Curriculum Analysis Taxonomy Physics

Topic	*2A early concrete*	*2B late concrete*	*3A early formal*	*3B late formal*
P.1 Floating and Sinking Density	At this level Mass, Weight, Volume, and Density are still `collapsed' in a global notion of `heaviness'; knows that wood will float, iron will sink, but without a general explanation available, he can only learn a series of individual facts about materials.	Specific theories of floating will be tested, and weight differentiated from mass as a variable. Volume will only partly be conceptualised, and so the weight/volume relationship will not yet be used as an explanatory tool. Different 'heaviness' of materials will be differentiated from 'bigness'. `A small or a large piece of plasticine will both sink, because the stuff is the same, with the same heaviness.'	Volume conceptualised and displacement seen to be a function of volume, not weight. Weight/volume relationship will be utilised to generate hypotheses in the floating/sinking problem. Complete solution including density of liquid unlikely to be discovered, but rules about relative density can be learned. 'You can find out if two things are the same substance by seeing if their weight/ volume ratio is the same.'	Can handle relationship between, say, density, mass, and spacing of particles. Could formulate a theory of floating relating density of solid to density of liquid, or is likely to find that the clue to the floating and sinking problem is the weight of displaced liquid.

Topic	*2A early concrete*	*2B late concrete*	*3A early formal*	*3B late formal*
P.2 Force and Pressure	Pressure = Force. `Stiletto-heel' effect. i.e. The effect of a force is greater if it acts through a thinner surface. `Force' is a concept which is ordered—`this bigger than *that'*	Force in liquids is greater at greater depth. Vacuum is treated as a negative force. Air exerts a global force. Force can be partitioned, e.g. where 1 kg weight is lowered on to different numbers of 1 cm^3 blocks. The word `pressure' may be used, but still given a working definition of 'force'.	Distinguishes force from pressure. Pressure is treated as force per unit area. The pressure in a gas or liquid is the same in all directions.	Can apply the pressure concept to the general understanding of conditions of equilibrium, e.g. in a hydraulic press, or water standing at the same height in two interconnecting tubes of different cross-sectional area.

Topic	*2A early concrete*	*2B late concrete*	*3A early formal*	*3B late formal*
P.3 Equilibrium of Physical Systems	Nominal equilibrium relationships, e.g. at ends of a see-saw in balance, both weights are the same. A smaller weight is more effective further from centre. To make a truck run down hill, put weight in it.	Produces an account of equilibrium in terms of bi-variate linear relationships. For a beam to balance, the heavier the weight the closer it must be to the centre. Likely to predict that halving the distance will compensate for doubling the weight. In the case of an inclined plane, can arrive at formulations like 'the greater the angle the more weight that is needed to stop a truck running down'.	If a system has two independent variables may find effect of each by a control of variables strategy. Can find equilibrium relationships where simple linear proportionality is involved, i.e. in a balance, given weights in 3:2 ratio will predict lengths from centre should be in 2:3 ratio. Can generalise to L1 W1 = L2 W2. For a given angle, in the inclined plane problem, will discover the relative weights as a proportion.	Quickly arrives at a proportionality formulation which can be tested as a hypothesis. Can generalise equilibria such as those of a balance in terms of a *work* principle (dynamic compensation of more force by less distance). Thus in the more complex inclined plane problem can test and discard a 'more weight/less angle' hypothesis and arrive at the quantitative solution.

Topic	*2A early concrete*	*2B late concrete*	*3A early formal*	*3B late formal*
P.4 Momentum	Intuitive, global concept of relative impetus of colliding bodies. Can make predictions with some success which imply that the speed and mass are allowed for. i.e. slower and heavier can balance faster and lighter.	Differentiation of velocity from mass as contributory components of momentum, i.e. has a *language* with which to talk about predictions.	Can use formula to calculate results of collisions when it is taught as an algorithm; i.e. as a procedure, together with elementary rules for the context of its application. Will realise that changes in momentum are caused by forces.	Reinterprets global concept of momentum in an analytical way. Deals with reciprocal relationship of mass and velocity, and can deal with Newton's first law as a conservation statement.

Topic	*2A early concrete*	*2B late concrete*	*3A early formal*	*3B late formal*
P.5 Velocity and Acceleration	Intuitive notion of speed, but speed and relative position not differentiated, thus likely to call that	Speed as relating distances and time (feet per second; m.p.h.)—hence speeds compared by distance travelled in same time. Intuitive notion of acceleration.	Acceleration conceived as rate of change of velocity. Thus 'ticker-tape' experiments on inclined plane begin to make sense. Can use second-power equations involving constant acceleration as a taught algorithm. $(S = ut + 1/2at^2)$	Acceleration as the limiting value of

Topic	*2A early concrete*	*2B late concrete*	*3A early formal*	*3B late formal*
P.6 Newton's Laws	See P 2, P4 and P5	See P 2, P4 and P5	See P.4 for First Law. Where accelerations are constant can handle Second Law as a relationship between Force, Mass, and Acceleration. Unlikely to grasp the necessity for the Third Law, but can see the sense of it when confronted with experimental evidence.	See P.4 for First Law. Can analyse problems to see how to apply the first two Laws, and plan sequence of computations. Since he tends to think in terms of proof strategies can eventually see (from many examples) the necessity for the Third Law, and will treat all three as a set of axioms which produce consistent results.

