Movie 1 Introduction to July 3rd Seminar ---

Saturn V Launch

Title Slide

(i) Recreating 1930's Physics Research

Rationale – to highlight the importance of 1930's physics research especially at the Cavendish. To allow students to replicate original experiments, varying parameters and making measurements.

(ii) Contemporary Wave Energy Research

*Rationale – to introduce students to contemporary research in marine energy, allowing them to change system parameters and note effect on power generated. To compare power generation across several devices. As well as socio-economic considerations (CAPEX, OPEX, LCOE) students must understand the **technical** aspects of energy production.*

It is important to note that all the simulations you will see are grounded in physics theory. This has been distilled from journal articles and PhD theses. All simulations have been **verified** by computing solutions in a second platform (Octave) and have been **validated** by comparison with published experimental and/or theoretical results.

Movie 2 Recreating 1930's Physics Research --

Rationale – to highlight the importance of 1930's physics research especially at the Cavendish. To allow students to replicate original experiments, varying parameters and making measurements.

We start in Cambridge, at the Cavendish Laboratory, New Museums Site in the heart of the city. We enter the High Energy Laboratory and pause to view the Cockcroft – Walton original photo, with brief explanation of the apparatus. A brief look-around the simulated lab to establish congruence with the original apparatus.

The accelerator is started producing the proton beam, then we move into the observation box where the protons hit a lithium target, but the scintillations from the expected alpha particles are not seen, because the accelerating voltage is too low. The accelerating voltage is raised to 150 kV, and alpha particle scintillations appear as predicted. Finally, the target is swapped out in order to investigate length of path of protons in air

A quick view around the 1MeV and 2 Mev Lab. In the 1970's this was converted to a teaching building (I was there!). The 1MeV accelerator is started showing accelerated protons, then we move into the detector room, lights out, and we can see the electronically recorded scintillations.

Now we go 'State-side' into a room where there is a collection of accelerators developed by Livingston. First the 'Lineac', a close-up shot showing the accelerator tubes of increasing lengths with gaps. The accelerator is started and ions emerge, you can clearly see the velocity of ions is increasing as they progress down the tube. Yes, a 'linear accelerator'. The frequency of the driving oscillator is changed to mismatch with ion velocities which destroys coherent acceleration. A great student investigation.

We move to the Cyclotron where ions are accelerated between the D's and circulated within the D's, forming spiral-like trajectories. When they reach the extremity of the D's the detector moved in and out of position. The second apparatus shows the accelerating chamber located between the deflecting magnet poles. An image of a recorded particle track is shown. (C++ code automatically generates Octave plot file)

Movie 3 Eco-Island ---

Rationale – to introduce students to contemporary research in marine energy, allowing them to change system parameters and note effect on power generated. To compare power generation across several devices.

It is important to note that all the animations you will see are grounded in physics theory. This has been distilled from journal articles and PhD theses. Most devices are under commercial development and therefore underlying models have to be established using appropriate theory. Many parameters are deduced from publically available movies and images.

Flythrough. Labs containing wave-tanks for scaled models, then Eco Wave Power buckets, past Haiyuan heaving buoys, past oscillating water columns (OWC), then Oyster bottom-hinged flap, finally over-topping breakwater (OBREC).

Rationale – to introduce students to contemporary research in marine energy, allowing them to change system parameters and note effect on power generated. To compare power generation across several devices.

Obrec – incident wave set to monochromatic (single period). Wave fills basin and empties through turbine connected to generator. Octave plot shows periodic wave height, water height in basin as it fills and empties, exit flow and turbine rpm and power generated. Note are params which can be varied, e.g., turbine tube diameter.

OWC – Explore structure from below then up to machine hall, start turbine running and view Wells turbine and power o/p on the HUD

Haiyuan – Start with alpha (electro-mechanical coupling factor) = 0 so no generation. Observe bobbing floaters. Raise alpha to 100, just under 2kW power generated. Raise alpha to 1000, power increases and floater amplitude decreases due to greater generator loading (feedback).

Eco Wave Power. Buckets are light so not in resonance with wave period, they operate in 'wave-rider' mode clearly tracking the wave surface.

Oyster. Start running, look underwater at hydraulic generator pistons. Power around 60kW. Reduce width from 26m -> 20m, power drops to around 40 kW.

Wave Tank Lab. First select Eco Wave bucket. Changing wave period is a useful student investigation. Swap apparatus out, call in 'Fukue' device – two coupled masses one has linear generator stator (coils) other with magnets. Change wave period, silly (non-physical) behaviour since no power take-off. Reducing wave amplitude doesn't help. But adding electro-mechanical coupling, alpha = 1000 brigs device under control. Note low power relative to full-scale devices. Octave plot shows effects of making the changes. Useful for student analyses.

Overview of MAS22 Simulation Engine

From maths model to C++ code input to ODE solver (C++) with Unreal 5 only used for the User Interface. We do not use the built-in physics engine, only make use of Unreal generated waves.

Example of maths for SHM and also for heaving bob showing hydrodynamic stiffness, viscous damping, radiation damping, power take-off and token wave excitation force. Next slide shows more reasonable expressions actually used.

Movie 4. Other Green Energy Systems

Installing **Voith Stream Diver at Diglis Weir**. First a view of the weir then over to the turbine unit showing the capture basin then dive down to the turbine. The turbine is activated and we return to the surface where the power raises to around 113 kW for the given parameters.

Ramsey Sound Tidal. We dive to the seabed and locate the turbine which responds to simulated tidal flow. Power is generated up to around 300kW and you can see the turbine rotating, responding to the change in tidal flow direction.

Aermotor Classical American Wind Wheel. This is just for fun to test out our approach to modelling. Wind model simulates changing speed and direction drawn from actual statistical distributions. You can even see the 'furling' behaviour when the wind speed exceeds the design speed. Octave snapshot of behaviour: plots show at the top a snapshot of windspeed change and then the rpm which shows the turbine needs time to respond to change due to its inertia. Bottom shows the power generated and you can see the effects of furling to 90 degrees causing the power to drop to zero.

Vortex Bladeless. Turbine without blades works by vortex shedding which applies periodic force to the compliant shaft. An alpha of 100 leads to powers around 100 mW, raising alpha to 200 then 300 reduces the power produced to 50 mW due to generator loading on the shaft. Commercial devices produced around 2015 but cannot find them anywhere. Graph shows history of changes to alpha; an increase produces an initial power peak which then relaxes to a lower power as observed.

Movie 5. (legacy 2014) Physlab for Schools and Colleges

Motivation: To develop an interactive immersive physics lab for schools and colleges in an era where actual experimentation may be difficult due to various constraint. Should align with UK A-Level curriculum and the US AP curriculum.

We enter the lab and look at a selection of SHM experiments. One in particular shows what would happen if you dropped Worcester down a hole through the Earth. You get SHM (which is easy to prove)! Then a 2D mass-spring oscillator.

Finally we enter a space containing the Drude model of electrical conduction, where accelerated electrons collide with scattering centres, lose memory of their velocities which establishes a drift velocity i.e. electric current. Investigation shows the current is proportional to applied field – Ohm's law.