inkPhysics

ANSWER BOOK

The physics of the eye

Medical physics · Year 13

AQA 3.10.1

17 questions · 51 marks

NAVY EDITION

SECTION A · Warm-up

A1 The image is real, inverted and diminished (1). Most of the refraction happens at the cornea, the curved front surface, because that is where light meets the largest change in refractive index; the lens makes the smaller adjustment (1). [2]

A2 The near point is the closest object the eye can focus sharply, taken as 0.25 m for a normal adult eye (1). The far point is the furthest object it can focus sharply, which is at infinity for a normal eye (1). [2]

A3 Accommodation is the eye changing its optical power so that objects at different distances are all focused onto the retina (1). It is the lens that changes: ciliary muscles alter its shape and so its focal length (1). [2]

A4 $P = 1/f = 1/0.40 = +2.5$ D (1). For the second lens $f = 1/P = 1/(-4.0) = -0.25$ m; the negative focal length means it is a diverging lens (1). [2]

A5 The dioptre (D), equivalent to one per metre, m^{-1} (1). The focal length must therefore be in metres before the reciprocal is taken. [1]

A6 Myopia (short sight) is an eye that is too powerful for its length, so parallel rays focus in front of the retina and the far point is at a finite distance (1). Hypermetropia (long sight) is an eye with too little power for its length, so rays from a near object would focus behind the retina and the near point is further away than 0.25 m (1). [2]

SECTION B · Standard

B1 Relaxed means the object is at the far point, so u is infinite and $1/u = 0$ (1). $1/f = 1/u + 1/v = 0 + 1/0.022$ (1), so $f = 22$ mm and $P = 1/0.022 =$ **45** D (1). Leaving the 22 in millimetres gives a power a thousand times too small. [3]

B2 The image is still on the retina, so $v = 0.022$ m and only f changes (1). $1/f = 1/0.30 + 1/0.022 = 3.33 + 45.45 = 48.79$ (1), so $f =$ **20.5** mm (1). Writing $v = 0.30$ m is the standard error: 0.30 m is where the object is, not where the image is. [3]

B3 The lens must take an object at infinity and form a virtual image at the far point, so u is infinite and $v = -0.25$ m (1). $1/f = 0 + 1/(-0.25)$ (1), so $P =$ **-4.0** D, a diverging lens (1). Dropping the minus sign on v gives +4.0 D, which would make the sight worse. [3]

B4 The lens must take the page at u = 0.25 m and form a virtual image at the eye's own near point, so v = -0.75 m (1). 1/f = 1/0.25 + 1/(-0.75) = 4.00 - 1.33 (1), so P = **+2.7** D, a converging lens (1). [3]

B5 m = v/u = 0.023/10 (1) = 2.3×10^{-3} (1). Image height = 1.8 × 2.3×10^{-3} = 4.1 mm, about **4** mm (1). The image is inverted, and a few millimetres across is all the retina ever receives. [3]

B6 The cornea, or sometimes the lens, is not the same shape in every direction across its face, so its power differs between two perpendicular directions and a point object cannot be brought to a point image in both at once (1). The prescription gives the spherical power SPH in dioptres and the additional cylindrical power CYL in dioptres (1), together with the AXIS in degrees from 0 to 180, which states the direction along which the cylinder acts (1). [3]

B7 Many rods are connected to a single nerve fibre, so the light caught by all of them is added together into one signal (1). That summed signal is large enough to register when very little light is arriving, which gives the sensitivity (1). But the brain cannot tell which rod of the group was lit, so detail within the group is lost, whereas each cone in the fovea has effectively its own fibre and so stays a separate signal (1). [3]

SECTION C · Stretch

C1 At the far point u is infinite, so P = 1/0.023 = 43.5 D (1). At the near point P = 1/0.40 + 1/0.023 = 2.50 + 43.48 = 46.0 D (1). The range of accommodation is 46.0 - 43.5 = **2.5** D, which is exactly 1/0.40 because the 1/v term never changes (1). At the near point f = 1/46.0 = 21.7 mm (1). The near point lies beyond the normal 0.25 m, so the eye is hypermetropic: it cannot supply enough power for close work (1). [5]

C2 For distance: u infinite, v = -0.20 m, so P = 1/(-0.20) = **-5.0** D and f = -0.20 m (1). With the lens worn, the nearest object is the one whose image the lens forms at the eye's own near point, so v = -0.12 m (1). 1/u = 1/f - 1/v = -5.00 - (-8.33) = 3.33 (1), so u = **0.30** m (1). The corrected near point is 0.30 m, beyond the normal 0.25 m, so the wearer has to hold a book further away than before or take the glasses off to read (1). [5]

C3 Looking straight at the star puts its image on the fovea, which is packed with cones and carries no rods (1). Cones need bright light, so a faint image there produces little response (1). Looking slightly to one side moves the image off the fovea onto the rods, which are far more sensitive because many of them share a nerve fibre and their signals are added together (1). Rods are of a single type only, so they report brightness and carry no information about wavelength (1), and the star therefore appears colourless; colour vision needs the three types of cone, which are not responding at this light level (1). [5]

C4 Separation = distance × angle = $0.25 \times 3.0 \times 10^{-4}$ (1) = 7.5×10^{-5} m, about **0.08** mm (1). The limit is set by the spacing of the cones in the fovea: two points are seen as separate only if their images fall on two cones with at least one unstimulated cone between them (1). Each fovea cone has its own nerve fibre, so those two signals stay distinct all the way to the brain; on the rods, where fibres are shared, the same two points would merge (1). [4]