A LEVEL PHYSICS

WORKED SOLUTIONS

4.2. Materials MCQ

1. A mass m is added to a vertical spring that is initially unextended, as shown in **Diagram 1**.

The mass is then lowered until it hangs stationary on the spring, as shown in **Diagram 2**.

The extension of the spring is now ΔL.

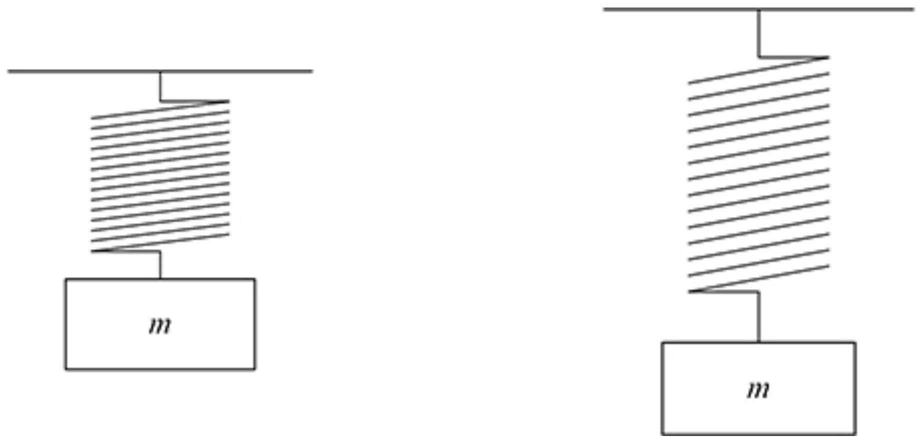


Diagram 1 **Diagram 2**

How much energy is transferred from the mass–spring system?

A $\frac{mg\Delta L}{2}$ ☒

B $mg\Delta L$ ☐

C $\frac{3mg\Delta L}{2}$ ☐

D $2mg\Delta L$ ☐

$E_e = \frac{1}{2}F\Delta L$ $F = W = mg$

$E_e = \frac{1}{2}mg\Delta L$

(Total 1 mark)

2. A wire is made from a material of density ρ.
The wire has a mass m and an initial length L.
When the tensile force in the wire is F the extension of the wire is ΔL.

What is the Young modulus of the material?

A	$\frac{F\rho L^2}{m\Delta L}$	●
B	$\frac{FL^2}{m\rho\Delta L}$	○
C	$\frac{F\rho}{m\Delta L}$	○
D	$\frac{FmL^2}{\rho\Delta L}$	○

$V = AL$

$E = \frac{\sigma}{\varepsilon} = \frac{F/A}{\Delta L/L} = \frac{FL}{A\Delta L} = \frac{FL^2}{V\Delta L}$

$\rho = \frac{m}{V}$ $V = \frac{m}{\rho}$ $E = \frac{FL^2}{(m/\rho)\Delta L}$

$E = \frac{\rho FL^2}{m\Delta L}$

(Total 1 mark)

3. Two wires **X** and **Y** have the same extension for the same load.
X has a diameter d and is made of a metal of density ρ and Young modulus E.
Y has the same mass and length as **X** but its diameter is $2d$.

What are the density and the Young modulus of the metal from which **Y** is made?

	Density	Young modulus	
A	$\frac{\rho}{2}$	$\frac{E}{4}$	○
B	$\frac{\rho}{2}$	$4E$	○
C	$\frac{\rho}{4}$	$\frac{E}{4}$	●
D	$\frac{\rho}{4}$	$4E$	○

(Total 1 mark)

$\rho = \frac{m}{V} = \frac{m}{AL} = \frac{m}{\pi d^2/4 \cdot L}$ $\rho \propto \frac{1}{d^2}$ $d \to 2d \therefore \rho_2 = \frac{\rho_1}{4}$

$E = \frac{FL}{A\Delta L} = \frac{FL}{\pi d^2/4 \cdot \Delta L}$ $E \propto \frac{1}{d^2}$ $d \to 2d \therefore E_2 = \frac{E_1}{4}$

4. A tensile force produces an extension ΔL in a steel wire of initial length L and diameter d.

The same steel is used to make a second wire of initial length $2L$ and diameter $\frac{d}{2}$ ← ∴ $\frac{A}{4}$

What is the extension when the same force is applied to the second wire?

