Give the marks for the points in the marking scheme; an answer in other words that says the same is right.

1 Spot the error

ANSWER U · 3

He added where he should have subtracted: the formula $\frac{1}{f} = \frac{1}{u} + \frac{1}{v}$ gives $\frac{1}{v} = \frac{1}{f} - \frac{1}{u}$.

So $\frac{1}{v} = \frac{1}{10} - \frac{1}{15} = \frac{1}{30}$, and **v = 30 cm**, m = 30 ÷ 15 = **2**: real, inverted, twice as tall. (The object is between F and 2F, so the image must be beyond 2F and magnified. His answer couldn't be right: v = 6 cm is closer than the focus.)

MARKING SCHEME

- ✓ He added; it should be $\frac{1}{v} = \frac{1}{f} - \frac{1}{u}$.
- ✓ v = 30 cm.
- ✓ m = 2: real, inverted, magnified.

2 Find the bad reading

ANSWER A · 4

(The readings are made up.)

i. $\frac{1}{15} + \frac{1}{60} = \frac{5}{60} = \frac{1}{12}$, and four other pairs give the same: **f = 12 cm**, so P = 1 ÷ 0.12 = **+8.33 D**.

ii. **u = 40 cm**: its *v* gives f = 14.6 cm, and *v* should fall steadily as *u* grows. It should be $\frac{1}{v} = \frac{1}{12} - \frac{1}{40} = \frac{7}{120}$, **v = 17.1 cm**.

iii. **u = 24 cm**, where v = u too: m = 1, the same size, and 24 cm = 2f.

MARKING SCHEME

- ✓ f = 12 cm from the pairs.
- ✓ P = +8.33 D.
- ✓ u = 40 cm doesn't fit; v should be 17.1 cm.
- ✓ At u = v = 24 cm = 2f.

3 The school hall

ANSWER A · 4

i. $\frac{1}{u} = \frac{1}{10} - \frac{1}{300} = \frac{29}{300}$, so **u = 10.3 cm**. m = v ÷ u = 300 × $\frac{29}{300}$ = 29, so the picture is 3 × 29 = **87 cm** tall.

ii. $\frac{1}{u} = \frac{1}{10} - \frac{1}{500} = \frac{49}{500}$, so u = 10.2 cm: **towards the lens**, by about 0.1 cm. m = 49, so the picture is **147 cm** tall.

MARKING SCHEME

- ✓ u = 10.3 cm.
- ✓ m = 29 and a picture 87 cm tall.
- ✓ u = 10.2 cm: towards the lens.
- ✓ m = 49 and a picture 147 cm tall.

4 Show that

ANSWER

i. $\frac{1}{v} = \frac{1}{f} - \frac{1}{u} = \frac{u-f}{uf}$, so $v = \frac{uf}{u-f}$, and $m = \frac{v}{u} = \frac{f}{u-f}$.

ii. m = 15 ÷ 5 = **3**.

iii. f = u − f, so **u = 2f**.

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iv. u − f gets smaller and smaller, so **m grows without limit**: the image moves far away and gets very large, and at F it is at infinity. HA · 4

MARKING SCHEME

✓ $v = \frac{uf}{u-f}$.

✓ $m = \frac{f}{u-f}$, and m = 3.

✓ u = 2f.

✓ m grows without limit as u approaches f.

5 One screen, two places

ANSWER HA · 5

i. u = 30, v = 60: $\frac{1}{30} + \frac{1}{60} = \frac{3}{60} = \frac{1}{20}$. u = 60, v = 30 gives the same sum, since u and v only change places.

ii. m = 60 ÷ 30 = **2**, and m = 30 ÷ 60 = **0.5**. One is the reciprocal of the other (their product is 1).

iii. $\frac{1}{20} = \frac{1}{u} + \frac{1}{70-u} = \frac{70}{u(70-u)}$, so u(70 − u) = 1,400, or $u^2 - 70u + 1{,}400 = 0$. Its discriminant is $70^2 - 4 \times 1{,}400 = 4{,}900 - 5{,}600 = -700$, which is negative, so it has no real solution: **no place for the lens gives a sharp image**. The bulb and screen are too close for this lens.

MARKING SCHEME

✓ Both positions satisfy the lens formula.

✓ m = 2 and m = 0.5, reciprocals.

✓ The equation derived.

✓ The discriminant is −700, negative.

✓ So no position gives a sharp image.

6 Work backwards

ANSWER A · 4

i. $v_e = -25$ cm: $\frac{1}{u_e} = \frac{1}{2.5} + \frac{1}{25} = \frac{11}{25}$, so u_e = **2.27 cm**.

ii. $v_o = 16 - 2.27 = 13.73$ cm. $\frac{1}{u_o} = \frac{1}{0.5} - \frac{1}{13.73}$, so u_o = **0.519 cm**, just beyond the focus.

iii. $m_o = 13.73 \div 0.519 = 26.5$, and $m_e = 1 + \frac{25}{2.5} = 11$, so M = 26.5 × 11 = **about 290**.

MARKING SCHEME

✓ u_e = 2.27 cm.

