Czujko. He hopes to follow up some of these PhDs to discover their views in a few years' time. "My guess is they will be real happy. These people are earning entry-level salaries of $60,000 to $70,000 per year. I want to feel their emotional pain, but..."

Perhaps sympathy should be reserved for the 43 per cent of 1997 physics PhDs who took postdoc positions. A study by the Commission on Professionals in Science and Technology published 18 months ago found that many new PhDs are forced to spend increasing lengths of time in low-paid, temporary, postdoc positions. The survey showed that of PhDs who took postdoc positions in all subjects (not just physics) in 1993, only 13 per cent had achieved tenure-track positions two years later. By 1995, the figure in tenure-track posts was only 16 per cent.

The AIP survey of 1997 PhDs shows that, of those in temporary postdoc positions, three-quarters were in those positions only because they could not find a full-time, permanent post. Because physics faculties are unlikely to increase in size, the best that can be done to minimize the waste of highly trained postdocs in low-paid temporary posts is to try to keep faculties with the same staffing levels, which means attracting physics majors and holding their interest.

Tailor-made courses

One institution with an imaginative response to the problem is Rutgers University in New Jersey, which draws from a blue-collar population. The students are often the first in their family to go to university and are people who are likely to want to get a job after their first degree rather than going on to do a PhD. This is not because they are not smart enough, but is the result of economic reality. Rutgers is teaching a physics course deliberately structured to this reality. About 800 US institutions offer bachelors degrees in physics, and many are seeking ways to change the curriculum to attract more students.

At masters level, too, there is a need to tailor education to students' realistic job prospects. Surprisingly few masters courses include options of obvious value to business. In the United States there is the additional problem that holders of masters degrees tend to be perceived as failed PhDs rather than as bona-fide holders of a higher degree.

Those who want to study physics to bachelors, masters or doctoral level would be well-advised to question whether the course

Modelling makes the money go round

The esoteric and intriguing world of derivatives trading is attracting increasing numbers of physicists. As yet only a trickle of some tens of people each year are joining the business in the United States and United Kingdom, but nevertheless the financial sector is an emerging job market for physicists.

Derivatives trading can be speculative and purely for profit, even to the extreme of becoming a gambling addiction. Equally, however, this field can satisfy a socially responsible and economically meaningful function by, for example, minimizing the risk of financial institutions. Banks shelter from the unpredictable winds of economic fortune by buying or selling derivatives. This allows banks to sell mortgages to individual customers at affordable levels and stay in business, despite fluctuations in interest rates.

A derivative is a contract whose value derives from the value of an underlying security such as a stock price, interest rate or foreign exchange level. The derivative might be an option to buy a stock at a given price in the future. In other words, the holder of an option can buy a stock for, say, $150 on a given day in the future. If the value of the stock on that date is $180, the individual will exercise his or her option and buy the stock at $150. If the value is lower, the individual will not buy. Either way, the individual will have paid the derivative trader for the option.

The financial institution selling the derivative must, of course, be able to provide the stock at the value agreed if the customer exercises his or her option, but it clearly does not want to lose money if the stock has soared in value beyond that anticipated. Myron Scholes and Fisher Black, an economist and an applied mathematician working together at the Massachusetts Institute of Technology, came up with a formula in the 1970s for pricing options.

Another class of derivatives is known as futures. The idea behind futures is easiest to grasp in the context of a commodity such as orange juice. The holder of a futures contract agrees to buy orange juice at a given price in the future, and thus the seller of the contract assumes the risk of a possible increase in the price. Unlike in the case of an option, the contract holder cannot walk away from the deal if the price of orange juice declines. The customer pays the dealer for the privilege of being protected from that risk.

Options are the simplest types of derivatives, says Andrew Lesniewski, a former Harvard physicist who made the move to Wall Street in preference to heading a mathematics department at a US university. Currently, Lesniewski trades exotic derivatives at the French investment bank Paribas.

More complex derivatives are contracts that protect the buyer from unfavourable variations in, say, interest rates or foreign exchange. The buyer could be a mortgage company worried about refinancing when interest rates decline, a US portfolio manager holding foreign stocks in his or her portfolio, or a European company whose balance sheet depends on the US dollar price of crude oil. The derivatives dealer decides how much he or she will charge to assume the risk of the unfavourable market movement in interest rates, foreign exchange, or oil price. "Derivatives can be as customized and as complex as you want," says Lesniewski.

To protect itself, the derivatives trader will have its own constantly changing portfolio of derivatives. The trader needs to hedge its portfolio against future movements of a range of commodities, stocks and financial indicators. It must price its derivatives so that they are good value to the company needing to off-load risk, while remaining viable itself despite the risk it is carrying. Risk management of a portfolio of derivatives held by a financial institution is the key role of a trader. In the case of interest-rate derivatives, this involves sophisticated mathematical models of the shape and dynamics of the yield curve, or term structure of interest rates.

Hence there is a need for people able to reduce complex systems to their essentials and to describe them mathematically. "The people we recruit must be smart," says Lesniewski. They need a sophisticated knowledge of probability theory, stochastic processes, partial differential equations and numerical analysis. It is a job that physicists, statisticians and mathematicians can do. "What I find challenging," he says, "is that it is a new, dynamic and growing area of the economy. You can do original work, make a significant contribution and see concrete results."

Yet there is a need for caution. Derivatives traders need a realistic knowledge of the role of money. "It's not just that money is the bottom line in this business," says Lesniewski. "Derivative trading is about buying, selling and managing money and predicting how economic factors will influence its behaviour. If you are not comfortable with money, it is not for you."

Further reading:

Hull, J. *Options, Futures, and Other Derivative Securities* (Prentice Hall).