Topic	*2A early concrete*	*2B late concrete*	*3A early formal*	*3B late formal*
P.7 Electricity	Bulbs light when connected to batteries. A bright bulb has more energy than a dim bulb. Likely to internalise a 'one connection' model of electricity flow. No potential/current distribution.	Can use voltage as a global measure of electrical forces. Although readings on an ammeter are used, as a measure of electricity, concept of current tends to be collapsed under voltage, so effects of current are given a 'voltage' explanation.	Notion of resistance as V,/ ratio. Can use a fluid model of current flow and predict with it properties of circuits, e.g. where direction of some of the batteries are changed, or where series is changed to parallel. Draws circuits in terms of a consistent two-connection model—e.g. will realise that a light-bulb must have a second connecting point for the filament.	Potential as an intensive property is distinguished from the extensive property of electricity, and hence potential as work required to transfer charge between two points. Potential drop in different parts of a complex circuit may be modelled (still needs to be taught well!).

Topic	*2A early concrete*	*2B late concrete*	*3A early formal*	*3B late formal*
P.8 Temperature and Heat	No distinction between heat and temperature. Temperature as a qualitative concept of hotness and coldness.	Temperature quite well conceptualised as linear 1:1 mapping of the number line on to `degree of hotness'. Amount of heat only imperfectly conceptualised —usually collapsed under temperature. Amount of heat depends on mass of hot substance.	Caloric model of heat/temperature relationship, and calculations involved. Kinetic theory picture accepted as providing explanation of particular phenomena, but not integrated with heat/temperature model.	Can use kinetic theory as predictive and explanatory model. Therefore can begin to appreciate the First Law of thermodynamics, and can deal with thermal equilibria as dynamic and statistical.

Topic	2A early concrete	2B late concrete	3A early formal	3B late formal
P.9 Kinetic Theory			Used to explain only phenomena in simple correspondence with model. e.g. expansion due to greater vibration of particles, so particles expand or take up more space. Solution seen as intermingling of particles, so volume of solute is conserved.	Can appreciate its use as a deductive model proceeding from simple postulates. Relative properties of gases, liquids, and solids explained. Relative diffusion rates of different gases, and of gases into a vacuum compared with into air. Ready to appreciate quantitative derivation of gas laws and to conceive of temperature as only the mean value of a wide range of kinetic energies.

Topic	2A early concrete	2B late concrete	3A early formal	3B late formal
P.10 Energy and Power		Work is expended energy Energy has many sources Power can be differentiated from work All three concepts are intuitive and anthropomorphic	Work as a Force x Distance product. Kinetic energy as defined as $1/2mv^2$—hence deduction about stopping distances of cars from different speeds. Electric energy as Vxlxt product. Power as work done in unit time. Heat energy as calories.	Equivalence of different energy forms having each a capacity (extensive) and a potential (intensive) aspect. Energy as a general product of extensive and intensive factor. Can begin to appreciate the problem of Heat as a form of energy is only partly convertible to work.

Topic	2A early concrete	2B late concrete	3A early formal	3B late formal
P.11 Thermodynamics			Conservation of energy as a learnt kept. Mechanical equivalent of Heat as adarnt fact.	Capable of seeing dE= W–q as a postulate which connects measured quantities to a formal model which, like Newton's Laws, appears to yield consistent predictions. Thus can eventually see that Heat, as a form of energy, needs a second postulate to connect it with other forms of energy.

Topic	*2A early concrete*	*2B late concrete*	*3A early formal*	*3B late formal*
P.12 **Light**		Can use a linear propagation (straight line) model to 'explain' reflection of seen rays from a flat mirror. `The smaller the angle it goes in, the smaller the angle it goes out.' Shadows larger the nearer the object is to the light.	Can use the Lens Laws to deal with real images (linear propagation model) but as algorithm. Uncomfortable with wave model as phenomena of light too obliquely connected with properties of model. Wavelength/frequency relationship as a computation algorithm. Light as part of em spectrum.	Can use wave model to account qualitatively for diffraction/interference phenomena. Can see Lens Laws as a deductive system and can learn to compute within their rules. Transverse and Longitudinal waves and velocity of transmission relating wavelength and frequency. Em spectrum and frequency of waves related to properties of emitting resonator.