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IGCSE PHYSICS 0625 · TOPICAL PAST PAPERS

Forces & Elastic Deformation — Paper 2

Worked Solutions (Theory / Structured)

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Forces & Elastic Deformation — Paper 2 · Worked Solutions

Megalecture worked solutions — model answers with working; please verify before classroom use. These solutions cover the topical Paper 2 (Theory / Structured) compilation on **Forces & Elastic Deformation (IGCSE Physics 0625)**. Every part was solved from first principles by the Megalecture team using Hooke's law ($F = kx$), extension = stretched length − original length, and the data given in each question (with g as stated, usually 10 N/kg). Graph readings are taken to the nearest sensible value and a small tolerance should be allowed.

Question 1 — May/June 2010 · Paper 21 · Q2

A 4.0 N weight stretches a spring from an unstretched length of 8.0 cm to 14.0 cm (within the limit of proportionality).

(a) State what is meant by the *limit of proportionality*.

The limit of proportionality is the point (force/extension) beyond which the **extension is no longer directly proportional to the load** — i.e. the spring stops obeying Hooke's law and the load–extension line ceases to be straight.

(b) The 4.0 N weight is replaced with a 2.0 N weight. Calculate the new length of the spring.

Extension with 4.0 N: $x = 14.0 - 8.0 = 6.0$ cm.

Extension ∝ load, so halving the load halves the extension: $x = \frac{1}{2} \times 6.0 = 3.0$ cm.

New length = original + extension = 8.0 + 3.0 = **11.0 cm**.

(c) Describe how the apparatus is used to obtain readings for an extension–load graph.

Record the pointer reading on the rule with **no load** (the original position). Hang a known weight, read the new pointer position, and find the **extension = new reading − original reading**. Repeat for a range of known weights, then plot extension (y-axis) against load (x-axis).

Question 2 — May/June 2012 · Paper 22 · Q1

(a)(i) State what is meant by the *mass* of a body.

Mass is the **quantity (amount) of matter in a body**. It is also a measure of the body's inertia (its resistance to a change in motion) and is measured in kilograms.

(a)(ii) Describe how the scale is used to find the extension of the spring.

Read the pointer position on the scale with no masses on the pan, then read the new pointer position with the masses added. The **extension = (loaded reading) − (unloaded reading)**.

(b)(i) Using values from Fig. 1.2, explain why spring B is "easier to stretch" than spring A.

For the same force, spring B stretches further (e.g. at 20 N spring A extends about 4 cm but spring B extends about 5 cm). Spring B has the **smaller spring constant**, so a given force produces a larger extension — it is easier to stretch.

(b)(ii) Explain how Fig. 1.2 shows that at 25 N spring B has reached its limit of proportionality but spring A has not.

At 25 N the graph for **spring B has begun to curve** (it is no longer a straight line), showing it has passed its limit of proportionality, whereas the line for **spring A is still straight** at 25 N, so spring A has not yet reached its limit.

(b)(iii) Determine the force that makes spring B's extension 1.0 cm greater than spring A's.

In the straight (proportional) region: spring A reaches 25 N at 5.0 cm ⇒ $F = 5.0\,x_A$; spring B reaches 20 N at 5.0 cm ⇒ $F = 4.0\,x_B$.
So $x_A = F/5$ and $x_B = F/4$. Require $x_B - x_A = 1.0$ cm.
$F/4 - F/5 = 1 \Rightarrow F(1/20) = 1 \Rightarrow F =$ **20 N** (read from graph as the force where the two extensions differ by 1.0 cm).

Question 3 — May/June 2013 · Paper 21 · Q1

Fig. 1.1 plots force (0–2.0 N) against the length of the spring (cm); the straight line crosses force = 0 at a length of about 11 cm.

(a) Determine the length of the unstretched spring.

The unstretched length is the length when the force is zero — where the line meets the length axis (force = 0): length = **about 11 cm**.