- **A** $\frac{\Delta L}{2}$ ○
- **B** 2ΔL ○
- **C** 4ΔL ○
- **D** 8ΔL ●

$$E = \frac{FL}{A\Delta L} \qquad \Delta L = \frac{FL}{EA}$$

$$\Delta L_2 = \Delta L_1 \cdot \frac{L_2}{L_1} \cdot \frac{A_1}{A_2}$$

$$= \Delta L \times 2 \times 4 = 8\Delta L$$

(Total 1 mark)

5. Which combination of properties would produce the smallest extension of a wire when the same tensile force is applied to the wire?

$$\Delta L = \frac{FL}{EA}$$

	Cross-sectional area	Length	Young modulus of material		
A	X	$3L$	E	○	3
B	$2X$	L	E	○	1/2
C	X	$3L$	$4E$	○	3/4
D	$2X$	L	$4E$	●	1/8

(Total 1 mark)

6. The table contains information on four wires. It shows the stiffness of each wire and the maximum strain energy stored in the wire when extended to the breaking point.

Assume each wire has the same initial dimensions and obeys Hooke's law.

$$E_e = \frac{1}{2}kx^2 \qquad x = \sqrt{\frac{2E_e}{k}}$$

Which wire extends the least before reaching the breaking point?

	Stiffness / N m^{-1} (k)	Maximum strain energy / J (E_e)		
A	4.0	1	○	$\sqrt{2/4} = 0.71$
B	9.0	1	●	$\sqrt{2/9} = 0.47$
C	16	3	○	$\sqrt{6/16} = 0.61$
D	25	3	○	$\sqrt{6/25} = 0.49$

(Total 1 mark)

7. A steel wire **W** has a length l and a circular cross-section of radius r. When **W** hangs vertically and a load is attached to the bottom end, it extends by e.
Another wire **X** made from the same material has the same load attached to it.

Which length and radius for **X** will produce an extension of $\frac{e}{4}$?

$E = \frac{FL}{\pi r^2 e}$

$e = \frac{FL}{\pi r^2 E}$

$e \propto \frac{L}{r^2}$

	Length of X	Radius of X		L/r^2
A	$0.5l$	$2r$	○	$1/8$
B	l	$4r$	○	$1/16$
C	$2l$	$2r$	○	$2/4 = 1/2$
D	$4l$	$4r$	●	$4/16 = 1/4$

(Total 1 mark)

8. What is the name given to a material that breaks without deformation when a force is applied to it?

A Plastic ○

B Brittle ●

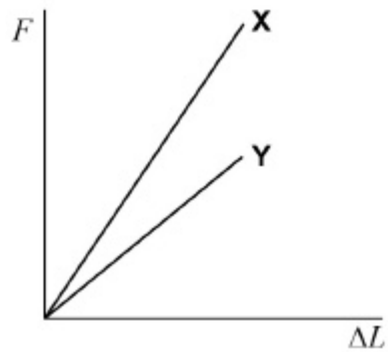
C Stiff ○

D Elastic ○

(Total 1 mark)

9. Two separate wires **X** and **Y** have the same original length and cross-sectional area.

The graph shows the extension ΔL produced in **X** and **Y** when the tensile force F applied to the wires is increased up to the point where they break.



Which statement is **incorrect**?

A For a given extension more energy is stored in **X** than in **Y**. ✓

B The Young modulus of the material of wire **Y** is greater than that of wire **X**. ✗

C Both wire **X** and wire **Y** obey Hooke's law. ✓

D Wire **X** has a greater breaking stress than wire **Y**. ✓

(Total 1 mark)

10. What **cannot** be used as a unit for the Young modulus?

A N m^{-2} ✓

B Pa ✓

C kg m^{-2} s^{-2} ✗

D kg m^{-1} s^{-2} ✓

$E = \frac{FL}{A\Delta L} \rightarrow \frac{N\,m}{m^2\,m} = N m^{-2}$

(Total 1 mark)

$N = kg\,m\,s^{-2}$

$N m^{-2} = kg\,m^{-1}\,s^{-2}$