit time is $\pi r^2 v$ or that unit time has to be considered.

(c) *(i)* Some candidates, not being familiar with the expression *power = torque × angular speed,* assumed that the torque was produced by a resultant force at the tip of the blade. They then calculated the linear speed of the tip and substituted in to the formula $P = Fv$. Full credit was given for this approach if the assumption was explained. Unfortunately, many failed to give any explanation. In part *(ii),* most candidates were able to calculate the speed and then to determine the thrust. A number of candidates calculated the thrust (16300 N) as the rate of change of momentum of the displaced air. Full credit was given for this approach.

Q.17 *(a)* Almost all candidates were able to identify the four forces, although not always with conventional terminology. In part *(ii),* a surprisingly large proportion of candidates gave the condition as either zero resultant force or zero resultant turning moment, but not both. A significant number maintained that, for level flight, thrust must be greater than drag to ensure forward motion. Candidates recognised that, in *(iii),* the tailplane provides stability but few were aware of which axis of rotation is involved. Clear explanations of the restoring couple produced by the tailplane when a pitching displacement occurs were exceedingly rare. In part *(iv),* many candidates realised that loss of power would lead to a 'nose-down' situation which would result in a safe glide flight path. However, the reason for the 'nose-down' situation was rarely explained.

(b) A number of candidates tried to ascribe some significance to either the comparative lengths of arrows on the diagrams or to changes in wing shape. The majority decided that, in the event of loss of power, a 'nose-up' situation would arise which, without corrective action on the part of the pilot, would lead to a stall.

Q.18 *(a)* Explanations of upthrust were vague. Rarely was the direction of the force given or its magnitude related to the weight of fluid displaced. Similarly in *(ii),* a surprisingly large number of candidates were unable to explain clearly why, for example, a ship can float in water.

(b) Stability was not understood, with most candidates confusing it with equilibrium. Very few answers included the consequences of a small displacement from an equilibrium position. In part *(ii),* there were many verbose discussions about waves, tides and conning towers with comparatively few clear diagrams which showed the submarine displaced from its equilibrium position with the positions of centre of gravity, centre of buoyancy and the forces of weight and upthrust clearly marked. There were some good answers including

definitions of the metacentre and the implications of its position relative to the centre of gravity, but these were the exception.

(c) Here again, candidates failed to discuss the effects of the changing positions of the centre of gravity and the centre of buoyancy as the submarine submerges.

Paper 9240/4

General Comments

The vast majority of candidates who took this paper were able to complete both the practical tests in the allotted time with little or no help from the supervisors. There were only a few candidates who scored very low marks, and many candidates who had followed a suitable practical course were able to demonstrate adequately their practical skills. The level difficulty of the paper seemed to be about right, with many weaker candidates being able to at least make an attempt to perform both experiments.

Comments on Individual Questions

Q.1 Candidates were required to investigate the variation with temperature of the resistance of a thermistor. Most candidates were able to set up the equipment with no help from the supervisor. When help was given it was usually because the candidate had connected the voltmeter in series with the thermistor. Very nearly all of the candidates were able to obtain readings from their equipment, although some took more readings than they were asked to do (five readings only required) and so wasted time. Many gained credit for stating that 'the water was stirred' or 'placing the bulb of the thermometer near to the thermistor'. Very few mentioned the importance of maintaining a steady temperature when readings were being taken, and fewer stated how it was achieved.

Candidates were asked to calculate a value for the resistance of the thermistor, and justify the number of significant figures that they had given in this value. It was very common to see the weaker candidates give reasons which were based on decimal places and not significant figures. Candidates often gave explanations in terms of the accuracy of the meters. 'The current was measured to two decimal places so the value for R has to be given to two decimal places' was often seen. A significant number of candidates ignored this part of the question altogether. Generally it is accepted that calculated quantities will be given to the same number of significant figures (or one better) than the least accurate data used in calculating the quantity.

One mark was available in the scheme for general presentation. This was awarded when the results and analysis had been presented in a manner that could be followed easily. Most candidates were awarded this mark. The candidates usually presented their results in a table, and split tables were usually easy to follow. Many candidates wrote down their initial set of observations, and then proceeded to record the subsequent four observations in a table. These candidates were not penalised, but it would have obviously been better if all the results had been recorded in a single table of results.

