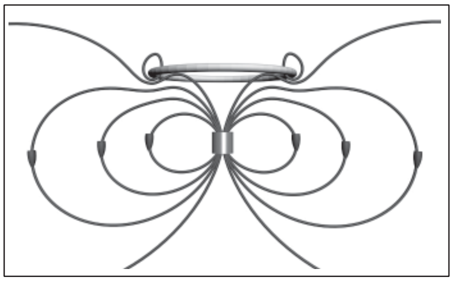

Fig. 2. Another frame of an animation of the magnetic field lines when a conducting ring falls in the magnetic field of a permanent magnet. The ring has come to rest again with maximum eddy current, with all of its initial gravitational potential energy now stored in the magnetic field.

fields transmit the forces that they do. Moreover, it is known physically that as the ring moves downward, there is a continual transfer of energy from the kinetic energy of the ring to magnetic energy. This point is difficult for the instructor to argue at an introductory level. However, it is easy to argue in the context of the animation, as follows.

The overall appearance of the downward motion of the ring through the magnetic field is that of a ring being forced downward into a resisting physical medium, with stresses that develop due to this encroachment. Thus, it is plausible to argue, based on the animation, that the energy of the downwardly moving ring is decreasing as more and more energy is stored in the magnetic field, and to argue conversely when the ring is rising. Because the field line motion is in the direction of the Poynting vector, electromagnetic energy can be explicitly seen flowing away from the immediate vicinity of the ring into the surrounding field when the ring is falling. Conversely, energy can be seen flowing back out of the surrounding field toward the immediate vicinity of the ring when the ring is rising. All of these features make watching the animation a much more informative experience than viewing any single static image of this situation.

The Technology Enabled Active Learning (TEAL) Project at the Massachusetts Institute of Technology (MIT) has created a number of animations of electromagnetic phenomena based on the methods discussed above. The animations are both passive (i.e., movies) and active (interactive Java 3-D applets and ShockWave visualizations), and are freely available for nonprofit educational use on the Web (see links at http://web.mit.edu/jbelcher/www/EOS). These visualizations have been used to good effect in the teaching of freshman electromagnetism at MIT, with learning gains of a factor of two as measured by standard assessment instruments.

This pedagogical approach using concepts growing out of research efforts in space and laboratory plasma physics is an example of how such research can inform and enhance the teaching of introductory physics in fundamental ways. There are other examples of this transference. For example, the spectacular images from NASA's Transition Region and Coronal Explorer (TRACE) spacecraft can be used to good effect in convincing students of the reality of magnetic fields, the electromagnetic interaction of moons with the magnetic fields of their parent planet are naturally occurring examples of Faraday's law, and so on.

This community of space physics researchers should make an effort to publicize the ways in which research efforts can be used to improve instruction in our educational system. Such examples serve as explicit examples of the importance of this research field, both in the investigation and conceptualization of new physical phenomena and as a forefront effort that feeds back into the educational system in important and demonstrable ways.

Acknowledgments

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NEWS

Rapid Determination of Earthquake Size for Hazard Warning

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The 26 December 2004 *M*9 Sumatra–Andaman Islands earthquake caused a tsunami that devastated Indian Ocean coasts within three hours after the earthquake. Improved tsunami warning and emergency response for future great earthquakes require knowing an earthquake's size within minutes after the event. Although the hypocenter of a distant earthquake is routinely determined from the first seismic *P* waves within about 15 min, several hours may pass before a reliable size determination for very large earthquakes is available (e.g., for the 2004 Sumatra–Andaman earthquake see *Menke and Levin* [2005]).

Seismologists specify the size of an earthquake using seismic scalar moment (M_0), a physical quantity proportional to the product of fault area and mean slip on the fault. Currently, analyses of long-period seismograms (period > 100 s) provide reliable estimates of M_0 for very large events [e.g., Harvard Centroid-Moment Tensor (CMT), *Dziewonski et al.*, 1981], but these seismograms are not available until an hour or more after the event.

Seismic *P* waves are the first signal from an earthquake to arrive at distant recording stations. Experience shows that high-frequency seismograms (period ≤1 s) contain predominantly *P* signal radiated directly from the rupture, with little interference from waves reflected at the Earth's surface or from the larger, later *S* waves. Thus, high-frequency *P*-wave recordings, available within 20 min after an event, provide an early and clear view of the rupture process.

Assuming that a large earthquake ruptures with constant velocity along a fault surface that is much longer than it is wide, it is found that fault area is proportional to rupture duration. Then, given a reference event with known M_0 and rupture duration, and assuming that rupture velocity and mean slip are the same for all events, M_0 can be estimated for a new event by direct comparison of the rupture durations of the two events.

Figure 1 shows high-frequency seismograms from the 2004 Sumatra–Andaman Islands earthquake and from the 28 March 2005 *M*8.6 Sumatra earthquake from two stations at different azimuths from the source region. The apparent duration of higher-amplitude signal is around 2 min for the 2005 event and 6–10 min for the 2004 event. By averaging these apparent durations at many stations, or through more sophisticated analysis [e.g., *Lomax*, 2005], approximate source durations of 8 min for the 2004 event and 2 min, 20 s for the 2005 event can be found. Multiplying the Harvard CMT moment for the 2004 event (3.95×10^{29} dyne-cm) by the ratio of the 2005 and 2004 durations gives an estimate of 1.2×10^{29} dyne-cm for the moment of the 2005 event, similar to its Harvard CMT moment of 1.11×10^{29} dyne-cm.