(b) Explain how the graph shows that the limit of proportionality is not reached.

The graph is a **straight line over its whole length** — force (and hence extension) stays directly proportional to one another, so the spring is still obeying Hooke's law and has not passed its limit of proportionality.

(c)(i) State what is meant by a *uniform acceleration*.

A uniform (constant) acceleration is one in which the **velocity changes by equal amounts in equal intervals of time** — i.e. the rate of change of velocity is constant.

(c)(ii)1 Determine the horizontal force on M (extension 9.0 cm).

From Fig. 1.1 the spring needs about 2.0 N to reach a length of 20 cm, i.e. an extension of ~9 cm from the 11 cm unstretched length. So the horizontal force on M ≈ **2.0 N**.

(c)(ii)2 Determine the acceleration of M (mass 0.20 kg).

$a = F/m = 2.0 / 0.20$
$a =$ **$10\ m/s^2$**.

Question 4 — May/June 2013 · Paper 22 · Q3

Chest expander treated as one spring: 0 → 0, 60 N → 10 cm, 120 N → 20 cm, 180 N → 30 cm (spring constant = 6 N/cm).

(a)(i) Calculate the work done on the spring (force 0 → 180 N, extension 30 cm, average force 90 N).

W = average force × extension = 90 × 0.30 m

W = **27 J**.

(a)(ii) Twenty extensions are made in 1.0 minute. Calculate the power.

Total work = 20 × 27 = 540 J in 60 s.

$P = W/t$ = 540 / 60 = **9.0 W**.

(b)(i) Force at the limit of proportionality is 800 N. Calculate the extension then.

Spring constant from the table: k = 60 N / 10 cm = 6 N/cm.

$x = F/k$ = 800 / 6 = **133 cm** (about 1.3 m).

(b)(ii) The force is increased from 800 N to 860 N. Suggest what happens to the extension.

Beyond the limit of proportionality the extension is **no longer proportional to the force** — the spring extends by a **larger amount** than Hooke's law predicts (extra extension per newton increases), and it may not return fully to its original length.

Question 5 — May/June 2015 · Paper 22 · Q1

A mass hung from a spring; Fig. 1.2 plots length (cm) against force (0–10 N), unstretched length 40 cm rising to 80 cm at 10 N (4 cm per N).

(a) Explain how the mass causes a force on the spring.

The Earth's gravity pulls down on the mass, giving it a **weight** ($W = mg$). This downward weight acts on the spring and stretches it.

(b) State what is meant by a *vector* quantity.

A vector quantity is one that has **both magnitude (size) and direction** (e.g. force).

(c)(i)1 State a formula relating unstretched length l_0, stretched length l and extension e.

$\boldsymbol{e = l - l_0}$ (extension = stretched length − original length).

(c)(i)2 A 9.0 N force acts on the spring. Determine the extension.

From Fig. 1.2 the length rises from 40 cm (at 0 N) to 80 cm (at 10 N), i.e. 4 cm per N.

At 9.0 N: length ≈ 40 + 9×4 = 76 cm, so extension = 76 − 40 = **36 cm**.

(c)(ii) Continue the line for forces greater than 10 N (spring easier to stretch).

Beyond 10 N the line should **curve upwards more steeply** — for each extra newton the length increases by more than 4 cm, because the spring is easier to stretch past the limit of proportionality.

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Question 6 — May/June 2016 · Paper 21 · Q2

Spring length 10 cm on its own, 30 cm with unknown mass X. Fig. 2.2 plots extension against mass; it is straight up to point P at about 350 g, 25 cm.

(a)(i) Name point P (where the line begins to curve).

Point P is the **limit of proportionality**.

(a)(ii) Determine the mass X.

Extension caused by X = 30 − 10 = 20 cm.
From Fig. 2.2, an extension of 20 cm (on the straight part) corresponds to a mass of **about 200 g** (0.20 kg).

(a)(iii) Calculate the weight of X (g = 10 N/kg).

