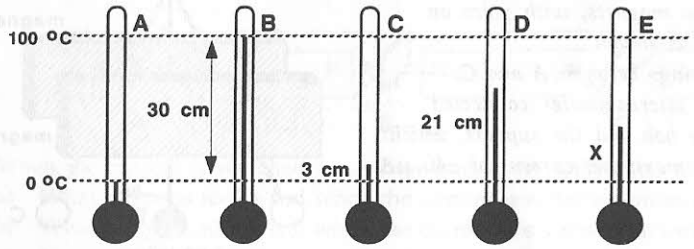
HEALTH PHYSICS

THERMOMETERS

1. a) What is the temperature of pure boiling water?
   b) What is the temperature of melting ice?
   c) What is the normal temperature of the human body?
   d) Suggest a temperature that would indicate hypothermia.

2. All the following thermometers are identical. Thermometer **A** is in melting ice and thermometer **B** is in boiling water. The lengths of the columns of mercury are shown.



   a) What is the temperature of thermometer **C**?
   b) What is the temperature of thermometer **D**?
   c) If thermometer **E** is in water at 35 °C, what is the value of **X**?

3. A thermocouple connected to a voltmeter gives a zero reading when both junctions are in melting ice. It gives a reading of 8 mV when the second junction is in boiling water.
   a) If the second junction is in a furnace at 1200 °C, what is the voltmeter reading?
   b) If the voltmeter reads 26.8 mV, what is the temperature of the second junction?

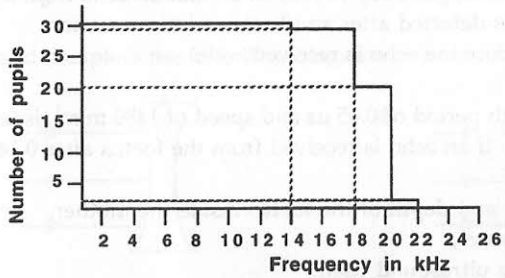
4. a) What is a bimetallic strip?
   b) Why does a bimetallic strip bend when it is heated?
   c) A strip bends through 3.75° when it is heated by 50 °C.
      i) How much does it bend when heated by 392 °C?
      ii) What is the temperature when the strip bends through 44.1°?

5. *In an alcohol in glass thermometer the column of alcohol is 215 mm from the bottom of the bulb when the thermometer is in boiling water and 45 mm from the bottom of the bulb when in melting ice.*
   a) If the alcohol stops 121.5 mm from the bottom of the bulb, what is the temperature?
   b) If the alcohol stops 19.5 mm from the bottom of the bulb, what is the temperature?
   c) If the temperature is 65 °C, where does the alcohol stop?

SOUND

6. The range of human hearing is approximately 20 Hz to 20 kHz. If the speed of sound in air is 340 ms^{-1}, calculate:
   a) the minimum wavelength that is heard,
   b) the maximum wavelength that is heard.

7. The histogram shows the range of hearing for a class of pupils.



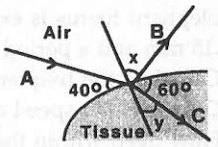
   a) What is the maximum frequency heard by any pupil?
   b) How many pupils can hear a sound of frequency 17 kHz?
   c) One pupil has a lower range than the others.
      i) What is his upper threshold of hearing?
      ii) Suggest a reason for this lower range.

8. a) State the noise level of ordinary conversation.
   b) State the pain threshold.

9. a) What is meant by ultrasound?
   b) A bat can hear sound with a wavelength of 8.5 mm. Show by calculation if this is ultrasound.

10. An object is detected by ultrasound as long as it is at least equal to one wavelength of the ultrasound. If the frequency of the ultrasound is 50 kHz, what is the size of the smallest object detected?

11. Ultrasound was applied to a pregnant woman without using a gel for good contact. The diagram shows what happened (not to scale).



    a) Name rays **B** and **C**.
    b) Calculate the size of angles **x** and **y**.

12. A series of sonar pulses is used by fishermen to detect shoals of fish under the water. The speed of sound in water is 1200 ms^{-1}.
    a) An echo is received after 0.3 s. How far had the sound travelled?
    b) How deep is the water?
    c) A second echo is received after 120 ms. How far had the sound travelled?
    d) How deep is the shoal of fish?

13. The speed of sound in the human body is 1500 m s^{-1} and an echo from a foetus is detected 0.1 ms after an ultrasound transmission. The frequency of the ultrasound is 250 kHz.
    a) How many pulses of ultrasound are emitted every second?
    b) What is the period of the ultrasound?
    c) How deep in the mother's body is the part of the foetus which provides the echo?

14. The speed of sound in the human body is 1500 m s^{-1} and an echo from a foetus, 5 cm inside the mother, is detected after an ultrasound transmission. How long does it take before the echo is received?

