LONDON SCIENCE COLLEGE

MARK SCHEME

PHYSICS

AS-Level

MATERIALS

TEST 3

Mark schemes

1 (a) Force proportional to extension ✓

up to the limit of proportionality (accept elastic limit) ✓ dependent upon award of first mark

Symbols must be defined
Accept word equation
allow '$F=k\Delta L$ (or $F \propto \Delta L$) up to the limit of proportionality ' ***for the second mark only***
allow stress ∝ strain up to the limit of proportionality' ***for the second mark only***

2

(b) Gradient clearly attempted / use of $k=F / \Delta L$ ✓

k = 30 / 0.026 = 1154
or 31 / 0.027 = 1148

correct values used to calculate gradient with appropriate 2sf answer given (1100 or 1200)

1100 or 1200 with no other working gets 1 out of 2

OR 1154 ± 6 seen

Do not allow 32/0.0280 or 33/0.0290 (point A) for second mark.

AND load used >= 15 ✓ (= 1100 or 1200 (2sf))

32 / 0.028 is outside tolerance. 32/0.0277 is just inside.

Nm^{-1} / N / m (newtons per metre) ✓ (not n / m, n / M, N / M)

3

(c) any area calculated or link energy with area / use of 1 / 2FΔL ✓

(or 0.001 Nm for little squares)

35 whole squares, 16 part gives 43 ± 1.0
OR equivalent correct method to find whole area ✓

0.025 Nm per (1cm) square × candidates number of squares and correctly evaluated
OR (= 1.075) = 1.1 (J) (1.05 to 1.10 if not rounded) ✓

3

(d) permanent deformation / permanent extension ✓

Allow: 'doesn't return to original length'; correct reference to 'yield'
e.g. allow ' ***extension beyond the yield point***'
do not accept: 'does not obey Hooke's law' or 'ceases to obey Hooke's law',

1

(e) any line from B to a point on the x axis from 0.005 to 0.020 ✓

straight line from B to x axis (and no further) that reaches x axis for 0.010<=ΔL<= 0.014 ✓

2

(f) work done by spring < work done by the load

Accept 'less work' or 'it is less' (we assume they are referring to the work done by spring)

1

[12]

2 (a) returns to original length/shape/position/state/zero extension/no **permanent** extension **(1)**

1

(b) (12 to 14 big squares/318 small squares ± 8 area of 1 big square = 10N × 0.05m = 0.50/small = 2 × 0.01 = 0.02)

statement of method that refers to **area (1)**

*accept triangle if **area** is mentioned*

5.0 to 8.0 (J) or clear attempt to calculate correct area **(1)**
triangle OK here 5.1 (J) for single triangle is max 2

6.0 to 7.0 (J) **(1)**

3

(c) (E =) $\frac{FL}{A\Delta L}$ **(1)**

(=) $\frac{10 \times 0.50}{5.0 \times 10^{-6} \times 0.04}$ **(1)** also gets first mark

incorrect values of F and ΔL get first mark only

2.5×10^7 (Pa) **(1)**

or (stress = F/A =) $10/5 \times 10^{-6}$ (= 2.0×10^6 Pa) **(1)**

(strain = $\Delta L/L$ =) 0.04/0.5 (= 0.08) **(1)**

$2 \times 10^6/0.08$ gets both marks

E correctly evaluated from incorrect value of stress and incorrect value of strain gets 1 mark only

use of 50 (N) and 0.04 (m) giving 1.25×10^8 (Pa) gains 2 marks

use of 5(N) and 0.4 (m) is max 2

2.5×10^7 (Pa) **(1)**

3

(d) (i) straight line through origin finishing at the same point as the rubber ± 1 small division **(1)**

1

(ii) **point beyond which**

graph is no longer linear

or force no longer proportional to extension

or Hooke's law limit **(1)**

1

[9]

3 (a) (i) weight of container (= mg = 22000 × 9.8(1)) = 2.16×10^5 (N) **(1)**

tension (= ¼ *mg*) = (5.39) 5.4×10^4 (N) or divide a weight by 4 **(1)**

(ii) moment (= force × distance) = 22000 *g* × 32 **(1)** ecf weight in (a) (i)