$W = mg = 0.20 \times 10$
W = **2.0 N**.

(b) Two identical springs side by side support X. State and explain how the extension compares with Fig. 2.1.

The extension is **halved** (about 10 cm instead of 20 cm). The weight of X is now **shared equally between the two springs**, so each spring carries only half the force and therefore stretches half as much.

Question 7 — May/June 2016 · Paper 22 · Q3

Three springs A, B, C measured for weights 1.0–3.0 N (lengths given). Spring A increases by a steady 0.8 cm per 0.5 N; spring C's increases jump (1.8 cm then 3.8 cm) at the top.

(a)(i) State which spring has been stretched past the limit of proportionality.

Spring C.

(a)(ii) Explain, using data from Fig. 3.1, how you obtained the answer.

For each equal 0.5 N step the length increase should be constant if the spring obeys Hooke's law. For spring C the increase per 0.5 N is 0.8, 0.8, 1.8 then 3.8 cm — the last two steps are **much bigger and unequal**, so the extension is no longer proportional to load: spring C has passed its limit of proportionality. (Springs A and B keep an almost constant 0.8 cm and 0.9 cm step.)

(a)(iii) Calculate the unstretched length of spring A.

Spring A increases by 0.8 cm for each 0.5 N (constant), so 1.6 cm per 1.0 N.
At 1.0 N the length is 6.1 cm, so unstretched length = 6.1 − 1.6 = **4.5 cm**.

(b) Describe how spring A can be used to find the mass of a small rock.

Calibrate spring A using known weights (record extension for each, drawing an extension–load graph). Hang the rock on spring A and measure its extension; read the corresponding **weight** from the graph. Then find the mass from $\boldsymbol{m = W/g}$ (dividing the weight by 10 N/kg).

Question 8 — May/June 2018 · Paper 22 · Q2

Load–length table: 0 → 200, 1.0 → 235, 2.0 → 270, 3.0 → 305, 4.0 → 350, 5.0 → 420 (mm). Spring constant in the linear region = 35 mm per N.

(a) Complete the table of extensions (length − 200 mm).

load / N	0	1.0	2.0	3.0	4.0	5.0
length / mm	200	235	270	305	350	420
extension / mm	0	35	70	105	**150**	**220**

(350 − 200 = 150 mm; 420 − 200 = 220 mm.)

(b) Calculate the load that produces an extension of 49 mm.

In the linear region the extension is 35 mm per 1.0 N (e.g. 105 mm at 3.0 N).
load = 49 / 35 = **1.4 N**.

(c)(i) Tick how each form of energy compares at A and at B (load pulled from A down to B, stationary at both).

Energy stored in the spring: **larger at B** (the spring is stretched more at B). Gravitational potential energy of the load: **larger at A** (the load is higher at A).

(c)(ii) Explain how conservation of energy applies as the student pulls the load down.

The energy is not created or destroyed — it is **transferred**. The student does work pulling the load down; this work (plus the loss of the load's gravitational PE as it falls) is **stored as elastic strain energy in the spring**. The total energy stays the same.

Question 9 — May/June 2019 · Paper 21 · Q3

A large spring stretched by an athlete; one extension increases its length from 70 cm to 93 cm, average force 400 N, 60 in a 60 s period.

(a) State the form of energy stored in the stretched spring, and the form of energy stored in the muscles.

Spring: **elastic (strain) potential energy**. Muscles: **chemical energy**.

(b) Suggest what happens if he extends the spring beyond its limit of proportionality.

The extension stops being proportional to the force, and the spring becomes **permanently deformed** — it will not return to its original length when the force is removed.

(c)(i) Calculate the work done in one extension (70 cm → 93 cm, average force 400 N).

Extension = 93 − 70 = 23 cm = 0.23 m.
$W = F \times x$ = 400 × 0.23 = **92 J**.

(c)(ii) Describe how this value is used to find his average power over the 60 s.

