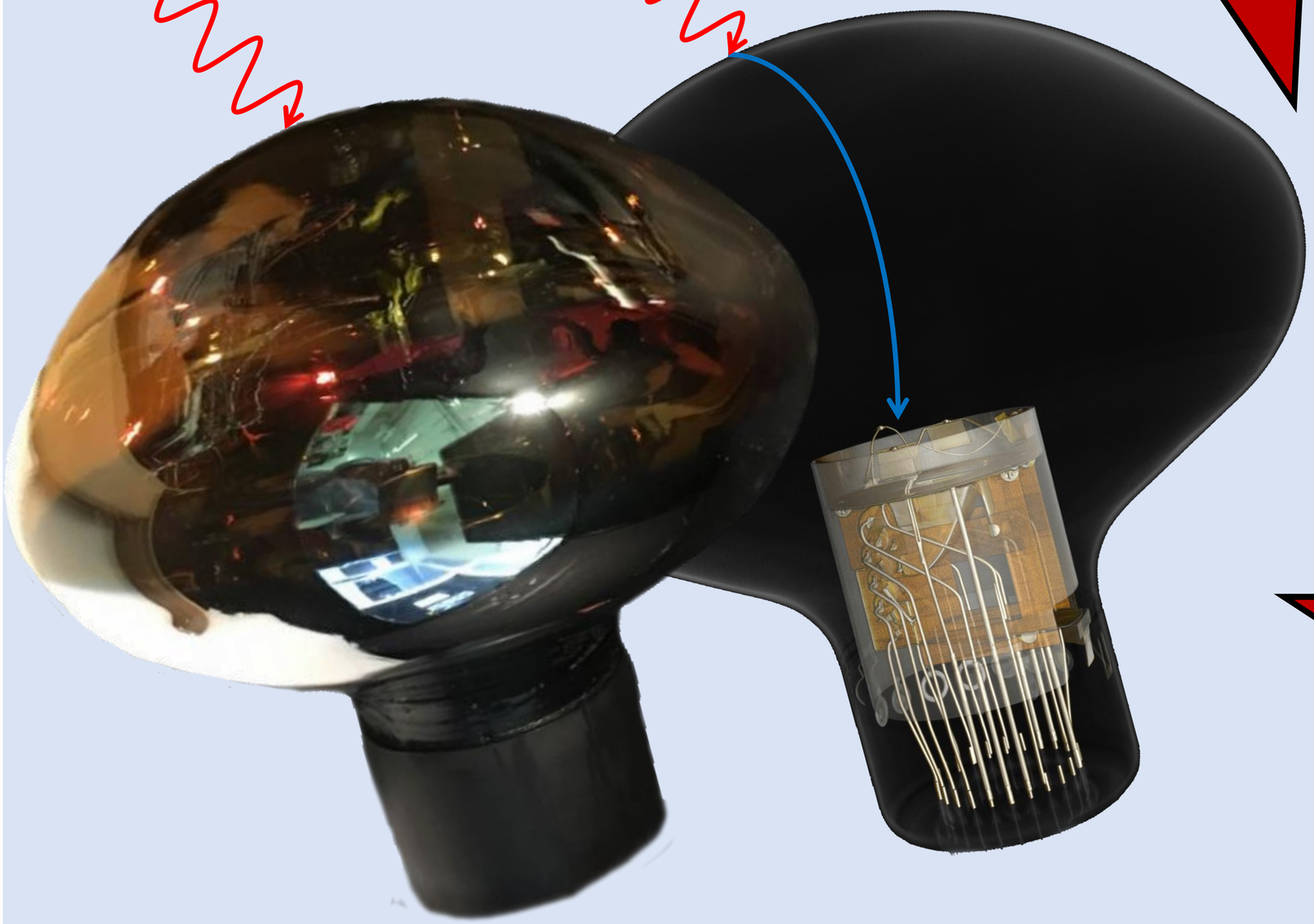
TIDDLYWINKS
PMT EDITION

3+
2-4 players

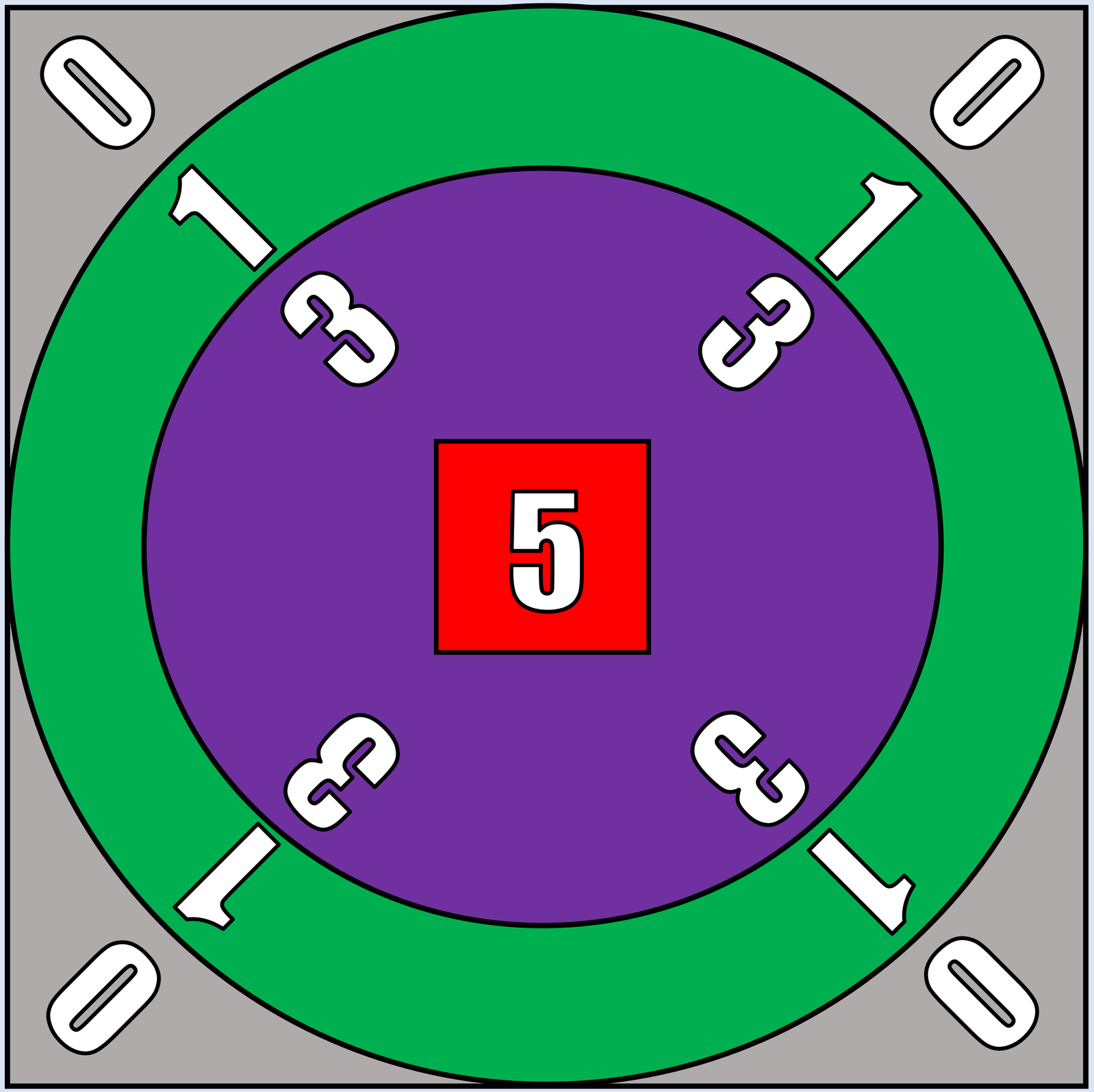
No two copies are alike!

Informative & Fun!



Scientific Pamphlet Included!

Contains: Target printout, Informative pamphlet included. Winks sold separately.