It is expected that candidates will record all the raw data from their experiment. A small number of candidates did not list the values of temperature as read from the thermometer, and gave values of T instead. Most candidates gave the correct labels on the column headings, but did not always state the units of the quantity being measured. Some candidates gave column headings that were ambiguous or incorrect. For example, 'I mA' was sometimes seen, which was unacceptable. I/mA, I in mA or I(mA) would all have been allowed. A few candidates gave only the unit of the quantity being measured at the head of the column.

When recording raw readings it is generally accepted that all the readings will be given to the same degree of accuracy. Most inconsistencies occurred in the recorded values of temperature, where some values were given to the nearest degree, and others were given to the nearest tenth of a degree.

A number of candidates forgot (or were not able to) convert the readings on the milliammeter into amperes when calculating values for the resistance.

There was much confusion amongst the candidates when it came to the number of significant figures that should be quoted in the values of $1/T$ and $\ln(1/R)$. Generally it is accepted that calculated quantities will be given to the same number (or one better) of significant figures of the least accurate data which is being used in the calculation. A significant proportion of candidates who had measured temperatures to the nearest tenth of a degree (three significant figures) gave values of $1/T$ to two significant figures with resulting loss of accuracy. Other candidates who had measured temperature to the nearest degree (2 significant figures) gave values for $1/T$ to four, or sometimes five, significant figures, which was not justified.

The units for $1/T$ were often omitted, both in the table of results and on the graph. Candidates were told to take readings from their equipment for temperatures varying from about 20 °C to about 80 °C. It is generally considered to be good practice to allow reasonable intervals between readings. Some candidates chose to use intervals of less than 10 °C between readings and incurred a one mark penalty.

Most candidates correctly plotted a graph of $\ln(1/R)$ vs $1/T$, although a few disregarded the instructions and plotted $1/R$ vs $1/T$ or $\ln(1/R)$ vs $\ln(1/T)$.

The choice of scales made many candidates often resulted in the plotted points occupying a very small portion of the graph grid. It is generally expected that candidates will make full use of the whole of the page when plotting a graph.

It was disappointing to see a small number of weaker candidates using non-linear scales on their axes in an attempt to plot points on the bold lines of the graph grid. Some candidates chose very awkward scales (e.g. one large square on the graph paper equating to three units of the plotted quantity) and were penalised.

Most candidates were able to plot the points correctly (to within one small square on the graph grid). A few candidates tried to plot points in the margin by the side of the graph grid. Other errors included plotting only four of the observations (instead of five) and making the plots so thick (half square or greater) that the plot could not be located properly.

Most candidates drew a reasonable straight line through the plotted points. Marks were only lost when the 'off-line' points were all on one side of the line of 'best-fit'. When measuring the gradient of the line many candidates drew a 'triangle' on the line that was too small. It is generally considered to be good practice to choose two points on the line that are far apart from each other so that an accurate value for the gradient can be determined. In many cases candidates drew triangles that occupied less than half the length of the line that they had drawn.

The main errors that candidates make in measuring the gradient were:

(i) using $(y_1-y_2)/(x_2-x_1)$, which gave a positive value for the gradient instead of a negative one;

(ii) not including the multiplying factor of 10^{-3} when reading the $1/T$ axis, resulting in values of the gradient being too small;

(iii) misreading the scales when measuring Δy or Δx;

Many of the weaker candidates experienced difficulties in finding a value for the y-intercept. A significant number of candidates read an intercept value from wherever their line happened to cross an axis. In some cases this was the x-axis. In other cases values were taken from a y-axis that the candidate had drawn that did not pass through the origin. Only the better candidates were able to calculate a value for the y-intercept by using a point on the line.

It was pleasing to see that the vast majority of candidates were able to express the given equation in logarithmic form ($\ln(1/R) = -B/T + \ln A$). However, only the very best candidates equated –B with the gradient of the line and lnA with the y-intercept. The most common error made by the candidates was to state that gradient = B instead of –B.

Many candidates had difficulties with the units of the constants A and B. Again, only the very best candidates were able to state the unit of A to be Ω^{-1} and the unit of B to be K.

Q.2 Most candidates had the general ideal of what to do, and nearly all managed to describe some kind of valid experimental procedure. A few candidates were unsure how to use the plumb-line, and some of these candidates suspended the plumb-line inside the tube of oil. Others tied the cotton to the tube and allowed the bob to rest against the glass wall of the tube. The better candidates drew a diagram showing how the plumb-line was used.

