www.megalecture.com · www.youtube.com/@megalecture

Online tutoring for Cambridge IGCSE, O Level & A Level Physics

IGCSE PHYSICS 0625 · TOPICAL PAST PAPERS

Electromagnetic Spectrum — Paper 2

Worked Solutions (Theory / Structured)

Fahad H. Ahmad

Contact: +92 323 509 4443

M.Eng NUS Singapore · B.Eng NUST · 15+ years of teaching experience in Singapore, UAE & Pakistan · 60,000+ subscribers and 20 million+ video lecture views.

Electromagnetic Spectrum — Paper 2 · Worked Solutions

Megalecture worked solutions — model answers with working; please verify before classroom use. These are original Megalecture solutions to the topical structured/theory compilation on **Electromagnetic Spectrum (IGCSE Physics 0625 / 5054, Paper 2)**. Every part is solved from first principles; calculations use $c = 3.0 \times 10^8$ m/s and the wave equation $c = f\lambda$. Final answers are shown in **bold** with units. Use these to mark and improve your own responses.

> **Order of the EM spectrum** (increasing wavelength / decreasing frequency): gamma rays → X-rays → ultraviolet → visible light → infra-red → microwaves → radio waves. All EM waves are transverse, carry energy, and travel at $c = 3.0 \times 10^8$ m/s in a vacuum.

1 — 5054/02/M/J/03/Q4

Ordering the spectrum · uses of infra-red

(a) Correct table in order of **increasing wavelength** (radio waves given on the long-wavelength end). Match each band to its correct order of magnitude:

short wavelength →						long wavelength
gamma rays	X-rays	ultraviolet	visible	infra-red	microwaves	radio waves
10^{-14} m	10^{-10} m	10^{-8} m	10^{-6} m	10^{-5} m	10^{-2} m	10^{3} m

(b)

3.0×10^8 m/s (the speed of all EM waves in a vacuum, the same for every band).

(c)

Two uses of infra-red: **cooking / grilling food (heating)** and **television remote controls / short-range remote signalling**. (Also acceptable: thermal imaging, optical-fibre communication, intruder alarms.)

2 — 5054/02/M/J/04/Q9

Drawing the spectrum (5 named parts)

(a)(i) A correct spectrum diagram showing visible light, infra-red and three other parts, in order of **increasing wavelength** (left to right). One valid answer:

increasing wavelength →				
ultraviolet	**visible light**	**infra-red**	**microwaves**	**radio waves**

Marks are awarded for: visible and infra-red placed correctly, three further correct bands, and the whole sequence in the right order with an arrow showing increasing wavelength. (X-rays/gamma rays could replace any of the three extra bands provided they go on the short-wavelength side of visible.)

3 **5054/02/M/J/08/Q5**

Emitters · detecting X-rays · imaging bones

(a) Main type of EM wave emitted:

Object	Main type of EM wave emitted
radio transmitter	radio wave
remote control for a television	**infra-red**
radioactive source	**gamma rays**

(b)(i)

X-rays are detected by a **photographic film / plate** (or a digital / fluorescent detector screen).

(b)(ii)

X-rays **pass through (are transmitted by) soft flesh / tissue** but are **absorbed (blocked) by the denser bone**. The bone therefore leaves a shadow on the film, producing a clear image of the bone against the exposed background.

4 **5054/21/M/J/11/Q5**

Fluorescent tube · UV frequency

(a)

The coating **absorbs the ultra-violet radiation** and **re-emits the energy as visible light** (fluorescence). This converts harmful/invisible UV into useful visible light, making the tube an efficient lamp.

(b)

A region with wavelengths shorter than UV: **X-rays** (or gamma rays).

(c) Frequency of the UV radiation ($\lambda = 3.6 \times 10^{-7}$ m):

WORKING

$c = f\lambda \Rightarrow f = c / \lambda = (3.0 \times 10^{8}) / (3.6 \times 10^{-7})$

$f =$ **8.3×10^{14} Hz**

5 **5054/21/M/J/12/Q5** *Naming P and Q · properties · satellites*

Order shown: gamma · P · ultraviolet · visible · Q · microwaves · radio (shortest → longest λ).

(a)(i)

P (between gamma rays and ultraviolet) = **X-rays**.

(a)(ii)

Q (between visible light and microwaves) = **infra-red**.

(b)

Two other properties of all EM waves: **they are transverse waves** and **they travel at the same speed (3.0×10^8 m/s) in a vacuum**. (Also: they transfer energy; can travel through a vacuum; obey $c = f\lambda$.)

(c)

Component used for satellite communication: **microwaves**.

6 **5054/22/M/J/13/Q4** *Ordering · satellite TV transmission*

(a)

Increasing wavelength: **gamma rays → visible light → infra-red**.

(b)(i)

Microwaves are used to transmit the television signal up to the satellite.