✓ v_o = 13.73 cm.

✓ u_o = 0.519 cm.

✓ m_o = 26.5, m_e = 11, M about 290.

7 The right way round

ANSWER A · 3

i. M = 90 ÷ 3 = 30, so 0.5° × 30 = **15°**.

ii. M must be 20 ÷ 0.5 = 40, so f_e = 90 ÷ 40 = **2.25 cm**, and L = 90 + 2.25 = **92.25 cm**.

iii. The lens with the short focal length would now be the objective: M = 3 ÷ 90, so everything looks **30 times smaller**.

MARKING SCHEME

✓ 15°.

✓ f_e = 2.25 cm and L = 92.25 cm.

✓ M = 1/30: things look 30 times smaller.

8 Find the unknown lens

ANSWER

i. +4 + P = +1, so P = **−3 D**, and f = 1 ÷ (−3) = −0.333 m = **−33.3 cm: concave**.

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ii. $\frac{1}{v} = \frac{1}{100} - \frac{1}{50} = -\frac{1}{100}$, so **v = −100 cm**, and m = −100 ÷ 50 = −2: on the object's side, **virtual, upright, twice as tall**. (The object is inside the pair's focus.) A · 4

MARKING SCHEME

✓ P = −3 D.
✓ f = −33.3 cm, concave.
✓ v = −100 cm.
✓ m = −2: virtual, upright, twice as tall.

9 Fair test

MARKING SCHEME A · 3

✓ Changes the curve; measures the focal length with a far view.
✓ Any two things kept the same.
✓ A shorter f, and so a greater power, for a more curved lens.

10 Your phone's camera

ANSWER A · 4

i. P = 1 ÷ 0.006 = **about +167 D**.

ii. $\frac{1}{v} = \frac{1}{6} - \frac{1}{5{,}000}$, so v = 6.007 mm. m = 6.007 ÷ 5,000 = 0.0012, and the image is 1,700 × 0.0012 = **about 2 mm** tall.

iii. $\frac{1}{v} = \frac{1}{6} - \frac{1}{500}$, so v = 6.073 mm. It moves 6.073 − 6.007 = **about 0.07 mm**, which is why a tiny motor can do it.

MARKING SCHEME

✓ About +167 D.
✓ v = 6.007 mm, so m is about 0.0012.
✓ Image about 2 mm tall.
✓ v = 6.073 mm: a move of about 0.07 mm.

11 Predict, then explain

MARKING SCHEME U · 3

✓ No: above about 1,500× only a bigger blur.
✓ Points closer than half a wavelength blur, and viruses are smaller.
✓ The whole image stays, dimmer, since each point's rays still pass through the upper half.

12 Correct the misconceptions

ANSWER U · 3

1. The size of the power tells how strongly a lens bends light, and the sign only which way: −8 D is much stronger.
2. The focal length must be in meters: P = 1 ÷ 0.20 = +5 D.
3. Their **powers** add, $P = P_1 + P_2$, not their focal lengths.

MARKING SCHEME

✓ −8 D is stronger; the sign only gives the direction.
✓ f in meters: +5 D.
✓ Powers add, not focal lengths.

13 Think

ANSWER

Write f = −F, where F is the size of the focal length. Then $\frac{1}{v} = -\frac{1}{F} - \frac{1}{u}$, the sum of two negative numbers, so **v is always negative: always virtual**.

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The size of $\frac{1}{v}$ is $\frac{1}{F} + \frac{1}{u}$, which is larger than $\frac{1}{u}$, so the size of v is smaller than u. Then the size of $m = \frac{v}{u}$ is less than 1: **always diminished**. HA · 3

MARKING SCHEME

- ✓ 1/v is the sum of two negative numbers.
- ✓ So v is negative: always virtual.
- ✓ The size of v is less than u, so the size of m is less than 1.

14 Make your own

ANSWER HA · 2

Any set that fits $f = \frac{uv}{u+v}$, for example u = 20 cm, v = 30 cm: f = 600 ÷ 50 = 12 cm. Check: $\frac{1}{20} + \frac{1}{30} = \frac{5}{60} = \frac{1}{12}$.

MARKING SCHEME

- ✓ Three whole numbers that fit, with u and v different.
- ✓ The check worked out.

See it at Science Playground

Exhibits and plants at the center, Bhaktapur, that go with this unit. Book a class visit at science-playground.com/booking.

- **Rays of Light** (exhibit): Put the convex lens in the three beams and find where they meet, the principal focus; a concave lens spreads the beams apart.
- **The Single Lens Camera** (exhibit): The lens casts a real, upside-down image of the scene on the box's screen: the light really meets there.
- **The Fresnel Lens** (exhibit): Look through it at the letters: they look bigger and upright, a convex lens used as a magnifying glass, kept thin by cutting it into rings.
- **The Water Bowl Magnifier** (exhibit): A bowl of water magnifies like a lens: find where the pebbles look largest, as people once did with water-filled glass spheres.

Marks by level	Knowledge	Understanding	Application	Higher ability	Total
Marks	0	9	26	14	**49**

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