TC *[66 marks]*

1a. *[5 marks]*

Markscheme

(i) attempted substitution into thin lens equation; *(allow incorrect signs)*

$v = \left(\frac{2\times5}{2-5}\right) = (-)3.3;$

$m\left(= -\frac{v}{u}\right) = \frac{3.3}{2} = 1.7;$

(ii) virtual because *v* is negative;
erect/upright because virtual/because *m* is positive;
enlarged/magnified because *m* is greater than 1;
Do not allow correct properties without an explanation.

Examiners report

[N/A]

1b. *[2 marks]*

Markscheme

different colours/wavelengths/frequencies have different refractive indices/speed of light (in glass);
(image with colour distortions due to the) different focal points (of said colours/wavelengths/frequencies);

Examiners report

[N/A]

1c. *[1 mark]*

Markscheme

use of a chromatic doublet / use of a combination of lenses;

Examiners report

[N/A]

2a. *[2 marks]*

Markscheme

use of piezoelectric crystal / quartz;
crystal changes shape/vibrates when an alternating electric field is applied to it;
crystal dimensions are cut to achieve resonance at required frequency;

Examiners report

[N/A]

2b. *[5 marks]*

Markscheme

(acoustic impedance of air =) 330 × 1.3 = (=430 (kgm^{-2} s^{-1}));

(acoustic impedance of skin =) 1500 × 1000 = (=1.5×10^{6}(kgm^{-2} s^{-1}));

$\frac{I_R}{I_0} \approx 1/0.999$;

little/no transmission (because the reflected intensity is approximately equal to the incident intensity);

gel (has similar impedance to skin and so) is required as it excludes air from the interface (so transmission occurs);

Accept first two marking points if implied in the third marking point.

Examiners report

[N/A]

2c. *[3 marks]*

Markscheme

A-scan is a “graph” of returned intensity against time but B-scan is a 2-D image of section through patient;

A-scan: ultrasound probe is fixed in position;

B-scan: operator moves ultrasound generator and computer records echo returns;

Examiners report

[N/A]

3a. *[3 marks]*

Markscheme

for a ray attempting to move from a high to a low refractive index medium;

the phenomena in which the angle of incidence is greater than the critical angle;

(critical angle is) the angle of incidence for which the angle of refraction is 90° / *OWTTE;*

leading to a reflected but not to a refracted ray;

*Award **[3 max]** for a clearly drawn annotated diagram.*

Examiners report

Total internal reflection was not usually well explained. Far too many candidates gave disorganised accounts and were unsure which angle was the critical angle.

3b. *[2 marks]*

Markscheme

$$\frac{\sin\theta_c}{\sin 90^\circ} = \left(\frac{\sin\theta_c}{1} = \right)\frac{1.50}{1.62}$$

;

$\theta_c = 67.8^\circ$;

*Award **[2]** for a bald correct answer.*

Examiners report

The value of critical angle was frequently wrong in part (b) as the wrong pair of refractive indices was used.

3c. *[1 mark]*

Markscheme

pulse width/duration increases / pulse amplitude decreases / colour separation;

Examiners report

In (c) there was often confusion between attenuation and dispersion.

4a. *[7 marks]*

Markscheme

(i) identifying focal length from diagram ***or*** f=5.0cm;

$\left(P = \frac{1}{f} = \frac{1}{5.0}\right) = 0.20\left(\text{cm}^{-1}\right)$ **or** 20 (D) **or** 20

(m^{-1});

*Award **[2]** for a bald correct answer.*

(ii) first ray from tip of object correctly refracted by lens;
a second ray from tip of object correctly refracted;
correct extrapolation back to tip of image;
Accept rays without arrows and solid construction lines back to the image.

(iii) image is virtual;
image cannot be formed on a screen / rays do not cross;

Examiners report

The magnifying glass ray diagram was almost always correct in (a). All candidates knew that the image was virtual, but often gave vague statements about what this means.

4b. *[3 marks]*

Markscheme

(i) $\theta_0 = \left(\frac{82}{4\times10^3} = \right)2.05 \times 10^{-2}(\text{rad})$;

$M = \left(\frac{0.1}{2.05\times10^{-2}} = \right)4.9$;

Allow ECF in second marking point for using incorrect angle.
*Award **[2]** for a bald correct answer.*

(ii) $\left(f_o = 4.9 \times 15\right) = 74(\text{cm})$ ***or*** 73 (cm); *(allow ECF from (b)(i))*
Allow 75 (cm) due to rounding.

Examiners report

Part (b) was also done well with only a few candidates making POT errors when finding the angular magnification of the telescope.