The magnet that was supplied was intended to be used to allow candidates to retrieve the balls from the bottom of the tube. It was evident that some candidates had been supplied with magnets that were not strong enough for this purpose, and encountered difficulties. A surprising number of candidates used the magnet to release the ball (held against the side of the tube).

One mark was available to candidates who used a reasonable distance of fall for the balls (50 cm or greater). A few used smaller distances (<10 cm) and obtained very inaccurate times.

Further credit was given to candidates who gave details of good experimental procedures such as leaving a sufficiently large enough distance at the top of the tube in order to allow the balls to reach terminal velocity, or explaining how the zero error on the micrometer was dealt with when measuring the diameter of the largest ball. Most candidates realised that they had to repeat the experiment to improve the accuracy of the results, and took several values of the times of fall (which were nearly always averaged correctly).

A surprisingly large number of candidates experienced difficulties using a micrometer to measure the diameter of the largest ball. There were wide variations between centres where nearly all the candidates knew how to use a micrometer, and others where the supervisor's value for the diameter of the largest ball did not agree with any of the candidates' measured values.

A number of Centres did not supply values for the diameters of the balls used by the candidates, which presented difficulties for the examiners when it came to checking values. Centres are reminded that they should make every effort to ensure that the information requested is supplied, and that it is accurate and complete.

Some candidates wasted time by measuring the diameters of all the balls that were supplied, and did not use the values of the diameters of the four smallest balls as supplied by the Centre.

A number of candidates used only four balls in their experiment. It was difficult to determine whether this was due to one ball being 'lost', or the Centre supplying only four balls, or that the candidate had chosen to use only four balls in their experiment. Generally it is considered to be good practice to have at least five points on a graph, and candidates who used only four balls were penalised.

A few candidates detached the plumb-bob from the cotton and used it as the largest ball.

As in the first experiment, it is expected that candidates will record all their raw readings. Many candidates gave values for the radii of the balls, and the diameters. Some candidates became confused when recording their results in the table, and it was common to see values of the diameters of the balls labelled as radii.

Most candidates recorded their results clearly, but again, as in the first experiment, many candidates did not label each column of results with a quantity and a unit. The consistency of the raw readings recorded by candidates was much better in this experiment than the first experiment. This was probably because digital stopwatches were used by most centres, and the vast majority of candidates gave all the times of fall to two decimal places. It would have been sensible for candidates to give values for the times of fall to 0.1s rather than 0.01s, but no marks were deducted if candidates recorded values of time of fall to 0.01s.

As in the first experiment, candidates were confused as to the number of significant figures that they should give in their calculated values. Candidates should be quite clear that they should give calculated values to the same number of significant figures (or one more) than the least accurate data used in the calculation.

Credit was given to candidates who plotted a suitable graph from their results. Any valid choice of variables was allowed, and most candidates chose to plot a graph of terminal velocity against radius^2. On the whole candidates chose sensible scales for this graph, and most graphs that were seen filled the whole of the graph grid.

If the experiment had been done carefully, the results should show that the points lie on a smooth curve passing through the origin. Many candidates, who obtained a set of points on the graph grid that clearly showed a curved trend, attempted to draw a straight line through the points in order to 'prove' that the given relationship was 'true'. A number of candidates tried to 'derive' the suggested relation theoretically, and assumed that the relationship was true before they had even started the experiment. Only the very best candidates had enough confidence in their results to suggest that the given relationship did not hold under the conditions in which the experiment was performed.

Candidates were asked to suggest some improvements to their experiment. Many vague responses were seen that were unable to gain any credit. Examples of these type of answers are:

(i) 'use a computer to take the readings'

(ii) 'use an electronic timer to improve the timing'

(iii) 'do the experiment more carefully'

Several referred to techniques that should have been used in the first place (e.g. 'next time I would make the tube vertical'). Candidates' responses that gained credit in this section usually involved falling balls breaking beams of light from a light gate connected to a timer. Some candidates suggested using longer tubes in order to reduce the error in the measurement of time.

Paper 9240/9 (Centre-Based Assessment of Practical Work)

Much interesting practical work is being made available to candidates by their teachers in Centres. The Moderators were pleased to note that the majority of Centres have assessed each skill many more times than the minimum number required.

