ASTR 220 Midterm 1 Solutions
Spring 2005

The correct answers to the multiple choice questions were marked on your test.
Different versions of the midterm had the same short answer questions, but in a different order.

1. *Explain why the Earth's surface has so many fewer craters than the surfaces of the other terrestrial planets.*

   The Earth was the victim of many impacts during the heavy bombardment, just like the other terrestrial planets. Originally the Earth's surface was as cratered as the Moon's. However, the Earth has a lot of surface activity. The geologic processes of volcanism, tectonics, and erosion erase craters. Lava produced by volcanoes covers up craters. Tectonic stresses that compress the lithosphere and form mountains or stretch it and form cracks destroy the features previously present on the crust. Erosion destroys craters on the crust by gradually wearing them away, by water, wind, or ice.

2. *Explain why a good theory must be able to make predictions.*

   A theory must make predictions so that it can be tested. Predictions use the ideas put forward in a theory to tell in advance what scientific phenomena might be observed. Scientists then try to observe the predicted phenomena. If the prediction is successful, then the theory is strengthened. If the prediction is unsuccessful, then scientists must re-think the theory. If a theory doesn't make predictions, it can't be tested and therefore can't ever be proven or disproven.

3. *The K-T impactor had a mass of about $1 \times 10^{15} kg$ and hit at a velocity of about $50 km/s$. How much kinetic energy did it have on impact?*

   We know that kinetic energy is $K = \frac{1}{2}mv^2$, where m is the mass of the impactor and v is the velocity. The units of kinetic energy are Joules, which are $kg \cdot m^2/s^2$.

   The mass and velocity are given to us, so let's plug them in.

   $$K = \frac{1}{2}(1 \times 10^{15} kg)(50 km/s)^2$$

   What units will we get when we multiply this through? They will be $kg \cdot km^2/s^2$, which are not Joules. We need to change the velocity into m/s.

   $$v = (50 km/s)(1000 m/km) = 5 \times 10^4 m/s$$

   Now find the kinetic energy.

   $$K = \frac{1}{2}(1 \times 10^{15} kg)(5000 m/s)^2 = 1.25 \times 10^{22} kg \cdot m^2/s^2 = 1.25 \times 10^{22} J$$

4. *Explain qualitatively the criterion we used in class to decide if an impact was large enough to destroy the planet it hit.*

   We know that during an impact, the kinetic energy of the impactor is transferred to the planet that it hits. A shockwave is created in the surface. If enough energy is transferred from the impactor to the surface, the disruption of the planet by the shockwave will be enough to break apart the planet. The energy of the impactor must overcome the gravitational potential energy of the planet's gravity holding itself together. If the impactor's kinetic energy is at least that large, then the planet will be destroyed.

5. *Briefly discuss the current threat of an impact on Earth. Focus on two types of impactors: ones about 1 km in size and ones similar to the K-T impactor (about 10 km across).*

   Current near-Earth object surveys have found over 700 objects at least 1 km in size. However, most of these are not "potentially hazardous" because they don't come within 20x the Earth-Moon distance. Impacts of objects this size are pretty rare: about every 1 million yrs. We don't know of any immediate threat.

   There are many fewer near-Earth objects that are at least 10 km across. That makes the chances of them hitting us a lot less. Impacts of objects this size are even rarer: about every 100 million yrs.

   Of course, these risk assessments don't consider the possibility of a random comet being nudged in toward the Sun by some object outside of our solar system: we can't really calculate that risk, but it's very, very small.

Essay 1

1. *State the Alvarez Theory of dinosaur extinction.*

   The Alvarez Theory can be stated as: "Sixty-five million years ago, between the Cretaceous and Tertiary geologic periods, a large object from space hit the surface of the Earth. The resulting effects from the impact caused the dinosaurs and a large fraction of other species to become extinct."

2. *List three predictions the theory makes that are related to the* ***impact*** *part of the theory. Discuss the evidence supporting each prediction.*

   Here are all six predictions and supporting evidence.