= 6.9 or 7.0×10^6 **(1)** **N m** or correct base units **(1)** not J, nm, NM

(iii) the counterweight **(1)**

provides a (sufficiently large) anticlockwise moment (about Q) or moment in opposite direction (to that of the container to prevent the crane toppling clockwise) **(1)**

or
left hand pillar pulls (down) **(1)**
and provides anticlockwise moment

or
the centre of mass of the crane('s frame and the counterweight) is between the two pillars **(1)**

which prevents the crane toppling **clockwise**/to right **(1)**

7

(b) (i) (tensile) stress $\left(= \frac{\text{tension}}{\text{csa}}\right) = \frac{5.4 \times 10^4}{3.8 \times 10^{-4}}$ ecf (a) (i) **(1)**

= $1.4(2) \times 10^8$ **(1)** **Pa** (or N m^{-2}) **(1)**

(ii) extension = $\frac{\text{length} \times \text{stress}}{E}$ or $\frac{FL}{EA}$ **(1)**

$= \frac{25 \times 1.4 \times 10^8}{2.1 \times 10^{11}}$ and (= 1.7×10^{-2} m) = 17 (mm) **(1)**

5

[12]

4 (a) (i) the lines are not straight (owtte) **(1)**

(ii) there is no permanent extension **(1)**
(or the overall/final extension is zero or the unloading curve returns to zero extension)

(iii) (area represents) **work done** (on or energy transfer to the rubber cord) or **energy** (stored) **(1)** not heat/thermal energy

3

(b) the mark scheme for this part of the question includes an overall assessment for the Quality of Written Communication

QWC	descriptor	mark range
good-excellent	The candidate provides a comprehensive and coherent description which includes nearly all the necessary procedures and measurements in a logical order. The descriptions should show awareness of how to apply a variable force. They should know that measurements are to be made as the force is increased then **as it is decreased**. In addition, they should know how to calculate/measure the extension of the cord. **At least five different masses/'large number' of masses are used. Minimum 7 masses to reach 6 marks**. The diagram should be detailed.	**5-6**
modest-adequate	The description should include most of the necessary procedures including **how to apply a variable force** and should include the necessary measurements. They may not have described the procedures in a logical order. They may not appreciate that measurements are also to be made as the cord is unloaded. They should know **that the extension** of the cord must be found and name a **suitable measuring instrument (or seen in diagram – label need not be seen)/how to calculate**. The diagram may lack some detail.	**3-4**
poor-limited	The candidate knows that the **extension or cord length** is to be measured for **different forces –** may be apparent from the diagram. They may not appreciate that measurements are also to be made as the cord is unloaded. They may not state how to calculate the extension of the cord. The diagram may not have been drawn.	**1-2**
incorrect, inappropriate or no response	No answer at all or answer refers to unrelated, incorrect or inappropriate physics.	**0**

The explanation expected in a competent answer should include a coherent selection of the following physics ideas.

diagram showing rubber cord fixed at one end supporting a weight at the other end or pulled by a force **(1)**

means of applying variable force drawn or described (eg use of standard masses or a newtonmeter) **(1)**

means of measuring cord drawn or described **(1)**

procedure

measured force applied (or known weights used) **(1)**

cord extension measured or calculated **(1)**

repeat for increasing then decreasing length (or force/weight) **(1)**

extension calculated from cord length – initial length **(1)**

[9]

5 (a) (i) the extension produced (by a force) in a wire is directly proportional to the force applied **(1)**
applies up to the limit of proportionality **(1)**

(ii) elastic limit: the maximum amount that a material can be stretched (by a force) and still return to its original length (when the force is removed) **(1)**
[or correct use of permanent deformation]

(iii) the Young modulus: ratio of tensile stress to tensile strain **(1)**
unit: Pa or Nm^{-2} **(1)**

5

(b) (i) length of wire **(1)**
diameter (of wire) **(1)**

(ii) graph of force vs extension **(1)**
reference to gradient **(1)**

gradient = $E\frac{A}{l}$ **(1)**

[or graph of stress vs strain, with both defined
reference to gradient
gradient = *E]*

area under the line of *F* vs *ΔL* **(1)**
[or energy per unit volume = area under graph of stress vs strain]

6

[11]