15. An ultrasound signal, with period of 0.45 μs and speed of 1480 m s^{-1}, is used to examine an unborn child. If an echo is received from the foetus after 0.14 ms, calculate
    a) the distance travelled and depth of the foetus inside the mother,
    b) the frequency of the wave,
    c) the wavelength of the ultrasound used.

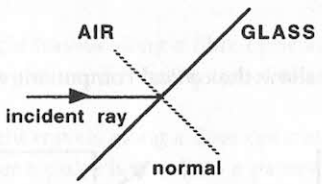
16. An ultrasound signal, with a period of 0.8 μs and a wavelength of 1.2 mm, is used to examine an unborn child.
    a) Calculate the frequency of the ultrasound used.
    b) Calculate the speed of the ultrasound.
    c) How long will it take for an echo to be received from a depth of 6 cm?

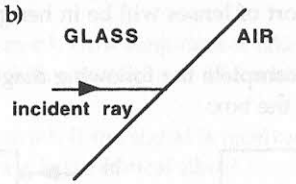
17. An ultrasound signal, with a period of 0.75 μs and a wavelength of 1.125 mm, is used to examine an unborn child.
    a) Calculate the frequency of the ultrasound used.
    b) Calculate the speed of the ultrasound.
    c) Calculate the depth of the part of the foetus within the mother which gives an echo after:
    i) 1×10^{-4} s,
    ii) 0.1 ms,
    iii) 0.25×10^{-3} s.

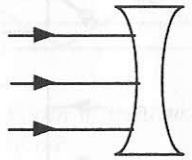
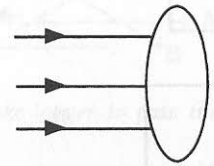
18. An elephant foetus is examined at the zoo using an ultrasound with a wavelength of 1.15 mm and a period of 0.78 μs.
    a) Calculate the frequency of the ultrasound used.
    b) Calculate the speed of the ultrasound.
    c) How deep within the elephant is the part of the foetus which gives an echo after 1.2 ms?

19. A man uses a 'silent' dog whistle to call his dog.
    a) Explain why the dog can hear it but the man cannot.
    b) Suggest a possible frequency for the dog whistle.
    c) Another whistle emits sound of wavelength 18 mm. Will this act as a 'silent' whistle. Explain your answer.

LIGHT

20. Copy and complete the following diagrams:
    a)


    b)


21. Copy and complete the following diagrams:
    a)

    b)

    c) Name the lenses in diagrams **a)** and **b)**.

22. *A convex lens has a focal length of 10 cm.*
    Draw ray diagrams to scale showing the formation of the images for:
    a) an object placed 15 cm from the lens,
    b) an object placed 20 cm from the lens.

23. *A convex lens has a focal length of 30 cm.*
    Draw ray diagrams to scale showing the formation of the images for:
    a) an object placed 60 cm from the lens,
    b) an object placed 90 cm from the lens.

24. Describe the shape of the lens in the eye when looking at:
    a) distant objects,
    b) objects which are close by.

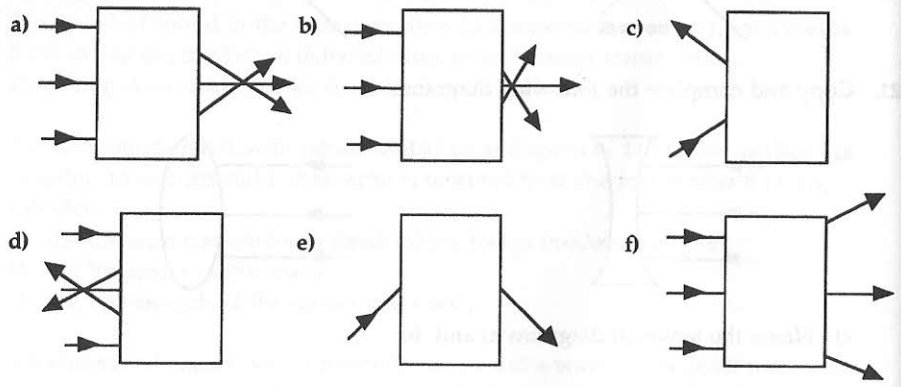
25. Draw diagrams to show where parallel rays of light are focused:
    a) for someone suffering from long sight,
    b) for someone suffering from short sight.

26. Describe the vision of a man suffering from:
    a) short sight,
    b) long sight.

27. A man can read his book with no trouble but needs glasses to see his cat at the bottom of the garden.
    a) What eye defect is he suffering from?
    b) What sort of lenses will be in his glasses?

28. A woman can watch a tennis match with no problems but needs her glasses to read the programme.
    a) What eye defect is she suffering from?
    b) What sort of lenses will be in her glasses?