During moderation, the Moderators try to match the skill assessments listed on a Student Record Card as contributing towards assessment with the experiment in the sample of that candidate's work. In some instances, many pages of experimental work not counting towards the final overall mark are submitted, and it would be appreciated if those experimental accounts contributing to assessment could be indicated, perhaps by tagging. The Student Record Card should also clearly highlight the relevant assessments if more than the minimum are included. Centres should send copies of the instructions given to candidates and of the mark schemes used by teachers with an indication of how those schemes have been applied. Moderators were handicapped in their task by the non arrival of some of the vital evidence.

Questions taken directly from past Practical Examination Papers, or experiments from text books, tend not to be appropriate if they are too prescriptive and are often more appropriate for the assessment of Skill C1. However, such questions can be modified by the removal of prescriptive instructions such as detailed diagrams of the experimental set-up, the range of readings to take or what to plot, to create good material for a range of assessments.

It is not possible to award full marks for both Skill Cl and Skill C4 when assessed together in one experiment, since following instructions and displaying design skills are incompatible.

In presenting work for the assessment of Skill C2, candidates should aim for repeated readings, an appropriately wide range of readings of results, to an appropriate and consistent number of significant figures, correct units throughout and neat tabulation of readings. Work that does not display these attributes should not be awarded 5 or 6 marks for this skill and consequently the scores from some Centres were adjusted to reflect this.

Under Skill C3, candidates in some centres seem to be placing too much emphasis on the calculation of errors for each measured quantity, without an adequate understanding thus showing a failure to appreciate the underlying Physics. An analysis of the experiment, with some appreciation of its limitations, was often missing from high scoring candidates. Interpretation through graphical work, as has been noted in previous years, still remains in need of attention.

Appropriate practical tasks for Skill C4 should allow all the design criteria to be achieved. It would be good practice for candidates to start each design task with a statement of the problem set, which ideally should have several alternative approaches clearly available to the candidate, so that a variety of methods may be appraised.

For Skill C5 assessments, the use of graph-plotting computer packages should be limited, so that candidates are able to display their own skills at drawing graphs. Many cases were noted of candidates being awarded 6 marks for skill C5 despite obvious major errors, of which inappropriate significant figures was common. Again, scores from such Centres were accordingly adjusted.

Teachers in some Centres are, by correcting work carefully and by giving appropriate written advice and feedback, helping their candidates to improve their practical coursework. However, a significant amount of apparently uncorrected work, with few written comments, was included in the sample sent for moderation by other Centres, for which practical marks tend to be relatively lower and candidates' work tends to show less development.

Paper 9240/0 (Special Paper)

General Comments

The standard of candidates for this paper continued to maintain the high level shown in previous years, and the quality of presentation of work showed a gratifying improvement. The examiners were particularly grateful to note that most candidates had heeded the request in the 1994 rubric that 'answers and part-answers should be clearly labelled', and the warning that 'lack of orderly presentation many be penalised'.

Comments on Individual Questions

Q.1 This was the most popular question on the paper, being attempted by over 90% of candidates, and in general it seemed to be found to be fairly straightforward.

(a) Nearly everyone could pick up two marks here. A small minority of candidates did not appreciate the distinction between SI base units and SI units in general, and produced unexpectedly long lists of units. Some candidates did not recognise the distinction between a quantity (e.g. mass) and its unit (kilogram).

(b) Most candidates also had little trouble here. A few lost credit for failing to reduce their answers to parts *(ii)* and *(iii)* into base units (usually leaving them expressed in terms of the joule). Some candidates obtained incorrect answers in any case. If they failed to show their working (presumably relying on 'rough' working not submitted), as some did, the Examiners were unable to award any credit at all. A minority of candidates wrote down equations, from which to derive answers to parts *(ii)* and *(iii)*, in terms of 'Q' (for heat), and then interpreted the symbol to mean electric current.

(c) This part produced some separation of candidates, as the Examiners had hoped it would. Most could make sense of part *(i)*, although marks were deducted from candidates who failed to explain how they interpreted the information that the constant α had no units, and from candidates who merely produced a pile of unexplained algebra, usually ending with a statement to the effect that 's = s therefore true'. Part *(ii)* showed that a number of candidates did not understand the meaning of raising a value to a fractional power, and that virtually all candidates failed to read that they were required to calculate cooking times in minutes, not seconds. Graph-drawing skills showed the expected range of ability, with many candidates choosing unsuitable scales for their graphs (e.g. 3 cm to 0.5 kg) or failing to plot a range of values large enough to include an intercept in part *(iii)*. Part *(iii)* also showed considerable variation in candidates' abilities to choose the best straight line through a set of points, though the Examiners allowed considerable latitude in the acceptable values of A and B.