6 (a) tensile stress: force/tension per unit cross-sectional area or $\frac{F}{A}$

with F and A defined **(1)**

tensile strain: extension per unit length or $\frac{\Delta L}{l}$ with e and l defined **(1)**

the Young modulus: $\frac{\text{tensile stress}}{\text{tensile strain}}$ **(1)**

3

(b) (i) $E_S = \frac{F_s}{A}\frac{l}{\Delta L}$ **(1)** and $E_B = \frac{F_B}{A}\frac{l}{\Delta L}$ **(1)** hence $\frac{E_S}{E_B} = \frac{F_S}{F_B}$

(ii) $\frac{E_S}{E_B}$ = 2 **(1)**

$\therefore F = 2F_B$ **(1)**

$F_S + F_B$ = 15 N **(1)** gives F_S = 10 N

[or any alternative method]

(iii) $\left(E = \frac{F}{A}\frac{l}{\Delta L}\text{ gives}\right)$ $e = \left(\frac{F}{A}\frac{l}{E}\right) = \frac{10 \times 1.5}{1.4 \times 10^{-6} \times 2.0 \times 10^{11}}$ **(1)**

$= 5.36 \times 10^{-5}$m **(1)**

6

[9]

7 (a) (i) X **(1)**

stress (force) $\propto$ strain (extension) for the whole length **(1)**

(ii) Y **(1)**

has lower breaking stress (or force/unit area is less) **(1)**

(iii) Y **(1)**

exhibits plastic behaviour **(1)**

(iv) Y **(1)**

for given stress, Y has greater extension

[or greater area under graph] **(1)**

8

QWC 2

(b) (i) (use of $E = \frac{F}{A} \times \frac{l}{\Delta L}$ gives)

$F\left(= \frac{EA\Delta L}{l}\right) = \frac{2.0 \times 10^{7} \times 0.64 \times 10^{-6} \times 30 \times 10^{-3}}{160 \times 10^{-3}}$ **(1)**

(1) for data into correct equation, **(1)** for correct area

= 2.4 N **(1)**

(allow C.E. for incorrect area conversion)

(ii) (use of energy stored = ½*Fe* gives) energy = $\frac{2.4 \times 30 \times 10^{-3}}{2}$ **(1)**

$= 36 \times 10^{-3}$ J **(1)**

(allow C.E. for value of *F* from (i))

5

[13]

8 (a) (i) diagram to show:
(long) wire fixed at one end **(1)**
mass / weight at other end **(1)**
measuring scale **(1)**
mark on wire, or means to measure extension **(1)**

max 3

[alternative for two vertical wires:
two wires fixed to rigid support **(1)**
mass / weight at end of one wire **(1)**
other wire kept taut **(1)**
spirit level and micrometer or sliding vernier scale **(1)**]

(ii) measurements:
length of the wire between clamp and mark **(1)**
diameter of the wire **(1)**
extension of the wire **(1)**
for a known mass **(1)**

max 3

(iii) length measured by metre rule **(1)**
diameter measured by micrometer **(1)**
at several positions and mean taken **(1)**
(known) mass added and extension measured
by noting movement of fixed mark against vernier scale
(or any suitable alternative) **(1)**
repeat readings for increasing (or decreasing) load **(1)**

max 5

(iv) graph of mass added / force against extension **(1)**

gradient gives $\frac{F}{e}$ or $\frac{m}{e}$ **(1)**

correct use of data in $E = \frac{Fl}{eA}$ where A is cross-sectional area **(1)**

[if no graph drawn, then mean of readings
and correct use of data to give 2_{max}) **(1)**

max 2
(13)

The Quality of Written Communication marks are awarded for the quality of answers to this question.

(b) (i) for steel (use of $E = \frac{Fl}{eA}$ gives) $e = \frac{FL}{EA}$ **(1)**

$e = \frac{125 \times 2}{2.0 \times 10^{11} \times 2.5 \times 10^{-7}}$ **(1)**

= 5.0 × 10_{-3} m **(1)**

(ii) extension for brass would be 10 × 10_{-3}(m) (or twice that of steel) **(1)**
end A is lower by 5 mm √ (allow C.E. from (i))

max 3

[16]