29. Copy and complete the following diagrams to show the optical component which must be in the box:



POWER OF A LENS

$$\text{power of lens} = \frac{1}{\text{focal length in metres}}$$

30. Complete the following table:

	FOCAL LENGTH	POWER	TYPE OF LENS
a)	20 cm	------	convex
b)	----i)----	-5 D	---ii)---
c)	50 mm	----i)----	---ii)---
d)	----i)----	7.5 D	---ii)---
e)	1.2×10^{-2} m	----i)----	---ii)---
f)	----i)----	0.5 D	---ii)---
g)	- 8.5 cm	----i)----	---ii)---

31. a) A man has to wear glasses which have lenses of power 10 D.
        i) What is the focal length of the lens?
        ii) Is the man short or long sighted?
        iii) Should he wear his glasses to study a newspaper or watch football?
    b) His wife wears glasses with a focal length of -20 cm.
        i) What is the power of her lenses?
        ii) Is she short or long sighted?
        iii) When should she wear her glasses?

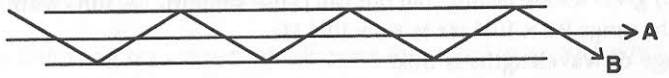
FIBRE OPTICS

32. Draw a diagram to show how a ray of light travels through an optical fibre.

33. Light travels along a fibre optic at 2×10^8 m s^{-1}. How long does it take a doctor to see the picture, if it has to travel 45 cm down into a patient and 45 cm back again?

34. Light travels along a fibre optic at 2×10^8 m s^{-1}. If the signal is received back 6×10^{-9} s after a pulse is sent into a patient, how long is the optical fibre?

35. *a) Light can take more than one path through an optical fibre.*



    i) Which of the two paths A or B will take longer to pass through the optical fibre?
    ii) What problems could this cause when using an optical fibre?
    iii) What steps could be taken to minimise this effect?

    b) Light travels down a fibre optic at 2×10^8 m s^{-1}.
    i) If it takes 4×10^{-7} s to pass along path A, how long is the fibre?
    ii) If one path is 71% shorter than the other, how long does it take to pass along path B.

LASERS

36. If a laser produces 5.8 kJ of energy in 5 min, what is its power?

37. An argon laser is used for eye surgery. It delivers 18 pulses in 0.2 s and each pulse delivers 0.023 J of energy for one particular treatment.
    Calculate the power of the laser.

38. A laser has a wavelength of 610 nm and is used to destroy birthmarks. It takes 0.04 J of energy for each cm^2 of the birthmark.
    a) What is the frequency of the laser?
    b) How much energy does it require in total for a birthmark which is 16 cm^2?
    c) If the laser has a power of 2000 mW, how long will the treatment take?

39. A laser is used with an endoscope to seal an ulcer in the stomach.
    If the laser has to travel 60 cm along the fibre optic to reach the ulcer and travels at 2×10^8 m s^{-1}, how long does it take?

USING THE SPECTRUM

40. Ultraviolet with wavelengths in the range 315 - 400 nm is called UVA and in the range 280 - 315 nm is called UVB.

a) Calculate the range of frequencies which correspond to UVA.
b) Calculate the range of frequencies which correspond to UVB.
c) Does radiation of frequency 10^{15} Hz fall in the UVA or UVB range?
d) Give one use of ultraviolet radiation.
e) Give one danger of too much ultraviolet radiation.

41. UVA (315 - 400 nm) can cause premature wrinkling of the skin, while UVB (280 - 315 nm) gives a long lasting tan but can cause sunburn. A sun cream absorbs radiation in the range 9.2×10^{14} Hz to 8.6×10^{14} Hz.

a) What range of wavelengths is this?
b) Does this sun cream absorb UVA or UVB radiation?

42. Ultraviolet and infrared travel to the Earth from the Sun at the speed of light. The Sun is 1.5×10^{8} km from the Earth.

a) What is the speed of light?
b) How long does it take the ultraviolet rays to reach the Earth from the Sun?
c) How long does it take the infrared rays to reach the Earth from the Sun?

43. The human body emits infrared radiation with wavelengths from 3 μm to 6 μm.

a) Calculate the range of frequencies emitted.
b) How is this information used in a thermogram?

44. X-rays travel at the speed of light. They have a range of frequencies from 5×10^{14} Hz to 5×10^{16} Hz.

a) Calculate the range of wavelengths which correspond to X-rays.
b) Give a medical use of X-rays.

45. *In computer aided tomography, 3-D pictures are built up by taking X-ray pictures of slices through the body. The slice can be 1, 2, 5 or 10 mm thick. A picture of a kidney, which needs to be 10 cm deep, has to be produced. Each slice builds up the image from 1500 detectors and takes 0.5 s. The information from each detector needs 1200 calculations to process the information.*

a) Calculate how many slices are required for the picture if the slices are:
i) 2 mm thick, ii) 10 mm thick.
b) Calculate how long the scan takes for the picture if the slices are:
i) 2 mm thick, ii) 10 mm thick.
c) Find how many calculations are required for the picture if the slices are:
i) 2 mm thick, ii) 10 mm thick.
d) Why is a computer required?