Numerical answers: *(c) (ii)* 43, 68, 89, 108, 125, 141 minutes; *(c) (iii)* A = 39 minutes per kilogram, B = 27 minutes

Q.2 This was another very popular question, being attempted by about 90% of candidates. The marks for this question were the highest for the whole paper, with about an eighth of those candidates who attempted it gaining full marks.

(a) Although this part was in general well done, few candidates managed to obtain full credit, owing to inadequate or illogical explanations. One or two candidates appeared to believe that the statement in part *(a) (ii)* was possible in the case of simple harmonic motion.

(b) Most candidates experience little difficulty with this part. Some took less trouble with their sketch graphs in part *(i)* than the rather generous allocation of marks might have suggested, failing to identify (for examples) the value of the maximum and minimum velocity components, and the times at which the velocity components began to change or reached zero. Nearly everyone obtained full credit for part *(ii)*, but in part *(iii)* the majority of candidates calculated the average speed rather than the velocity.

Numerical answers: *(b) (i)* 70 s, 1.70×10^3 m *(b) (ii)* (0.56, 1.11) m s^{-1} (or an equivalent expression of magnitude and direction)

Q.3 This question also proved popular, being attempted by 80% of candidates. Although it was also generally well done, it proved somewhat more demanding than questions 1 and 2. It also achieved the greatest discrimination between candidates.

(a) should have provided two easy marks, although in fact most candidates lost one through failing to identify the gravitational force as attractive. (The Examiners would have preferred an even more explicit statement identifying the direction of the force as being along the line joining the centres of mass of the two bodies, but since absolutely no-one offered this they decided not to deduct any marks for its omission.)

(b) represented the bulk of question 3, and, as the Examiners hoped, produced good discrimination between candidates. In part *(i)*, most candidates could see that the required link to the satellite's speed was obtained through the centripetal force, though full credit was only obtained by those who stated explicitly that it is the gravitational force that makes the satellite go round in a circle and that it therefore has to be equal to $M_S v^2/r$. Part *(ii)* produced a number of interesting errors. Many candidates failed to realise that if the orbit remains circular, $v^2 \propto 1/r$. However, an alarmingly large number were unable to cope with the concept of percentage changes, and a common error was to assume that if r changes by 0.1%, v must change by $\sqrt{0.001} = 0.032 = 3.2\%$. A few candidates merely misread the question to state that r decreases by 1%, and the Examiners were at pains to minimise the 'knock-on effect' of this error in subsequent parts of the question. Part *(iii)* produced a good spread of marks. Very few candidates saw that they could reduce the complexity of their calculations (and hence the scope for error) by factorising out the constant terms and manipulating only the variable term r. Many candidates calculated intermediate results to inadequate precision, and obtained widely inaccurate answers, and some failed to state whether the change in total energy represented an increase or a decrease. Part *(iv)* also provided good discrimination. Virtually all candidates recognised that the force they were seeking should, when multiplied by a distance, yield the answer to part *(iii)*, but a significant minority did not see that this distance was the distance travelled by the satellite in a week. Some found very ingenious fiddles to obtain the answer given in the question. Part *(v)* proved easy, and most candidates obtained full marks for it.

Numerical answers: *(b) (ii)* 0.05% increase *(b) (iii)* 6.1×10^7 J decrease *(b) (iv)* 0.012 N *(b) (v)* 5×10^6 s (using the accurate answer to part *(iv)*)

Q.4 This was an averagely popular question (attempted by 50% of candidates), which was generally well done.

(a) The Examiners were rather disappointed with the responses to this part, which tended to be imprecisely worded and (usually) to refer only to a single cell in a circuit – i.e. lacking in generality. However, responses to the remainder of the question showed that most candidates understood the concepts well enough at least in this particular case.

(b) produced few problems. Some candidates produced answer to part *(ii)* with fewer significant figures than the data justified. They were penalised for this only if they failed to show an intermediate result (i.e. before the unjustified rounding) of sufficient precision.

(c) was generally well done. Virtually all candidates could obtain the result in part *(i)*, and most could see how to turn it into a quadratic equation in R_L, and then solve it, in part *(ii)*. Very few candidates spotted that the maximum power condition in part *(iii)* corresponds to equality of the two roots. Most derived the results by differentiation (for which they obtained full credit), or quoted $R_L = R$ without proof (for which they lost a little).