(b)(ii)

The satellite **receives the (weak) signal from the ground station, amplifies it, and re-transmits (re-broadcasts) it** back down to receivers over a wide area of the Earth.

(b)(iii)

Advantage: **the signal can reach receivers all over a very large region / around the curvature of the Earth**, far beyond the range of a ground transmitter.

7 **5054/22/M/J/14/Q5** *Two further EM components*

(a)

Two components not already listed (visible, radio, X-rays, gamma, microwaves): **infra-red** and **ultraviolet**.

8 5054/22/M/J/16/Q6

Visible colours · components and uses

(a)(i)

Largest wavelength: **red**.

(a)(ii)

Highest frequency (of those shown): **blue**.

(b) Two further components (not visible, infra-red, UV or radio) with a use of each:

Component	Use
microwaves	satellite / mobile-phone communication (or cooking food)
X-rays	medical imaging of bones (or airport security scanning)

(Gamma rays — sterilising equipment or treating cancer — is an equally valid second component.)

9 5054/21/M/J/18/Q9

True / false statements

(a) Tick the correct box for each statement:

Statement	True / False
Gamma rays are used to kill cancerous cells but can also cause cancer.	**True**
Infra-red is used in sun-beds.	**False** (sun-beds use ultraviolet)
Radio waves have the highest frequency in the EM spectrum.	**False** (radio has the lowest frequency; gamma the highest)
The higher the frequency of the radiation the smaller is the wavelength in air.	**True** ($c = f\lambda$, so $f \propto 1/\lambda$)

10 5054/22/M/J/19/Q4

Star spectrum · peak wavelength · frequency

(a)

From the graph, the brightness peaks at $\boldsymbol{\lambda = 2.0 \times 10^{-6}}$ **m** (allow $1.8–2.0 \times 10^{-6}$ m).

(b)

2.0×10^{-6} m is just longer than visible light ($4–7 \times 10^{-7}$ m), so the region is **infra-red**.

(c) Frequency of the peak radiation:

WORKING

$f = c / \lambda = (3.0 \times 10^{8}) / (2.0 \times 10^{-6})$

$f =$ **1.5×10^{14} Hz**

11 5054/21/M/J/20/Q9 (part)

Ultrasound in medical imaging

(a)(i)

Ultrasound is sound of frequency above 20 000 Hz (20 kHz) — above the upper limit of human hearing.

(a)(ii)

At a boundary between two different materials, **some of the ultrasound is reflected** (and the rest is transmitted/refracted into the second material). The reflected pulse (echo) is detected.

(a)(iii) Distance from emitter to the child. Pulse A (emitted) at 0.02 ms, pulse B (echo) at 0.05 ms:

WORKING

time there-and-back $\Delta t = (0.05 - 0.02)$ ms = 0.03 ms = 3.0×10^{-5} s

total path = speed × time = $1500 \times 3.0 \times 10^{-5} = 0.045$ m

distance to child = half of this = 0.045 / 2 = **0.0225 m (2.25 cm)**

(a)(iv)

Approximate speed of sound: in **gases ≈ 300–340 m/s**; in **solids ≈ 5000–6000 m/s** (a few thousand m/s — much faster than in liquids or gases).

12 5054/21/M/J/20/Q9 (part)

X-ray imaging · frequency · safety

(b)(i)

To form the X-ray image, **X-rays pass through (are transmitted by) the soft tissue but are absorbed by the bone**. Where the rays reach the detector they darken/expose it; behind the bone fewer rays arrive, leaving a lighter shadow — producing an image of the bone.

(b)(ii) Frequency of the X-rays ($\lambda = 2.0 \times 10^{-9}$ m):

WORKING

$f = c / \lambda = (3.0 \times 10^{8}) / (2.0 \times 10^{-9})$

$f =$ **1.5×10^{17} Hz**

(b)(iii)

X-rays are **ionising and can damage / harm the developing cells of the unborn child** (risk of cancer or mutation), so ultrasound is used instead.

13 5054/22/M/J/20/Q5

Matching components to uses

(a) One line from each component to a suitable alternative use:

Component	Suitable use
microwaves	**satellite television** (communication)
ultraviolet	**sunbeds** (also valid: detecting forged notes / sterilisation)

("television controller" uses infra-red and "airport security check of cases" uses X-rays, so neither is the correct match for microwaves or ultraviolet.)

14 5054/21/M/J/21/Q4 (part)

Correcting wave statements

(b) Suitable correction for each ringed mistake:

Sentence (mistake ringed)	Correction
Sound travels at *3.0×10^8* m/s in air.	330 (about 330–340 m/s)
Sound with a higher pitch has a larger *amplitude*.	**frequency** (higher pitch = higher frequency)
X-rays are used for pre-natal scanning.	**ultrasound**
In the EM spectrum, *microwaves* have the highest frequency.	**gamma rays**

15 5054/22/M/J/22/Q8 (part)

Satellite internet · microwaves vs infra-red

Setup: station A communicates with station B via a satellite **3.0×10^4 km** above the Earth, using microwaves (speed 3.0×10^8 m/s); B then joins the internet by optical fibre.