Find the total work done = 92 J × (number of extensions) = 92 × 60 = 5520 J, then divide by the time: **power = total work / time = 5520 / 60 = 92 W**. (In words: multiply the work per extension by the number of extensions, then divide by 60 s.)

Question 10 — May/June 2020 · Paper 21 · Q3

Extension–load graph (Fig. 3.1): straight line through the origin, 3.0 cm at 4.0 N (0.75 cm per N), reaching the limit of proportionality at 8.0 N.

(a) State the two features of the graph that show extension is directly proportional to load.

1. The line is **straight**. 2. The line **passes through the origin** (0,0).

(b) Describe how to show the spring reaches its limit of proportionality at 8.0 N.

Continue adding known loads and measuring the extension. The point where the graph **stops being a straight line and starts to curve** is the limit of proportionality; if that occurs at a load of 8.0 N (extension no longer proportional to load above 8.0 N), the spring's limit is at 8.0 N.

(c) A block of wood gives an extension of 2.7 cm. Calculate its mass (g = 10 N/kg).

From the graph: 4.0 N gives 3.0 cm, so the spring extends 0.75 cm per N (k = 4.0/3.0 = 1.33 N/cm).
Weight = load = 2.7 / 0.75 = 3.6 N.
$m = W/g$ = 3.6 / 10 = **0.36 kg**.

Question 11 — Oct/Nov 2005 · Paper 2 · Q1

A 0.4 kg mass hangs at rest from a spring; g = 10 N/kg.

(a) State what is meant by the *mass* of an object.

Mass is the **amount of matter in the object** (a measure of its inertia), measured in kilograms.

(b)(i) Draw and name the two forces acting on the mass.

Two vertical arrows from the mass: **weight** acting vertically downward, and the **pull/tension of the spring (upward force)** acting vertically upward. (Both act along the same vertical line of action.)

(b)(ii) Calculate the size of each force (g = 10 N/kg).

Weight = mg = 0.4 × 10 = 4.0 N (downwards).
The mass is at rest, so the forces are balanced: the upward spring force is also 4.0 N.
first force = **4.0 N**; second force = **4.0 N**.

(c) The mass is pulled downwards. State and explain what happens to the upward force.

The upward force **increases**. Pulling the mass down **extends the spring further**, and a larger extension produces a larger spring force ($F = kx$).

Question 12 — Oct/Nov 2012 · Paper 22 · Q2

A 45 N load extends a copper wire by 2.5 mm (within the limit of proportionality); g = 10 N/kg.

(a)(i) Calculate the mass of the 45 N load.

$m = W/g = 45 / 10$
m = **4.5 kg**.

(a)(ii) Plot the extension–load graph for loads 0 to 45 N.

Because the wire obeys Hooke's law, the graph is a **straight line through the origin** from (0 N, 0 mm) to (45 N, 2.5 mm). (Plot extension on one axis, load on the other, and draw a single straight line joining these two points.)

(b) Use the graph to find the load that produces an extension of 1.3 mm.

The line is straight, so load ∝ extension: load = 45 × (1.3 / 2.5)
load = **23.4 N** (about 23 N).

Question 13 — Oct/Nov 2014 · Paper 22 · Q1

Length–load graph (Fig. 1.1): straight from about 8.5 cm (at 0 N) then curving at point P (~5 N). At 4.0 N the length is about 14.5 cm.

(a) Name point P (line stops being straight).

Point P is the **limit of proportionality**.

(b)(i) Determine the unstretched length of the spring.

The unstretched length is the length at zero load (the intercept on the length axis): **about 8.5 cm**.

(b)(ii) Calculate the extension for a load of 4.0 N.

From the graph, at 4.0 N the length is about 14.5 cm.
extension = 14.5 − 8.5 = **about 6.0 cm**.

(c) A block of wood gives an extension of 2.7 cm. Calculate its mass (g = 10 N/kg).