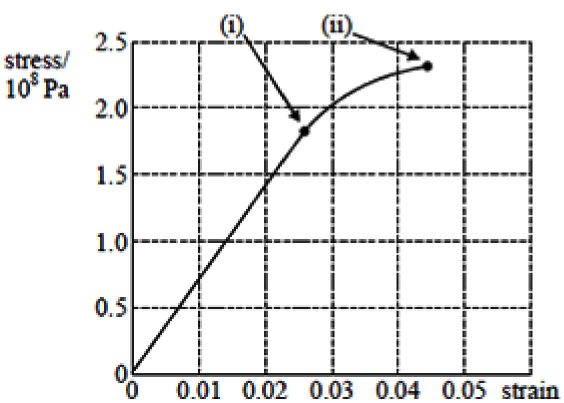
9 (a) (i) strain = 0.026 **(1)**
E = 6.92 × 10^9 Pa **(1)**

(ii) A = 1.96 × 10^{-7} (m^2) **(1)**
stress = 230 × 10^8 Pa **(1)**

(iii) breaking strain = 0.044 **(1)**

5

(b)



shape overall **(1)**

(i) straight line **(1)**
0 to (0.026, 1.8) **(1)**

(ii) curve **(1)**
to (0.044, 2.3) **(1)**

max 4

[9]

10 (a) The force per unit area **B1**

at which the material extends considerably / a lot / plastically /
or strain increases considerably etc
NOT doesn't return to its original shape / permanently deformed **B1**

for no (or a small) increase in) force / stress **B1**

(3)

(b) (i) strain = 8.4×10^{-4} (1.3×10^{-3} / 1.55 seen) (allow if in $E = FL / A\Delta L$) **B1**

or area of cross section = 2.54×10^{-6}
or π $(0.9 \times 10^{-3})^2$
stress = E × strain (explicit or numerically) and
stress = F / A or $E = FL / AL$ **C1**

force = 440 – 450 N(cao) **A1**

(3)

(ii) Energy = ½ $F \Delta l$ or ½ stress × strain × volume **C1**

0.29 J ecf for F from (b)(i) **A1**

(2)

[8]

Examiner reports

1

(a) This question was well answered. Some left out 'up to limit of *proportionality*' and some put *'elastic limit'* - though this was forgiven. Some gave the equation only in symbols, and this was not sufficient.

Again, with recall questions, not enough students are learning definitions and laws, producing instead vague descriptions rather than precisely memorised statements. E.g. *'Hooke's law is the extension of a spring when a force is applied.'*

(b) There were quite a few mistakes with units here; 'Nm', 'Nm^{-2}' and 'Pa' were all common incorrect units. In calculating the gradient, the point labelled '**A**' was often used. However, at this point, the line had clearly ceased to be straight and thus the answer fell outside the range of tolerance.

(c) For calculating the work done up to point **B**, there was much use of ½ FL = ½ × 38 × 0.045, and sometimes simply 38 × 0.045, rather than an attempt to sum up the area under the line. Many estimates of the area were wildly inaccurate due to the approach being too approximate, counting some areas twice or missing bits out.

Summing the area under a curve is a technique that students must practise.

(d) Most candidates got this correct. A few said words to the effect of *'no longer obeys Hooke's law'*, which was not sufficient.

(e) There were many careless graphs drawn here, with the line not drawn exactly parallel, and this lost a mark. This means that some very straightforward marks are needlessly dropped by many candidates. In order to ensure that a line is parallel, students should be encouraged to make a quick measurement of the distance between the lines at a couple of points.

It would also appear that many students elect to sketch with a pen and are then reluctant to scribble out their line and replace it with a more accurate one. For diagrams only, please encourage students to use an HB pencil; this will show up perfectly well on the scans that are seen by the examiners.

(f) The majority of candidates understood that the area underneath the unloading line was less than for the loading. However, a significant number of candidates thought that the work done would be the same since *'energy is conserved'*.

2 It was a little surprising that more candidates did not gain the mark to part (a). A common incorrect answer was ‘curve B’.

In part (b), the majority of candidates did not know that the work done is the area under the line or they did not know a suitable method to estimate area. The most common approach was to treat the curve as a straight line and use $W = ½ FΔL$.

The most reliable method in this case is to count the number of large squares, treating all part squares as half a square, and then multiply the total by the value of one square (0.5 J). If this method is taught, the candidates will always get the answer that appears on the mark scheme.

The typical Young modulus of rubber can be found in most data books. This is obtained for small values of strain. The majority of candidates knew what to in part (c) and many gained all three marks. Unfortunately, a significant number of candidates were careless in reading the question and used 0.40 instead of 0.040 and therefore 50 N instead of 10 N.