5. *[5 marks]*

Markscheme

(i) the absorption of energy/loss of power from the beam;

(ii) correct substitution

$\frac{I_0}{2} = I_0 e^{-\mu x_{\frac{1}{2}}}$;

taking natural logs

$\ln\frac{1}{2} = -\mu x_{\frac{1}{2}}$;

$\left(\ln 2 = \mu x_{\frac{1}{2}}\right)$

Answer given, marks are for correct working.

(iii)

$\mu = \left(\frac{\ln 2}{0.73} = \right) 0.95\,\text{cm}^{-1}$;

$I = \left(I_0 e^{-0.95\times 2.0} = \right) 0.15 I_0$;

or

number of half-value thicknesses

$= \frac{2}{0.73} = 2.74$;

$I = 0.5^{2.74} = 0.15 I_0$;

*Award **[2]** for a bald correct answer.*

Examiners report

Part (a) contains two standard questions and was well answered. In comparing the processes of computed tomography (CT) and conventional X-ray imaging many candidates did well. Common problems included not mentioning the fact that CT images are taken at all angles during rotation and that CT involves a far greater absorbed dose.

6a. *[1 mark]*

Markscheme

the product of the speed of sound and the density of the medium/substance;

Accept as an equation with symbols defined.

Examiners report

Part (a) was an easy mark, although the speed of light was mentioned too often.

6b. *[6 marks]*

Markscheme

(i) *The data is on the previous page and most candidates do not realize it is to be used here. So two alternative MS are given which try to be fair to all candidates.*

the impedance of gel and soft tissue are the same;
so the equation gives a reflection coefficient (OWTTE) of zero;

or *(knowledge based answer)*

gel replaces air which would cause unwanted reflection / air has a lower impedance than soft tissue;
the impedance of gel and soft tissue are the same/similar so reflection is reduced;

Do not reward bald "reflection will be less/reduced" for the second marking points as this is given in the question.
Do not accept "density" instead of impedance.

(ii)

$$\left(\left[\frac{6.1\times10^{6}-1.6\times10^{6}}{6.1\times10^{6}+1.6\times10^{6}}\right]^{2}\right)=0.34;$$

(iii) intensity reaching bone is $0.40I_0$;

intensity reflected from bone is $0.34\times0.40I_0$; { *(allow ECF from first marking point)*

intensity reaching transducer is $(0.40\times0.34\times0.40I_0)=0.054I_0$;