Numerical answers: *(b) (i)* 9.00 V, 50.0 kΩ *(b) (ii)* 4.95 MΩ *(c) (iii)* $E^2/4R$, R

Q.5 This was a mildly unpopular question, attempted by about 30% of candidates. Although the average mark was somewhat lower than for the first four questions, it provided good discrimination between candidates.

(a) was intended to be fairly straightforward, though the examiners were disappointed at the large number of candidates who merely asserted that the charges on two capacitors in series must be equal without explaining why this is so.

(b) produced responses divided fairly evenly between graphical and calculus solutions. Either approach was acceptable to the examiners, but most candidates appeared to believe that the energy stored was represented by the area under a graph of Q against V rather than the other way round. Credit was lost for this, even though it yields the same answer as the correct calculation.

(c) was found difficult by most candidates. Some believed that energy would be conserved, and merely stated, 'unity' for their answers. Some believed that both charge and energy would be conserved, and (understandably) failed to obtain a consistent result. Some recognised that charge is the conserved quantity, but interpreted E_2 as the energy store in the second capacitor, and a few obtained a correct solution.

(d) was the part of the question requiring the use of calculus to obtain full credit, and it was apparent to the Examiners that some candidates were unable to make the necessary manipulations. However, the commonest error was to assume that the potential difference across the capacitor remained constant (notwithstanding the explicit remark in the question that it is the charge that is constant). This yields the right answer for the wrong reason, for which limited credit was awarded.

Numerical answers: *(c)* $C_1/(C_1 + C_2)$

Q.6 This was a very unpopular question, being attempted by only about 20% of candidates. The average mark was similar to question 5, with a good spread.

(a) produced three fairly straightforward marks for most candidates.

(b) was found rather more difficult, at least in parts *(ii)* and *(iii)*. Part *(i)* required little more than recall, and most candidates could collect the three available marks. In part *(ii)*, most candidates could combine their answers from part *(i)* to see that the current through the primary is numerically one hundredth of the potential difference across it, but very few could see that this implied that, so far as the rest of the primary circuit is concerned, it behaves like a 100 Ω resistor. In part *(iii)*, no-one at all could see that when the switch is opened the bulb should go out ($I_s = 0$ hence $I_p = 0$), though one or two said that it would become dimmer. The majority said that it would become brighter, though they did not offer any reason for this.

(c) was found much less difficult, and most of the errors were careless ones (e.g. confusing the cross-sectional area A of the loop with its loop area s^2, and omitting a factor of 4 in calculating the mass of the loop in part *(iii)*.

Numerical answers: *(b) (ii)* 70.5 W *(c) (ii)* $B^2vAs/4\rho$ *(c) (iii)* 2.8 mm s^{-1}

Q.7 This was the least popular question on the paper, being attempted by only 10% of candidates. It also produced the lowest marks, though with a good spread.

(a) Most candidates could draw the I(V) characteristic of a typical diode, and obtained full marks for this part.

(b) produced a range of responses. Most candidates could describe the properties of an ideal operational amplifier, though some confused the input and output impedance characteristics. However, only a few were able to relate the input voltage difference to the presence of a feedback current from the output.

(c) caused little difficulty to most candidates, who recognised that the circuit could be analysed in two stages, the first forming $-(V_1 + V_2)$ and the second inverting this.

(d) produced the greatest separation of candidates. The best could see that the circuit functions as a clamp, acting as an input follower for input voltages less than +5 V and limiting the output to +5 V for input voltages greater than this. Others could see the behaviour for input voltages less than 5 V (diode reverse-biased) but could not see what would happen in the forward-biased case, and others again really did not know what to make of it.

Q.8 This was an averagely popular question, being attempted by about 40% of candidates. It produced surprisingly low marks, but again with a good spread.

(a) The Examiners were disappointed with the lack of sophistication of candidates' answers to part *(i)*, withholding the available mark from answers which merely equated pressure to 'force per unit area'. The mark was awarded to candidates who pointed out that the force is normal to the area, and one or two of the abler candidates also mentioned its isotropy (although not using that word) in a fluid. Again, part *(ii)* produced some weak answers, often consisting of little more than quoting 'p - ρgh' without proof and then differentiating it.