TARGET PRINTOUT

For adults & curious teens

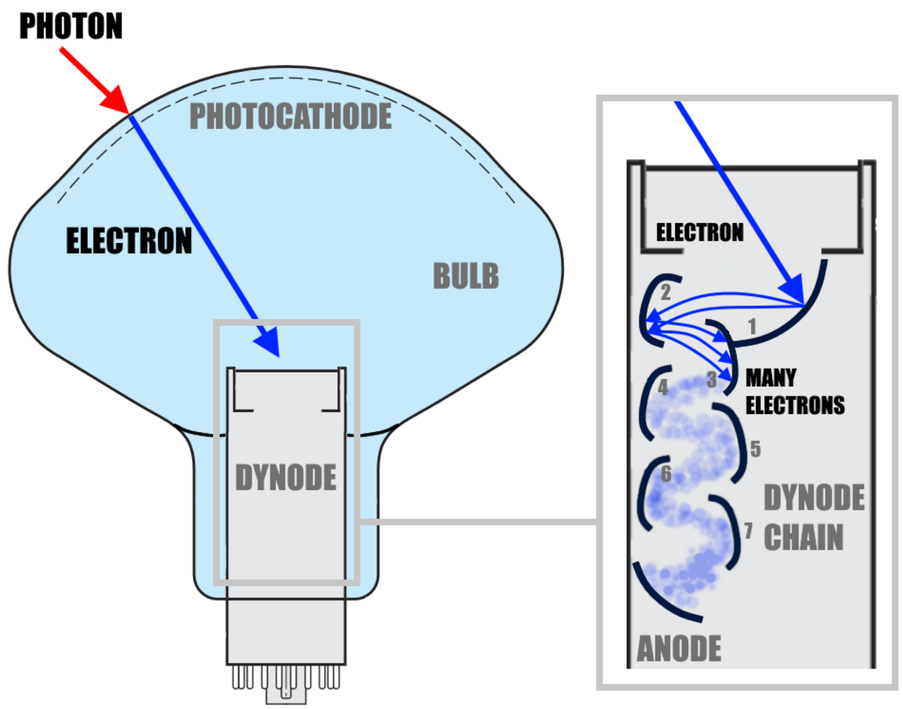
HOW DO PMTS WORK? WHAT DO THEY DO?

Photomultiplier tubes (PMTs) are very sensitive detectors used to detect light. They are sensitive enough to detect individual "PHOTONS", which are light particles.

PMTs are made of three major components, the BULB, the PHOTOCATHODE and the DYNODE. The photocathode is an area of the bulb that allows for individual photons to be converted into an ELECTRON via the "photoelectric effect". Electrons are very small particles that have charge, which means they can be influenced by electric and magnetic fields.

The electrons are then guided/accelerated towards the dynode, with the use of an electric field. The dynode collects the electron and converts into a detectable electrical signal by a method known as "electron multiplication". This is similar to the "photoelectric effect" but instead of a photon being converted into an electron, the accelerated electron hits the 1st dynode within the dynode chain and emits multiple electrons (as seen on the right labelled as 1).

Then these multiple electrons are guided/accelerated to the 2nd dynode, where they release more electrons. This process continues (from dynodes 1 to 7 in our picture) until millions of electrons have been produced. This large collection of electrons are finally absorbed by the ANODE, which allows us to detect the electrons as an electrical signal.



A blueprint of the Hamamatsu R7081 PMT with labelled PHOTOCATHODE, dynode and BULB, including the path travelled by the PHOTON and ELECTRON. Separate image displays ELECTRON multiplication within the dynode.

WHY IS EVERY COPY DIFFERENT?

PMTs rely on two processes to convert photons into a detectable electric signal: the photon has to be converted into an electron, and that electron has to make its way through the dynode chain (collection of our 7 dynodes) to be multiplied. The efficiency of these processes is different for **every** PMT due to differences in the manufacturing process (the dynode chains, bulbs and photocathodes aren't all perfectly alike).

WHY TIDDLYWINKS?

The efficiency of these processes are also different dependent on where the photon strikes the bulb. For example; if a photon that strikes the bulb directly above the dynode, it wont have to be redirected to reach the dynode and consequently successful electron multiplication will be much more likely when compared to electrons that have to be redirected from the edge of the photocathode. The photocathode covers an area of the PMT around the centre of the bulb, but not the entire bulb and for the R7081 PMT this coverage can vary beyond a certain radius (shown as the dashed line in the above blueprint).

Photons that strike the bulb on an area that has little or no photocathode coverage will rarely (if ever) allow for the electron to be emitted, and so will have significantly decreased efficiency across that area. These differences in efficiency align quite well with the classic game Tiddlywinks, and so the photocathode, dynode, and bulb have been converted into the corresponding areas in the game as shown in the "For the kids" section! Research into the differences in this efficiency across the PMT bulb is currently underway at the University of Edinburgh!