*Award **[2 max]** for an answer of 0.16 I_0 **or** 0.12 I_0.*

*Award **[3]** for a bald correct answer.*

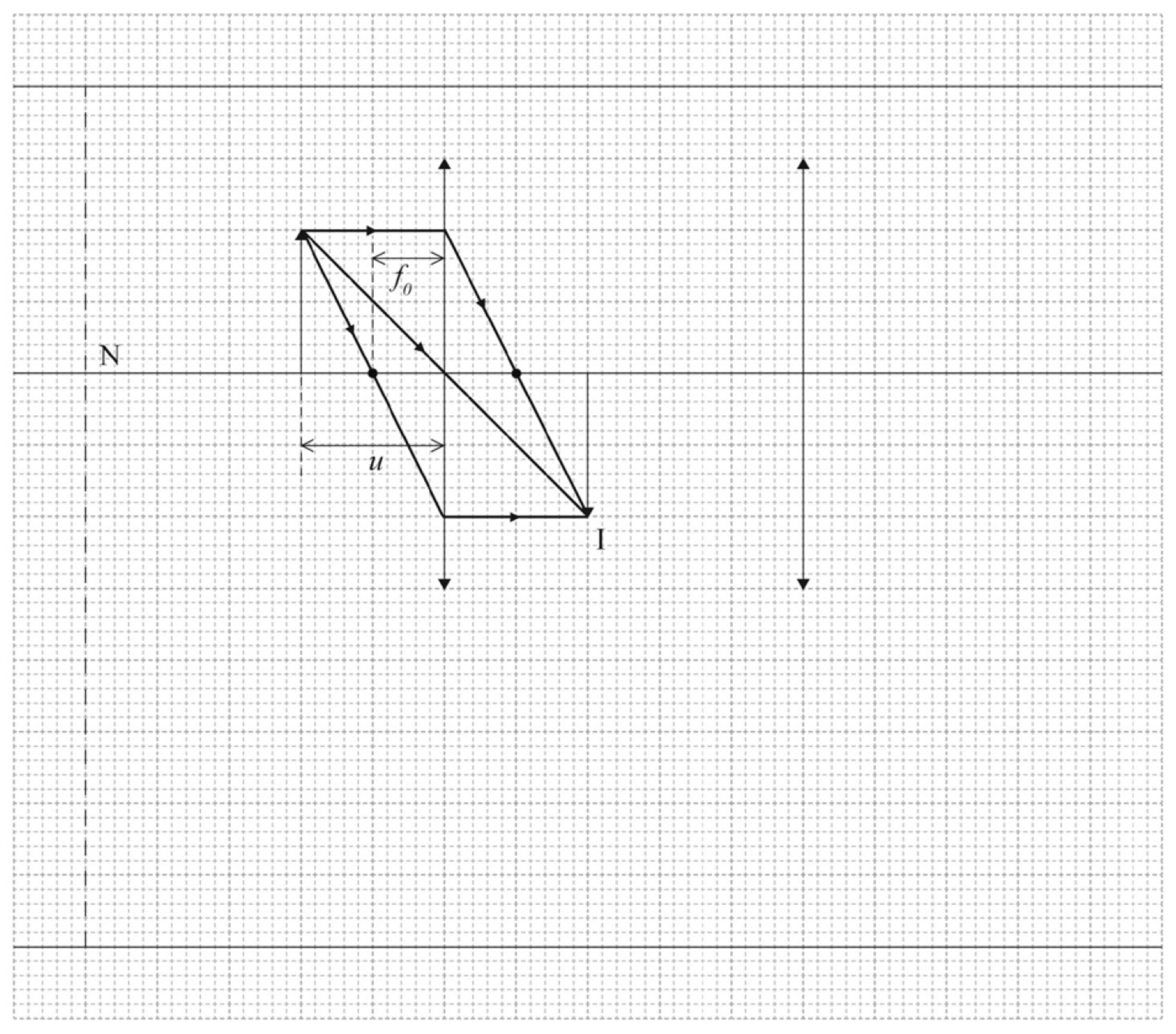
Examiners report

In (b)(i) many candidates ignored the data and answered using existing knowledge. The reflection coefficient was usually correctly calculated in (b)(ii). Part (b)(iii) was poorly answered. Most candidates did not take the time to analyse what was happening. Two attenuations and one reflection, so I = 0.4 × 0.34 × 0.4Io for 3 marks — but very few correct answers were seen.

7a. *[3 marks]*

Markscheme

(i) any two standard rays out of the three shown below;
converging to locate the image;



(ii) (image is real) because rays of light/energy pass through it;

Examiners report

This question was relatively well answered. In (a), the majority of candidates proved that they are able to use standard rays to find the position of the image, although too many candidates were not able to outline clearly enough whether the image is real.

7b. [6 marks]

Markscheme

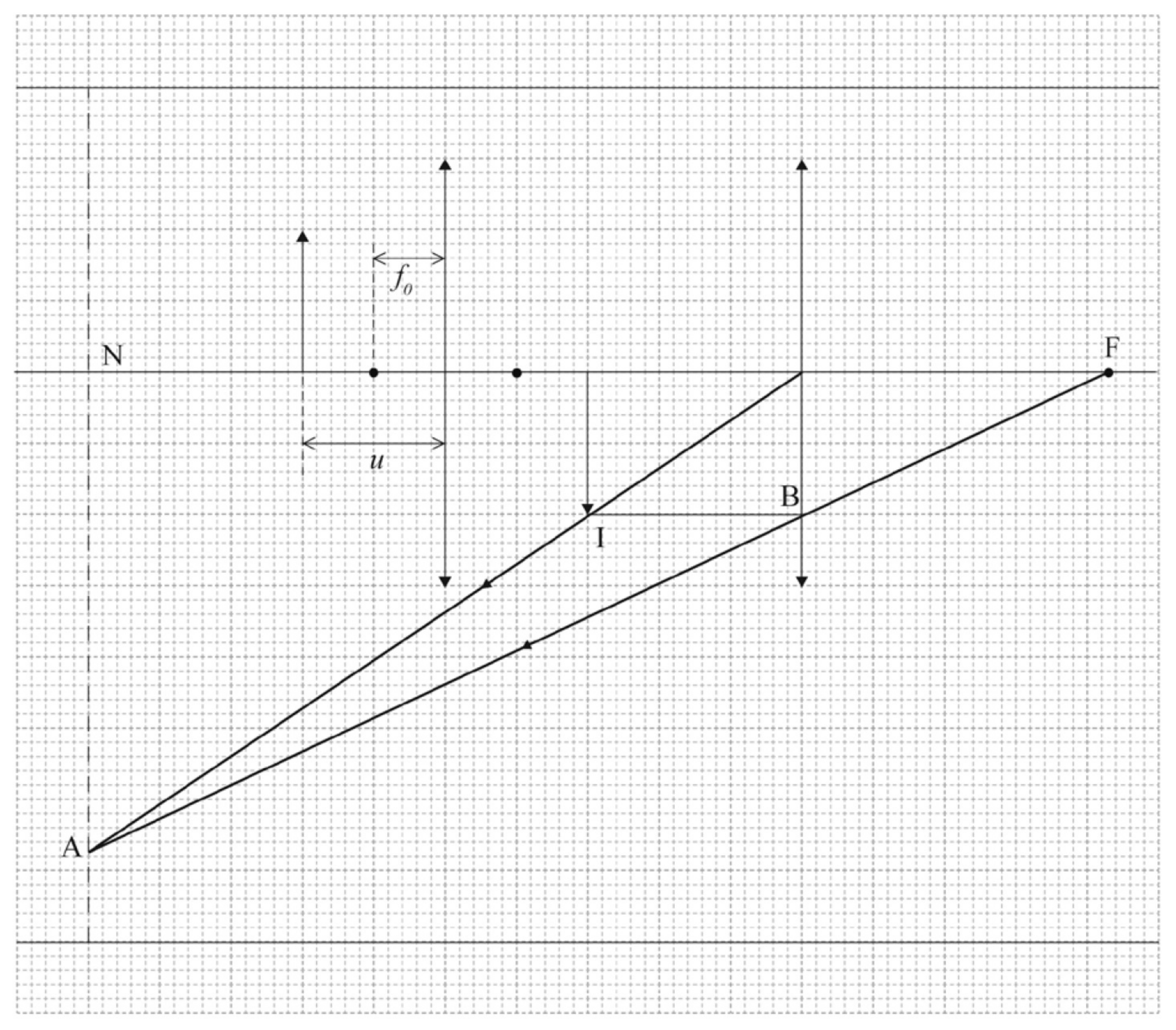
(i) the closest distance the unaided human eye can focus (without undue strain);