From the straight part, 4.0 N gives ~6.0 cm, so the spring extends 1.5 cm per N ($k \approx 0.67$ N/cm).
Weight = 2.7 / 1.5 = 1.8 N, so $m = W/g$ = 1.8 / 10 = **0.18 kg**.

Question 14 — Oct/Nov 2015 · Paper 22 · Q2

A force on rubber; then a spring loaded well beyond its limit of proportionality.

(a) State two effects the force has on the rubber.

1. It **compresses / squashes** the rubber (changes its shape). 2. It **changes its size** (the rubber deforms / flattens). (Either: change of shape and change of size/dimensions.)

(b)(i) Sketch the extension–load graph and label the limit of proportionality P.

Draw a line that is **straight from the origin** (extension proportional to load) and then **curves upward more steeply**; mark **P** at the point where the line stops being straight (the limit of proportionality).

(b)(ii) Suggest what is observed when all the masses are removed.

Because the spring was stretched beyond its limit of proportionality, it does **not return to its original length** — it stays permanently stretched (longer than at the start).

Question 15 — Oct/Nov 2017 · Paper 22 · Q2

A spring of mass 0.012 kg; a load extends one spring by 2.7 cm; a second identical spring is added in series.

(a) State two other properties that may change when a force is applied (besides velocity).

1. The object's **shape** (it can be deformed / stretched / compressed). 2. The object's **direction of motion** (and its size). (Acceptable: shape, size, direction.)

(b)(i) Calculate the weight of the spring (g = 10 N/kg).

$W = mg = 0.012 \times 10$

W = **0.12 N**.

(b)(ii) Suggest one reason why the second spring's extension differs from 2.7 cm.

The second spring also carries the **weight of the first spring (and its load) hanging below it**, so the total force stretching it is slightly different from that on the first spring — hence a different extension. (Equally acceptable: the springs are not perfectly identical.)

(b)(iii) Explain what is meant by *limit of proportionality*.

It is the point beyond which the **extension is no longer directly proportional to the load** — the spring stops obeying Hooke's law and the load–extension graph stops being a straight line.

(c)(i) State the form of energy stored in the stretched springs.

Elastic (strain) potential energy.

(c)(ii) The released load oscillates with decreasing distance until it stops. Explain why.

Resistive forces (**air resistance and internal friction**) do work against the motion, transferring the load's energy to the surroundings as **thermal energy (heat)**. As energy is removed each oscillation gets smaller until all the kinetic energy is gone and the load stops.

Question 16 — Oct/Nov 2018 · Paper 21 · Q3

Extension–load graph (Fig. 3.2): straight from origin, about 19 cm at 7.0 N (~2.7 cm per N), limit of proportionality at 7.0 N.

(a) Sketch the shape of the graph for loads greater than 7.0 N.

Continue the line so that it **curves upward more steeply** beyond 7.0 N (extension increases by more than 2.7 cm per added newton), since the spring has passed its limit of proportionality.

(b) A wooden block stretches the spring from 4.9 cm to 13.4 cm. Determine its weight.

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Extension = 13.4 − 4.9 = 8.5 cm.

From the straight part of the graph, 7.0 N gives about 19 cm, so the spring extends ~2.7 cm per N (*k* ≈ 0.37 N/cm).

weight = 8.5 / 2.7 = **about 3.1 N** (load read from the graph at an extension of 8.5 cm).

(c) Two identical springs share a load increased to 9.0 N. State and explain whether the limit of proportionality is reached.

With two springs side by side the 9.0 N load is **shared equally**, so each spring carries only 9.0 / 2 = 4.5 N. 4.5 N is **less than the 7.0 N limit** for one spring, so the limit of proportionality is **not reached**.

Note from Megalecture. Values read from graphs (Q3, Q5, Q6, Q13, Q16) carry a small reading tolerance — accept answers within roughly one small square of those quoted. These are original Megalecture worked solutions prepared for revision use; please verify before classroom use.