WHAT ARE PMTS USED FOR?

Due to their ability to detect individual photons, PMTs are regularly used in "Cherenkov Detectors". Cherenkov detectors are usually large tanks full of water (up to 50 kilotonnes!), with hundreds or thousands of PMTs lining the inside of the tank, facing inwards. If a reaction between two particles occurs within this body of water, it can produce a small amount of light via a number of effects, one being the "Cherenkov effect". This light is then detected by the PMTs to allow us to understand the reaction that produced this light. One such particle that Cherenkov detectors can detect via the Cherenkov effect is the NEUTRINO, which is a particle that interacts very rarely with other particles and so is very hard to detect!

For children

THE PMT BOARD

PMTs are highly sensitive detectors that are used to see very small amounts of light! The PMT is better or worse at seeing this light based on where it hits the BULB, so each section of the Tiddlywinks board corresponds to an area of the PMT, as shown below. The sections are:

- **0 POINTS –** You missed the PMT! Your light-wink never made contact with the surface and so the light wasn't seen!
- **1 POINT –** You hit the bulb! While your light-wink made contact with the PMT surface, it is very unlikely to be seen, better luck next time!
- **3 POINTS –** You hit the photocathode! This is a special area of the PMT that is much better at seeing light. Well done!
- **5 POINTS –** You hit the dynode! This is an opening inside the bulb that is like the PMT's "eye", so your light-wink will be seen much easier when landing right on top of it. Nice aim!

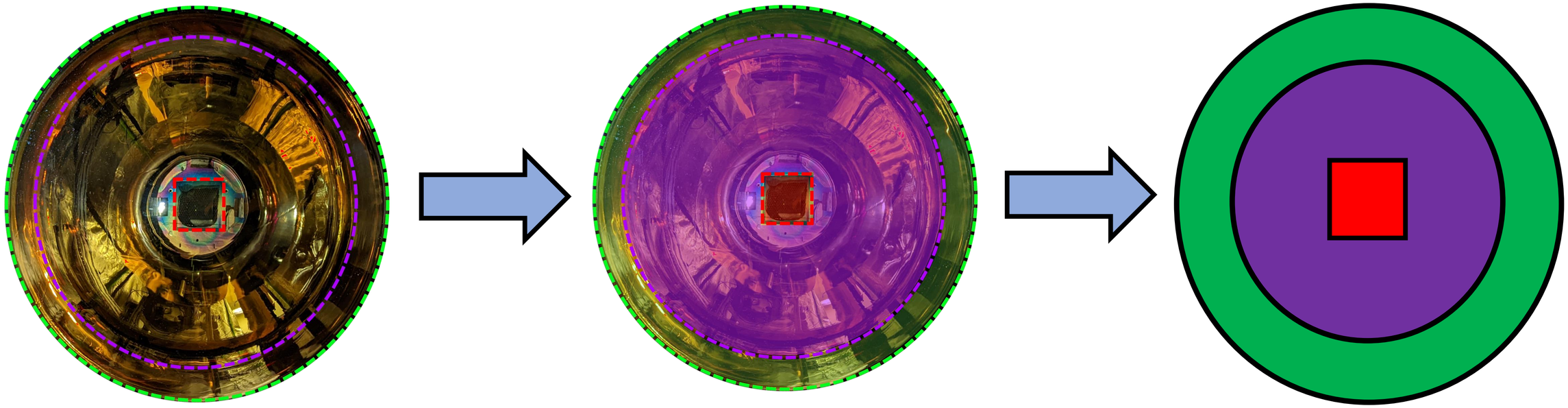
HOW TO PLAY

To play you will need the following things:

- A soft surface (like a carpet, for example) to play on.
- 4 "squidgers", one for each player, which is a disc of plastic a bit larger than a 50p coin.
- 24 individual "winks" of 4 differing colours and differing sizes, which are discs of plastic ranging from the size of a 1p coin to a 2p coin

Players use their squidger to flick the winks at the printout target by pressing down with their squidger on the top of the wink. Each player has winks of their own colour, and take turns flicking the winks towards the target.

The game is finished once every wink has landed on the target, and the points for everyone's winks are counted up to crown the winner!



Top-down image of the R7081 PMT as shown on the cover, and conversion of the bulb, photocathode, and dynode into equivalent Tiddlywinks sections.