NUCLEAR MEDICINE

46. **a)** Name the three types of radioactivity.
b) Which type causes most ionisation?
c) Describe an experiment which distinguishes between the three types.

47. The following counts per minute were measured in a room when no source was present.

18, 21, 17, 18, 19, 23, 18, 21, 15, 20

a) Calculate the average count rate.
b) Explain why there is a background count rate.
c) Why is it not constant?

48. The following counts per minute were measured in a room when no source was present.

29, 31, 27, 35, 22, 28, 31, 28, 30, 29

a) Calculate the average count rate.
b) Suggest why this background count rate is much larger than the one in **Q. 47.**

49. A student obtained the following results when he placed different absorbers between radioactive sources and a Geiger - Muller tube.

Absorbing Material	**Count Rate** in c.p.m.		
Air only	no source present - 20		
	Source A	**Source B**	**Source C**
Air only	678	445	1890
Paper	690	19	1345
Aluminium	682	21	28
Lead	122	18	19

a) Which source emits only alpha radiation?
b) What type of radiation is emitted by source C?
c) Why does the count rate with source A present not come down to the background count rate, even when lead is the absorber?

50. *What is the activity of a source in which there are 45 000 atoms decaying in 1 min?*

51. *What is the activity of a source if there are 17 million atoms decaying in 5 min?*

52. *If the activity of a source is 25 kBq, how many atoms decay in 30 s?*

53. *The activity of a source is 3 MBq, how many atoms decay in 5 min?*

HALF LIFE

54. What is meant by the half life of a radioactive substance?

55. The activity of a source drops from 1000 kBq to 125 kBq in 9 days.
Calculate the half life of the source.

56. The activity of a source drops from 4800 kBq to 150 kBq in 10 days.
Calculate the half life of the source.

57. The activity of a source drops from 720 MBq to 45 MBq in 20 years.
Calculate the half life of the source.

58. The activity of a source drops from 4096 kBq to 1 kBq in 2 days.
Calculate the half life of the source.

59. The activity of a source drops from 448 kBq to 3.5 kBq in 17.5 years.
Calculate the half life of the source.

60. A source has an activity of 1800 kBq and a half life of 2 days.
What is its activity 10 days later?

61. A source has an activity of 576 MBq and a half life of 30 years.
What is its activity 180 years later?

62. A source has an activity of 2400 kBq and a half life of 8 s.
What is its activity 32 s later?

63. A source has an activity of 3200 kBq and a half life of 5.3 days.
What is its activity 37.1 days later?

64. A source has an activity of 800 kBq after being stored for 4 days.
If the half life is 1 day, what was its initial activity?

65. A source has an activity of 1800 kBq after being stored for 72 s.
If the half life is 24 s, what was its initial activity?

66. A source has an activity of 40 kBq after being stored for 10 years.
If the half life is 2 years, what was its initial activity?

67. A source has an activity of 30 kBq after being stored for 2 days.
If the half life is 8 h, what was its initial activity?

68. A source has an activity of 40 MBq and a half life of 15 s.
How long will it take for its activity to drop to 625 kBq?

69. *A source has an activity of 25 MBq and a half life of 8 days.*
Approximately how long will it take for its activity to drop to below 1MBq?

70. *A source has an activity of 320 MBq and a half life of 1000 years.*
Approximately how long will it take for its activity to drop to 500 kBq?

71. *A background count rate of 20 counts per minute is measured in the absence of a source. When the source is present the count is 140 counts per minute initially, dropping to 35 counts per minute after 15 days. What is the half life of the source?*

72. *If the background count is 28 counts per minute and the count with a source drops from 932 to 141 counts per minute in 24 h, what is the half life of the source?*

73. *If the background count rate is 24 counts per minute and the count rate with a source present drops from 4120 to 25 counts per minute in 2 days, what is the half life of the source?*

74. In an experiment with a radioactive source, the count rate corrected for background radiation was measured and the following results obtained.

Time in minutes	**Corrected Count Rate** in c.p.m.
0	100
1	58
2	32
3	18
4	10
5	5.6

a) Plot a graph to show these results.
b) Estimate the half life of the source from these results.

75. *In an experiment with a source, carried out in an area where there is a high background radiation, the following results were obtained.*

Time in seconds	*Count Rate in c.p.m.*
0	*88*
30	*72*
60	*60*
90	*52*
120	*44*
150	*39*
180	*36*
210	*34*
240	*32*
270	*29*
300	*30*

a) Plot a graph to show these results.
b) Estimate the background count rate.
c) Estimate the half life of the source from these results.