   (a) **Impact effects can be seen worldwide at the K-T boundary.** The iridium anomaly has in fact been found in over 100 sites around the world, including fresh and saltwater deposits.

   (b) **High iridium levels and shocked material should be rare in the rock surrounding the K-T boundary.** One one good sample exists that encompasses a wide range in geologic time around the K-T boundary (a core sample from the Pacific floor that dates from 35 - 65 million yrs ago), but on the K-T boundary region shows such features.

   (c) **High iridium levels should be associated with craters.** As of the writing of the book, two craters have been found with match up (in Australia and Scandinavia), but not finding much evidence does not mean much since erosion has likely weathered away most craters on Earth.

   (d) **There should be a thin, worldwide K-T boundary layer with high levels of iridium.** This is basically re-stating part of the first prediction, but the K-T boundary does seem to have a similar appearance almost everywhere that it is exposed.

   (e) **The K-T boundary should contain shocked, metamorphosed material characteristic of impacts.** Such findings were first introduced by Bruce Bohor at a site in Montana, then confirmed at K-T boundary sides all over the world. Shocked quartz and glassy spherules are quit common at the boundary.

   (f) **A big crater exactly 65 million years old must exist somewhere.** The Chicxulub crater has been confirmed to be 65 million years old. It also is in a location that fits in with the thicker K-T layer found in North America and sediment layers found from the tsunami created by the impact. The zircon fingerprint is another strong confirmation that Chicxulub is the K-T impact.

3. *List one prediction the theory makes about the* ***mass extinction*** *part of the theory. Discuss the evidence supporting this prediction.*

   (a) Prior to the K-T boundary, most species were not already going extinct. Their extinction was sudden and right at the boundary.

   (b) Except where reworking has occurred, species that became extinct at the K-T boundary will not be found above the iridium horizon.

   We discussed the evidence supporting these predictions for four types of organisms: ammonites, plants, forams, and dinosaurs. Ammonite fossils support the two predictions very well: they were numerous right up to the K-T boundary, and then suddenly many types became extinct.

   Plants also support the predictions. At the K-T layer, over 80% of plant species became extinct. In addition, the first plants to recover after the impact were ferns, which are found to be the first plants to thrive again after natural disasters.

   Fossils of forams show that they became extinct suddenly at the K-T boundary. However, it is still in dispute whether they were previously dying out. This doesn't disprove the predictions above: it's OK for a small number of organisms to be dying out before the K-T impact.

   Few dinosaur fossils have been found near K-T boundary, but they show that dinosaurs were not dying out before the impact. No dinosaurs have ever been found above the K-T layer.

Essay 2 *Imagine an asteroid 1 km in diameter strikes the surface of the Earth.*

1. *Describe how the crater is created, focusing on the concept of energy conservation.*

   When the asteroid hits the surface, it will have kinetic energy from its motion. The asteroid will penetrate into the surface and then stop. Because energy must be conserved, its kinetic energy cannot disappear; it must change forms or be transferred to other objects.

   Much of the kinetic energy is transferred to the surrounding ground as kinetic energy. This powers a shockwave in the ground that travels outward in all directions. Some of the asteroid is vaporized, so some kinetic energy is transformed into radiative energy (heat and light).

   The shockwave clears out the cavity that will form the crater by pressing the ground outward and away. Above the impactor, the shockwave explodes upward into the air. The crater is created.

   Finally, the ground relaxes and cools. The kinetic energy of the ground moving in the shockwave eventually dissipates through friction and becomes thermal energy in the ground. As the ground cools, it radiates away the heat: the thermal energy of the ground is changed into radiative energy (heat is infrared light) and escapes.

2. *Approximately what will the diameter of the crater be? Explain how you came to this answer.*

   According to our rule of thumb, the crater will be about 10x larger than the size of the impactor, so the crater will be about 10 km across. This makes an assumption: that all impactors are made of the same material.