(d)(i) Time for data to travel from A to B (up to the satellite and back down):

WORKING

total path = $2 \times 3.0 \times 10^4$ km = 6.0×10^4 km = 6.0×10^7 m

time = distance / speed = $(6.0 \times 10^7) / (3.0 \times 10^8)$

time = **0.20 s**

(d)(ii)

One shared property of infra-red and microwaves: **both are electromagnetic / transverse waves and travel at 3.0×10^8 m/s in a vacuum** (both carry energy; both obey $c = f\lambda$).

(d)(iii)

An advantage of optical fibre over microwave links: **it carries much more data / a higher rate of information, with little signal loss and no interference**, and it is secure.

16 **5054/2/O/N/02/Q3** *Microwaves · frequency · repeater stations*

(a)(i)

EM waves with wavelengths longer than microwaves: **radio waves**.

(a)(ii)

All EM waves travel at the same speed, and $c = f\lambda$. So a **longer wavelength must have a lower frequency** (frequency is inversely proportional to wavelength).

(b)(i)

Aerials are placed on tall towers because **microwaves travel in straight lines (line of sight)**; height gives a clear path over hills/buildings and around the Earth's curvature.

(b)(ii)

Repeater/booster stations are needed because **the signal weakens (attenuates) with distance**; each station **receives, amplifies and re-transmits** it so it can travel on to the receiver.

17 **5054/02/O/N/05/Q4** *Ordering · UV use · common properties*

(a) In order of increasing wavelength:

shortest λ →			longest λ
X-rays	**ultra-violet**	**infra-red**	**microwaves**

(b)

One use of ultra-violet radiation: **sterilising / killing bacteria** (also: sunbeds, detecting forged banknotes / security marks).

(c)

Two common properties: **all are transverse EM waves that travel at 3.0×10^8 m/s in a vacuum** (also: all transfer energy; all can travel through a vacuum; all obey $c = f\lambda$).

18 **5054/02/O/N/06/Q11** *Space telescope · microwave travel time*

(a)(i) Time for the microwave signal to travel 600 km from the telescope to Earth (speed 300 000 km/s = 3.0×10^8 m/s):

WORKING

distance = 600 km = 6.0×10^5 m

time = distance / speed = $(6.0 \times 10^5) / (3.0 \times 10^8)$

time = **2.0×10^{-3} s (2.0 ms)**

(a)(ii)

Two similarities: both are EM/transverse waves; both travel at 3.0×10^8 m/s in a vacuum (and both transfer energy / obey $c = f\lambda$). **One difference:** infra-red has a **shorter wavelength (and higher frequency)** than microwaves.

19 5054/21/O/N/10/Q4

Satellite TV · distance from time delay

(a)(i)

EM waves are used because **they can travel through the vacuum of space** (no medium needed) and at very high speed, unlike sound. The signal can also be transmitted without wires over long distances.

(a)(ii)

Region used to transmit the TV signal to the satellite: **microwaves**.

(a)(iii)

Satellites allow the signal to **reach receivers over a very wide area / beyond the horizon** that a ground transmitter cannot reach directly.

(b) Distance travelled by the satellite signal in the extra 0.24 s:

WORKING

distance = speed × time = $(3.0 \times 10^8) \times 0.24$

distance = **7.2×10^7 m (72 000 km)**

20 5054/22/O/N/10/Q9 (part)

Violet light frequency · medical use · risk

(b)(i) Frequency of violet light ($\lambda = 4.0 \times 10^{-7}$ m), using $c = 3.0 \times 10^8$ m/s:

WORKING

$f = c / \lambda = (3.0 \times 10^8) / (4.0 \times 10^{-7})$

$f =$ **7.5×10^{14} Hz**

(b)(ii)

Two components with wavelengths shorter than violet light: **ultraviolet** and **X-rays** (gamma rays also acceptable).

(b)(iii) 1.

Medical application (e.g. X-rays): **used to image bones / detect fractures**, because X-rays pass through soft tissue but are absorbed by bone, forming a shadow image on a detector. (UV: sterilising instruments; gamma: treating cancer / sterilising.)

(b)(iii) 2.

Health risk of that component: it is **ionising and can damage living cells / cause cancer** (UV also causes skin burns and eye damage).

21 **5054/22/O/N/11/Q4** *Microwave: speed, wavelength, satellite TV*

(a)

Speed of microwaves in air: **3.0×10^8 m/s**.