(b) posed fewer problems. Most candidates could derive the net force on the block in part *(i)*, although some were clearly not too sure what they were doing as the algebra went round and round a few times before homing in on the result. Part *(ii)* consisted of little more than substituting into the equation of part *(i)*, and rearranging it to make ρ_f the subject in order to find the density of air. Most candidates could cope with this, though those that could not tended to obtain absurd values for the density of air (e.g. 800 kg m^{-3}) which they apparently did not notice.

(c) was found very difficult by most candidates, who failed to recognise that since the earlier parts of the question had been about fluid pressure, this one was likely to be on the same subject. Some candidates believed that the mass of fluid on either side of the vertical must be equal, for which there is no physical justification. The Examiners expected candidates to equate the hydrostatic pressures at the interface between the two liquids, and some candidates were able to do this successfully. An alternative method, equating the moments due to the weights of the two liquids, was found by some candidates, and those who were able to complete the analysis were awarded full credit.

Numerical answers: *(b) (ii)* 0.9993 kg *(c)* 40.8°

Q.9 This was a very popular question, being attempted by 80% of candidates, and it was done well by most of those who attempted it.

(a) was intended to provide an easy lead-in to the question, and very few candidates failed to collect the available mark.

(b) produced answers which suggested that most candidates had a good grasp of the meaning of latent heat, although attempts to relate the concept to changes at the microscopic level were occasionally somewhat hazy. The Examiners noted that some candidates appeared to believe that the kinetic energy of molecules increases during a change of phase.

(c) was also generally well answered. Most candidates found the calculation involved in part *(i)* relatively straightforward, the commonest error being to omit one of the terms in the sum. Part *(ii)* produced a larger number of problems. With the exception of those candidates who did not realise that the equilibrium temperature must be 0 °C, most could generally see what to do, but often managed to confuse themselves with algebra. However, they mostly saw how to use the result from part *(ii)* to perform the calculation in part *(iii)*.

Numerical answers: *(a)* zero *(b) (i)* 1.527 MJ *(b) (iii)* 0.224 kg

Q.10 This was an averagely popular question, being attempted by 40% of candidates. It was generally well answered.

(a) produced some rather disappointing responses. An unexpectedly large number of candidates identified binding energy as the energy required to form a nucleus from its constituent nucleons, or vaguely defined it as the energy which 'holds the nucleus together' – as though it were a sort of glue. Although most candidates could draw a plausible graph of binding energy against nucleon number, few felt brave enough to indicate typical values on the binding-energy axis, and explanations for the greater specific energy yield from fusion reactions compared with fission reactions were often rather vague.

(b) was usually well answered. Most candidates could see how to use the formula to calculate the energy yield, and could deduce the number of neutrons liberated by the reaction. The commonest error was to ignore the neutrons, giving an energy yield about ten times larger than its true value.

(c) also caused few problems. A couple of candidates did not know what a gigawatt was, and a few more calculated the mass consumed per second rather than per year.

(d) produced rather more problems. By far the commonest error, accounting for probably half of those candidates who attempted this part, was caused by failing to recognise that $Q/4\pi\varepsilon_0 r$ is a potential (voltage) and not an energy. This produced an answer too large by a factor of 6×10^{18}, though no-one commented on it. The Examiners concluded from this that most candidates have little 'feel' for the temperature necessary to initiate nuclear fusion.

Numerical answers: *(b)* 3.1×10^{-11} J *(c)* 4.0×10^{2} kg *(d)* 10^{9} K

PHYSICS 9240

Component Threshold Marks

Component	Maximum Mark	A(1,2)	B(3)	C(4)	D(5)	E(6)	N	U
1	60	43	37	33	29	25	21	0
2	80	61	53	47	42	37	32	0
3	110	68	58	50	43	36	29	0
4	60	45	40	37	34	31	28	0
9	60	54	52	48	45	42	39	0

Special Paper

1	81
2	67

Overall Threshold Marks

Combination	Maximum Mark	A	B	C	D	E	N	U
1, 2, 3 and 4	310	212	184	165	147	129	111	0
1, 2, 3 and 9	310	219	197	178	159	140	121	0

The percentage of candidates awarded each grade was as follows:

GRADE	A	B	C	D	E	N	U
Cumulative %	20.3	37.2	52.4	66.5	81.5	91.4	100

The total candidature was 2,803

These statistics are correct at the time of publication.