The majority of candidates were successful in part (d) (i). A common error was to draw another curve or a straight line at a tangent to initial slope of A.

Part (d) (ii) was another definition that caused problems for many candidates. Some failed to gain credit by confusing limit of proportionality with elastic limit. Some neglected to say ‘point beyond which the load and extension will no longer be proportional’.

3 A surprisingly large number of candidates divided the mass by four to get a .weight. of 5500 kg in part (a) (i). Many also forgot to divide by four in what should have been a fairly uncomplicated question.

In part (a) (ii), many candidates simply multiplied the mass of 22000 kg by 32, indicating a surprising confusion between weight and mass. For the unit mark there were many common errors such as N, NM, Nm^{-1}, Nm^{-2}, J, nm, kg and Nkg^{-1}.

A very easy mark for mentioning the .counterweight. was picked up by most candidates in part (a) (iii). However, not many went on to discuss the .anticlockwise moment. that this provides.

Most picked up the first two marks to part (b) (i), some as a result of the ecf for the tension. Many candidates used wrong units; pa, PA, Nm^{-1}, being common rather than Pa.

Those with an ecf in (b) (i) generally failed to get both marks to part (b) (ii) because they did not arrive at 17 mm. This may have given some candidates a clue that one of their previous answers was incorrect. The candidates who were successful on the first parts of the question invariably scored both marks here.

4 Most scored very well on parts (a) (i) and (ii), which were fairly straightforward questions, though occasionally the answers to (a) (i) and (a) (ii) were given the wrong way round.

In part (b) Quality of Written Communication was assessment. Many candidates did not specify a distance measuring instrument (a ruler); perhaps failing to state the obvious.

Very few recognised the need to specify a suitable number of different loads over the complete range. This would be important in order to obtain the true shape of the curve; six marks were only awarded if the candidate specified seven or more loads.

Many candidates forgot to include the unloading of the rubber cord in their answers and would have benefited greatly from re-reading the question and their answer here.

Candidates in a few centres appeared to use mnemonics to remember the elements necessary in answering this type of question; this seemed to work quite well.

5 Few candidates gained the maximum mark of five for part (a). In part (i), the necessary condition that the wire had not been stretched beyond the elastic limit or beyond the limit of proportionality was usually omitted. In part (iii) the Young modulus was often defined as stress/strain, which was not acceptable, and finally a large number of candidates failed to give the unit of the Young modulus, many going for the easy option of stating that it had no units.

Candidates who took the trouble to read the stem of the question carefully usually gave good answers, but those who thought that part (b) required a description of the experiment failed miserably. In part (i) the usual answer of measuring the cross-sectional area was not accepted. The only answers that gained both allocated marks were the diameter and the length of the wire. In part (ii) a graph of force vs extension, or stress vs strain (provided both were defined) were acceptable, but many who opted for the stress vs strain graph then went on in part (iii) to give the answer as the area under the graph, which, of course, is wrong, unless they referred to the energy per unit volume.

6 Normally, the question on elasticity realizes high marks. Not so this time, although there were many completely correct answers. The three definitions were usually correct although, as in past papers, the Young modulus was defined in terms of stress and strain, rather than tensile stress and tensile strain. There also appeared this year, references to the *stiffness constant* of the wire. It should be pointed out that the stiffness constant is not the same as the Young modulus.

The algebra involved in parts (i) and (ii) of (b) caused problems and a significant number of candidates failed on this section. However, part (iii) proved to be a straightforward calculation for the majority of candidates.

7 Examiners were pleased to find that part (a) was answered satisfactorily and that candidates not only chose the correct wire but were very often able to provide the correct reason for doing so. Many candidates gained full marks, while a large number only lost one or two marks.
Part (i) was usually correct, although reasons such as ‘the graph is a straight line’ were not accepted. A ‘constant gradient’ was accepted but few candidates gave this as a reason, most giving the proportionality of the quantities involved. In part (ii) answers such as ‘Y broke before X’ was not accepted. Examiners were looking for a reason in terms of lower breaking stress.

Answers to part (iii) were not so good and candidates who did not know the correct answer attempted an answer in terms of the gradients of the curves or the bending of curve Y as the tensile strain increased. Part (iv) gave the most trouble. Many candidates again tried an explanation in terms of the gradient, but a significant number followed the correct track and gave a reason in terms of the area under such a graph. Unfortunately the majority of these candidates referred to the area under the whole curve, whereas it should have been the area under the curve at a given tensile stress. Surprisingly, many candidates, even when using a given stress, gave the area under X as being greater than that under Y.

