Pendulums in practice

Paul Foulkes

My Own Right Time: An Exploration of Clockwork Design. By Philip Woodward. Oxford University Press: 1995. Pp. 176. £24.99.

To set out the general theory of the ideal pendulum is a fairly simple exercise in mathematics. The complications that arise when we examine how the device works in practice are altogether more intricate. Philip Woodward's book gives a splendid

From My Own Right Time

Clockwise — Woodward's remarkably accurate free pendulum clock W5.

account of this, with photos, drawings and graphs. While relating his own quest for an ever-more effective design for a mechanical time-keeper (his W5), he manages in clear and simple words to describe the main types of escapement mechanisms in clockwork right to the latest developments in mechanical art. For the purpose of keeping time, this has now been overtaken by the electronic revolution. Even so, much in mechanical horology remains both valuable and instructive in the field of applied mechanics.

The explanations of how these various devices work is supported by clear diagrams. To follow operations step by step is not always easy, but then the sequences are fairly complex, so that the reader must concentrate. The amount of mathematics is small and elementary, and calculus is avoided. This must have meant some self-restraint, since the author is an applied mathematician and physicist. Still, the effort is commendable, in view of the wide readership envisaged. Perhaps in a later edition the meagre appendix could carry some more theory. Meanwhile, we have here a study of great depth of the problems

of how to overcome the generally non-conservative damping forces we meet in practice.

To describe the quality of resonance in the resonator that constitutes the regulating mechanism, the symbol Q has been borrowed from electric circuit theory. This is the ratio of peak restoring force to peak damping force, a dimensionless number. The greater Q , the more efficient the resonator and therefore the more accurate the time-keeping. Woodward tells us that "for some reason horologists did not at first take kindly to it". The reason is surely clear: the inverse ratio, peak damping to peak restoring force, is intuitively more intelligible. The smaller that ratio, the better and more efficient the resonator. To achieve this, we must reduce the damping force, rather than indefinitely increase the restoring force. Hence $Q' = 1/Q$ is a quantity more easily visualized. To the mathematician this hardly matters, but it does to the practical mechanic.

In trying to give an intuitive account of the pendulum's basic lack of isochronism, the author bids us to imagine a pendulum swinging half a turn and coming to rest upside down. This is not a happy sug-

gestion, because such a position of 'rest' is unstable; the pendulum would in fact topple over. The 18 per cent rise in period for a swing of 90 degrees is computable from the general solution of the pendulum equation, which involves an elliptic integral and is therefore rightly omitted.

The chapters on statistical error analysis and on flicker noise take the subject rather further than most ordinary accounts. Finally, there is some discussion of a source of error against which no mechanical remedy exists. This is the possible seasonal variation of the acceleration due to gravity at the Earth's surface, g . This can occur when the density in a layer of material below ground changes, for example when water is absorbed by porous rock in the rainy season.

Such changes are not precisely predictable: the user simply has to adjust his clock in the event. Changes in a pendulum's length, thermal disturbances and frictional losses in various mechanisms can be allowed for, but changes in natural 'constants' are much more elusive. □

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Evolution of artificial intelligence

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Artificial Minds. By Stan Franklin. MIT Press: 1995. Pp. 449. \$30, £22.95.

WE are living in a postmodern age in which the functionalist architecture of artificial intelligence (AI), like the functional architecture of the Bauhaus, is beginning to look rather old fashioned. Stan Franklin takes the reader on a tour of the eclectic computational styles competing to replace the traditional symbol-processing paradigm that served as the unifying framework, and strait-jacket, for a generation of mind-modellers. He leads the mindful tourist on a whistle-stop tour of artificial neural networks, computational neuroethology, situated action, artificial life, chaos theory, quantum computing, neural Darwinism and a host of other hopeful approaches. Where symbolic AI was once the only game in town, there now seems to be one on every street corner.

A trend that has evolved over the past decade is a shift away from the toy worlds of early AI towards problems that arise from interaction with the real world. The first computers available to AI researchers had less computing power than a pocket calculator. So the problems attacked were highly simplified. Because computers are efficient at symbol processing, solutions were sought in the realm of logic. The world, however, is noisy and uncertain and does not come labelled by symbols, which

must be grounded in sensation and learned through experience. Inductive reasoning from incomplete knowledge is as important as deductive reasoning. Ironically, it is not logic but the theory of gaming that provides the mathematical framework for inductive reasoning in an uncertain world, and George Boole, in his 1854 book *An Investigation into the Laws of Thought*, which introduced Boolean logic, devoted the second half to the theory of probabilities.

Artificial Minds is organized around three debates in AI. The first is whether a computer can ever be programmed to think. This is a recurring question that does not seem to have a resolution, in part because the definition of thinking keeps changing. The problem has been revived recently by Roger Penrose, who doubts the possibility that algorithms could ever think like a mathematician.

I am highly sceptical of claims that something is impossible. A small change in an innocent-looking assumption can drastically change the conclusions. Some aspects of thinking have already been automated, but there are others, such as subjective feelings, that do not have an obvious mechanical analogue. There is a vast middle ground to explore and much of it can be approached with empirical studies of brains and the invention of ever-more clever devices.

The second AI debate, led by the con-