(b) Wavelength: the 40 cm from A to B contains **3 complete waves**:

WORKING
λ = total distance / number of waves = 40 / 3
λ = **13.3 cm (0.133 m)**

(c)

Microwaves carry the TV signal from a ground station **up to a satellite, which amplifies and re-transmits** them; the satellite beams the microwaves back down so receivers over a wide area pick up the signal.

(d)

Two common properties: **transverse EM waves** and **travel at 3.0×10^8 m/s in a vacuum** (also transfer energy; obey c = fλ).

22 **5054/21/O/N/12/Q4** *Spotting errors · X-rays in engineering*

(a) Three errors in the pupil's notes:

1. **“ultra-sound” should be “ultraviolet”** — ultrasound is not part of the EM spectrum.
2. **X-rays and gamma rays are in the wrong order** — gamma rays have the shortest wavelength, so the order should be gamma rays, X-rays, ultraviolet… (the diagram should start gamma then X-rays).
3. **infra-red and microwaves are in the wrong order** — for increasing wavelength infra-red comes *before* microwaves; the notes place infra-red after microwaves.

(So the correct increasing-wavelength order is: gamma rays, X-rays, ultraviolet, visible, infra-red, microwaves, radio waves — and the pupil also omits visible light.)

(b)

Application of X-rays in engineering: **checking metal welds / castings for hidden cracks or flaws** (radiography). X-rays pass through sound metal but are absorbed differently where there is a crack or void, revealing the defect on a detector.

23 **5054/22/O/N/16/Q10 (part)** *Detecting infra-red · intruder alarms*

(c)(iii) 2.

A blackened bulb makes a good detector because **a black (matt) surface is an excellent absorber of infra-red radiation**. It absorbs the IR efficiently, so its temperature rises more, giving a larger, faster thermometer reading.

(d)

In an intruder alarm, an **infra-red sensor detects the heat (infra-red radiation) emitted by a warm body**. When a person enters the area, the sudden change in infra-red received triggers the alarm circuit.

24 **5054/21/O/N/17/Q10** *Naming regions · IR remote frequency*

(a) Naming P, Q, R (order: P, X-rays, Q, visible/infra-red, R, radio):

- (i) P (before X-rays, shortest λ) = **gamma rays**
- (ii) Q (between X-rays and visible light) = **ultraviolet**
- (iii) R (between infra-red and radio waves) = **microwaves**

(b)

Components with frequency greater than visible light are those with shorter wavelength: tick **P (gamma rays), X-rays and Q (ultraviolet)**.

(c)(i) Frequency of the IR remote signal ($\lambda = 9.4 \times 10^{-7}$ m):

WORKING
$f = c / \lambda = (3.0 \times 10^{8}) / (9.4 \times 10^{-7})$
$f =$ **3.2×10^{14} Hz**

(c)(ii)

The remote contains an **infra-red LED that sends out coded pulses of infra-red radiation**; a sensor in the television detects these pulses and the coded signal tells the TV which command to carry out.

25 **5054/21/O/N/19/Q4** *Naming regions · X-ray imaging of bone*

(a) Components either side of the central visible band (gamma, X-rays, A, visible, B, C, radio):

- A (between X-rays and visible) = **ultraviolet**
- B (just longer than visible) = **infra-red**
- C (between infra-red and radio waves) = **microwaves**

(b)

Greatest frequency & smallest wavelength: **gamma rays** (both apply to the same end of the spectrum).

(c)

X-rays are **directed through the leg onto a detector / photographic film**. They **pass through the soft tissue but are absorbed by the denser bone**, so fewer rays reach the detector behind the bone. This leaves a shadow that shows the bone (and any break) on the image.

26 **5054/21/O/N/21/Q3** *The Sun · thermal radiation · travel time*

(a)

Reaction at the Sun's centre: **nuclear fusion**.

(b)(i)

The radiation from the Sun's surface is **electromagnetic radiation** (mainly visible light and infra-red, with some ultraviolet) — a continuous range of EM waves that can travel through the vacuum of space.

(b)(ii)

Speed of this radiation in a vacuum: **3.0×10^8 m/s**.

(b)(iii) Time for the radiation to travel 1.5×10^{11} m to Earth:

WORKING

time = distance / speed = $(1.5 \times 10^{11}) / (3.0 \times 10^8)$

time = **500 s (about 8.3 minutes)**

(c)

White clothes are an advantage on sunny days because a **white (light, shiny) surface is a poor absorber and good reflector of the Sun's radiation**. It reflects most of the incoming infra-red/light, so the wearer absorbs less heat and stays cooler.

Note from Megalecture. These are original Megalecture worked solutions prepared for revision use. All frequency/time calculations use $c = f\lambda$ with $c = 3.0 \times 10^8$ m/s. Several questions are drawn from longer past-paper questions; only the parts dealing with the electromagnetic spectrum are shown. Please verify against the official syllabus before classroom use.