Conversely, taking the 2005 event as a reference, a duration moment for the 2004 event similar to the Harvard CMT moment is obtained. Since the 8 min duration for the

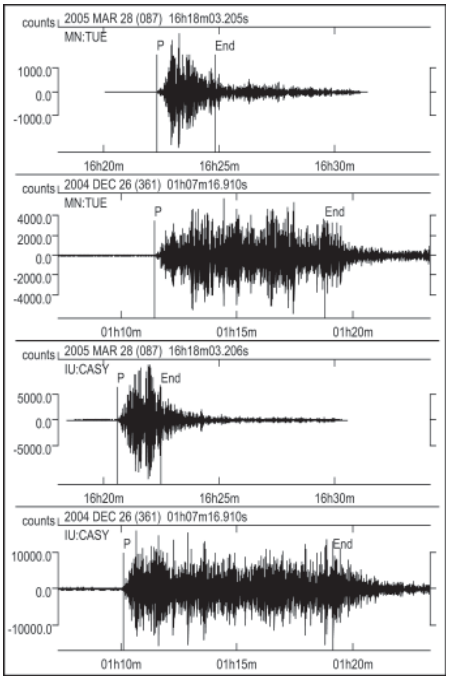

*Fig. 1. High-frequency (1-Hz Gaussian-filtered), vertical-component seismograms from the 2005 and 2004 earthquakes at two stations: MN:TUE, in Italy, at 85° distance to the northwest of the events (upper two traces), and IU: CASY, in Antarctica, at 70° distance to the south (lower two traces). P indicates the initial P arrival time, and "End" indicates an automated estimate [*Lomax, *2005] for the end of stronger signal. The time interval End–P gives an apparent duration.*

2004 event is due to radiation from the full 1100 km rupture zone [e.g., *Lomax,* 2005], the Harvard CMT moment likely represents this same rupture length. Therefore, any additional moment release (i.e., as inferred by *Stein and Okal* [2005] giving M_w as high as 9.3) is unlikely to be due to undetected slip in the northern part of the rupture zone and is probably associated with increased slip magnitude or fault width.

This analysis illustrates the value of high-frequency, *P*-wave recordings for accurate characterization of large earthquakes within the shortest possible time. Further study will likely produce a calibrated scale that relates source duration to seismic moment and magnitude, precluding the need for a reference event. The development of other tools using high-frequency, *P*-wave recordings may allow rapid and robust estimation of other source parameters, such as the source mechanism and the rupture extent [e.g., *Lomax,* 2005].

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—Anthony Lomax, Anthony Lomax Scientific Software, Mouans-Sartoux, France; and Alberto Michelini, Istituto Nazionale di Geofisica e Vulcanologia, Rome, Italy

G E O P H Y S I C I S T S

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Recent Ph.D.s

Hydrology

Modeling of the possible effects of ENSO and macocirculation patterns on precipitation: an Arizona case study, **Agnes Galambosi**, University of Arizona, Tucson, December 2003, Advisors: L. Duckstein and F. Szidarovszky.

Honors

Jan Achenbach has been awarded the 2003 National Medal of Technology, which was presented by President George W. Bush. The award recognizes those "who embody the spirit of American innovation and have advanced the nation's global competitiveness."

William Krabill has received The William T. Pecora Award for excellence in remote sensing, presented by NASA and the U.S. Department of Interior. The award is given annually to "individuals or groups that make outstanding contributions in the field of remote sensing and its application to understanding the Earth."

FORUM

Space Policy and Humanities Policy

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In his 14 January 2004 speech on the future of space exploration, U.S. President George W. Bush proposed a return to the Moon followed by "human missions to Mars and to worlds beyond." Bush's proposal called for robotic missions and new manned space vehicles to replace an aging set of space shuttles, and sought a new justification for space exploration. In the words of former NASA Administrator Sean O'Keefe, in *The Vision for Space Exploration,* this plan is not "merely for the sake of adventure, however exciting that might be, but seeks answers to profound scientific and philosophic questions."

Bush's proposal stimulated renewed reflection on the goals of our nation's space policy and on the means (financial and otherwise) for achieving these goals. A return to such first-order questioning of our goals for space has been long overdue. The Columbia Accident Investigation Board, which was convened by NASA in 2003 following the shuttle disaster, described "a lack, over the past three decades, of any national mandate providing NASA a compelling mission requiring human presence in space" [*Keiper,* 2003].

This lack of a mandate reflects our nation's inattention to the philosophic and spiritual roots of space exploration. It is, of course, a truism that our interest in space expresses fundamental aspirations of the human spirit. Even the appeal to scientific curiosity as the reason for research is but another expression of the traditional philosophic and religious search for truth, the desire to understand the deep nature of things. Scientists today remain the heirs of philosopher Immanuel Kant who, in an essay written in 1784, uttered the cry "sapere aude"—dare to be wise.

It is curious, then, that we rarely consult with those specifically trained in and devoted to matters of the human spirit in the design and implementation of space policy. Of course, from the beginning of the U.S. space program 45 years ago to the most recent NASA pronouncements, there has been no lack of comments speaking to the humanistic aspirations lying behind space travel. In the words of Adam Keiper, paraphrasing Tom Wolfe, the early space program "was about guts and glory, about the endurance of the human body and soul in the deadly void." (ibid) But such sentiments are liable to become platitudes if they are not followed up by careful, in-depth reflection into the meaning and values of exploring and inhabiting space.

Following O'Keefe's comment, it is time that we draw more consciously upon the expertise of scholars trained in the areas of art, philosophy, and religion in the design of our space policy. Take the example of the space station. We have missed an opportunity by not treating the space station as a humanities laboratory as well as a science laboratory. Treating the space station as a humanities laboratory would