



Key Stage 5 – Wave Machine

Notes for teachers

At a glance

Scientists at the University of Oxford have been studying how electrons flow in tiny electrical components made of individual molecules. One property they are hoping to harness is the ability of individual electrons to constructively or destructively interfere. In this lesson students look at some of the other uses of interference (of light waves) and prepare a ‘news item’ about the recent discovery of gravitational waves.



Learning Outcomes

- When two or more waves meet the effects of those waves are additive. The amplitude of the resultant wave at that point can be larger or smaller.
- Coherent light waves of the same frequency can interfere with each other; if they are exactly out of phase they destructively interfere, if exactly in phase they constructively interfere.
- Interference has practical uses such as coating lenses or building scientific instruments.

Each student will need

- Student worksheet

Possible Lesson Activities

- **Starter activity**

Watch the Oxford Sparks ‘How does electricity flow through small objects?’ animation. If we could build components for computers that were highly energy efficient and based on molecules what



would be the advantages? Are there any disadvantages?

- Possible advantages :
 - i. Less energy consumption (cheaper to run, better for the environment)
 - ii. We could potentially build far more powerful computers (this has happened every time we've made components smaller)
 - iii. The computers would be much smaller so we could carry more powerful computers with us (in phones, wearable technology etc)
 - iv. Computers might become cheaper
- Possible disadvantages:
 - i. More complicated technology would be even harder for people to fix themselves so it would encourage buying new stuff
 - ii. People might become more reliant on computers if they carry them with them all the time
 - iii. Parts of the world with the latest technology may have an advantage over parts still using older technology
 - iv. Initially the new computers might be expensive

- **Main activity: Wave Machine**

- Hand out the first page of the student worksheet and ask the students to read it.
- The video they watched earlier talks about quantum interference of electrons, but interference happens with other waves too.
- If they have already covered superposition and interference ask them to recall where they have come across interference patterns before (e.g., Young's slits, thin film interference, diffraction gratings, etc.).
- Go through the answers to the question posed on the first page (i.e., Larger Amplitude corresponds to louder sound, higher/deeper water waves, brighter light).
- Hand out the rest of the student handout. This outlines two different uses of interference: anti-reflective coatings for lenses and interferometers that are used as a tool by scientists for research.
- N.B., Both of these have been simplified somewhat, for instance although the 'optical' path for the waves travelling through the lens is $\lambda/4$, because they have different refractive indices the actual thickness is $\lambda/n_f/4$ where n_f is the refractive index of the coating. Both waves also experience a phase shift of π radians on reflection. There are several simplifications for the interferometer as well, including the absence of a compensating plate to allow for the path difference between the front and back of the mirrors.
- ANSWER to question – The diffraction pattern would change if a section of glass was introduced as the waves would slow down when passing through the glass introducing a delay which would change the relative phase between the two waves.

- **Main Activity: Gravity Waves**

- The last section of the student worksheet briefly outlines Advanced LIGO and the discovery of Gravity Waves. Ask the students in small groups to research and prepare a short 'News Item' for TV reporting the decision for this research to be given the Nobel Prize and



with some background about the science behind it. This could be rehearsed ready to perform live or recorded (video or audio) for future playback.

- **Plenary**

- Ask students to share their news segment with the other students. This could be in a subsequent lesson.

Weblinks

- Oxford Sparks 'How does electricity flow through small objects?' animation:
<https://youtu.be/wF13tGlzA8>
- TED talk about LIGO, the discovery of the Gravitational Waves and where that might take us in the future:
https://www.ted.com/talks/allan_adams_what_the_discovery_of_gravitational_waves_means/discussion