Do not accept 25cm without explanations.

(ii) standard ray through the center of the eyepiece to locate point A;

standard ray through points A and B;

extrapolated to the principal axis to locate the focus F, 10.7cm from the eyepiece; } *(allow focal lengths between 9 cm and 12.5 cm if the two standard rays are clearly identified)*



or

v=-25cm;

u=+7.5cm;

$$f = \left[\frac{1}{u} + \frac{1}{v}\right]^{-1} (= 10.7\text{cm});$$

(iii) counting small squares, size of final image=33.3 and size of object=10;

$$m = \frac{33.3}{10} = 3.3;$$

or

$m_1 = 1$ and $M_2 = \left(\frac{25}{7.5} = \right)3.3;$

$$M = \left(m_1 \times M_2 = \right)3.3;$$

Examiners report

There were many correct answers to (b)(i), despite the general tendency for a lack of clarity in the answers to "define" questions. (b)(ii) and (iii) were well answered by the more able candidates. Generally the answers lacked clarity, explanation of formulas used and clarity of layout of working. More alternative solutions were accepted if clearly explained. Only a few construction based solutions was found, although this is by far the more understandable approach to the problem.

8a.

[2 marks]

Markscheme

waves of different wavelength/frequency;
travel at different velocities;
the index of refraction of the medium depends on the wavelength/frequency;

Examiners report

Too many candidates showed that they do not know the terminology and vaguely described other phenomena instead of dispersion, quite often scattering. Breaking into component colours was sometimes mentioned by the candidates but this was not accepted as correct as the question was about electromagnetic waves, not only about light. A reasonable number of correct answers were seen with reference of both different speed and index of refraction.

8b.

[2 marks]

Markscheme

during simple harmonic motion the charge oscillates/accelerates;
(oscillating/accelerating) charges radiate/produce (varying) electric/magnetic fields / produce electromagnetic waves;

Examiners report

In (b) only the stronger HL candidates clearly connected accelerated charge with the production of electromagnetic radiation. Most SL answers simply repeated the production of electromagnetic waves, missing the importance of the acceleration of the electron and not relating it to electric and magnetic fields.

9a.

[1 mark]

Markscheme

probability of a single photon being absorbed in 1m of the material / reference to $I = I_0 e^{-\mu x}$ with symbols defined;

Examiners report

Candidates do not use precise enough wording in definitions, as seen in answers to (a).

9b.

[6 marks]

Markscheme

at 0.1MeV, μ=30(m^{-1});
$0.1 = e^{-30x}$;
$x = \frac{\ln 0.1}{-30}$;
x=0.077(m);

(ii) (at 10MeV,) μ is smaller (than at 0.1MeV);
so (10MeV X-rays are) more penetrating;
Award second mark only if first mark has been awarded.

Examiners report

In (b), the majority of candidates had no problem with the determination of attenuation coefficient from the graph and used it in the calculation of the result.