The final calculation in part (b) did not cause too much difficulty and, provided the initial equation for the Young modulus was correct, candidates produced a correct answer with correct units. One common error which again arose from not reading the question thoroughly, was using the extended length of the elastic cord as the extension. Converting the cross-sectional area of the cord from mm^2 to m^2 caused some problems, but this error was carried forward after the initial penalty had been imposed. The calculation in part (ii) was also done well by those who knew the expression for the energy stored, or were aware that it was given in the data sheet. Some answers, resulting from a carry forward of an incorrect force in part (i) gave energies amounting to several million joules. This attracted no comment.

8 Almost all candidates gained reasonable marks on part (a)(i) even though some of the descriptions were lacking in detail. Most of the diagrams were reasonably drawn with the aid of a ruler. Candidates who drew freehand usually produced inferior diagrams which failed to gain all the available marks. A variety of methods were shown, usually two wires hanging vertically, linked together by means of some vernier arrangement and a spirit level. Also shown was a horizontal wire on a bench. Although this is not such an accurate method, it was accepted but many candidates showed the mark on the wire as being about half way along. This of course is only acceptable if the length of the wire is measured to that point, but this was usually overlooked in the description. The least satisfactory method was suspending a single wire with a ruler alongside although this did gain some marks. There were an alarming number of diagrams which showed a completely unrelated length of wire, a ruler, an isolated hook with a mass attached and a micrometer. Needless to say, such efforts gained no marks.

In part (ii) candidates could have saved themselves considerable time and effort by reading the question carefully and just listing the measurement they would make. Many candidates listed the area of cross section as a measurement. This was not acceptable since area is a derived quantity and it is the diameter which is measured. Many candidates also listed the ‘width’ of the wire, which again was not accepted.

The descriptions in part (iii) were, on the whole, quite reasonable, although most effort seemed to go into describing how the length of the wire and its diameter were measured and not giving sufficient attention to the experiment, i.e. measuring the extension for each mass added and increasing the total mass to a certain value. There were very few references to repeating the readings while unloading. This particular section of the question was also used to award the quality of written communication marks and most candidates scored well on this.

The descriptions in part (iv) of how to use the measurements to give the Young modulus was reasonably done with about 50% of the candidates drawing a graph of force vs extension or stress vs strain and using the gradient accordingly. Candidates who only used one set of values to give one value of the Young modulus were not awarded all the available marks.

The calculation in part (b)(i) was performed satisfactorily, with the majority of candidates calculating the correct extension for the steel wire. Marks were lost in part (ii) when the answer was given without any reasoning.

9 In part (a)(i) there were many good answers with the calculation clearly set out and the answer quoted correctly to 2 significant figures and with the correct unit. Some candidates incorrectly attempted to calculate the stress for a force of 45N while others had difficulty in converting from mm to m in determining the strain. In part (a)(ii) about 25% of the candidates could not calculate correctly the cross-sectional area of the wire since they used the diameter and not the radius, or they failed to convert the radius from mm to m. Most candidates were able to calculate correctly the value for the breaking strain.

The sketch graph in part (b) was often carelessly drawn. Sketch graphs gaining full marks showed a straight line up to the limit of Hooke's law followed by a curved region up until the breaking point. The nature of the curved region of the graph was treated generously in the marking. Most candidates marked correctly their values of stress and corresponding strain on the axes.

10 (a) It was expected that within the answer candidates would show that they understood the meaning of stress. Only a minority of the candidates did this. The idea that small increases in stress would produce large increases in strain was not commonly given. Many simply stated that the material would become plastic.

(b) (i) Most candidates were able to gain 2 or 3 marks for this question. Some made mistakes in arithmetic following use of the correct formula and substitution. Others used the wrong formula for area of cross section, $2\pi r^2$ or $\pi r^2 L$ being seen frequently.

(ii) This was usually well done but a significant proportion of the candidates misread the question and gave the strain rather than the strain energy as the answer. Some made the going hard by using ½ *stress* × *strain* × *volume*. Others simply determined ½ *stress* × *strain* thinking that this was the strain energy.