Mid-Term Examination for Physics 102

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March 10, 2010

Relax. This test is supposed to be a learning experience. It will be graded generously. It is a multiple-choice test. You get several points just for printing your name on the form in the tedious way required by the machine-readable form.

Question 1: When was the known universe very hot? (a) Last week. (b) Several thousand years ago. (c) Several million years ago. (d) Several billion years ago — in fact, probably between 13 and 15 billion years ago. (e) Several trillion years ago. D

Question 2: Large collections of stars held together by gravity are called galaxies. Our sun is an average star in the galaxy we call the Milky Way. How many stars are in the Milky Way? (a) As many as in Hollywood. (b) More, but not more than a million. (c) Nobody really knows, but there could be more than a hundred billion stars in the Milky Way. (d) The sun is the only star in the Milky Way. (e) Because of all the milk, nobody has any idea how many stars are in the Milky Way. C

Question 3: Four minutes after the Big Bang, what was the universe made of? (We leave aside dark matter and dark energy.) (a) Mostly photons, neutrinos, electrons, protons, and helium nuclei. (b) Green cheese — where do you think the Moon came from? (c) Atoms of all the elements of the periodic table in roughly equal amounts by weight. (d) Just photons. (e) Earth, air, fire, and water. A

Question 4: What elements were the most abundant at four minutes after the Big Bang? (a) Nitrogen and oxygen — roughly 75% nitrogen and 25% oxygen. (b) Hydrogen and helium — roughly 75% hydrogen and 25% helium. (c) Iron and calcium. (d) Uranium and radium. (e) Neon, argon, krypton, xenon, and radon. B

Question 5: How does our sun (and other ordinary stars) produce the energy they radiate? (a) It burns uranium as in a nuclear reactor. (b) The sun is so very hot — about 15 million degrees — that it can radiate for millions of years. (c) The inner third of the sun is at a temperature of 15 million degrees and under high pressure. By a complicated series of nuclear reactions, first described by Hans Bethe in 1938, four protons and two electrons turn into one helium nucleus and two neutrinos. The decrease in mass Δm is liberated as energy according to Einstein's formula $\Delta E = (\Delta m)\, c^2$. (d) In the sun, matter and antimatter annihilate into photons. (e) There is a black hole at the center of the sun, and as the gases of the sun fall into the black hole, they liberate energy. C

Question 6: For several thousand years after the Big Bang, most of the energy of the universe was (a) dark energy, (b) depleted uranium, (c) black holes, (d) radiation in the form of particles moving at or nearly at the speed of light, (e) neutrinos. D

Question 7: For the past few billion years, the energy of the universe was mostly that of (a) dark matter, (b) dark energy, (c) hydrogen and helium gas, (d) black holes, (e) government debt. B

Question 8: A proton is released with a velocity of 1000 meters per second (m/s) toward the sky in a strong magnetic field that points toward the north. What happens to the proton after it is released? (a) Nothing. (b) The proton decays into a neutron, a positron, and a neutrino. (c) The proton races off toward the north. (d) The proton keeps moving at 1000 m/s but veers west, eventually moving in a circle. (e) The proton gradually stops spinning. D

Question 9: A proton is released with a velocity of 1000 m/s in a certain direction in empty space far, far away from any star, planet, or gas. What happens to the proton after it is released? (a) Nothing: the proton continues to move at the same speed and in the same direction until eventually it is scattered by encounters with photons, stars, planets, or gases. (b) The proton decays into a neutron, a positron, and a neutrino. (c) The proton races off toward the north. (d) The proton keeps moving at 1000 m/s but veers west, moving in a circle. (e) The proton gradually slows down because it runs out of momentum. A

Question 10: A steel ball with a mass of 1 kilogram (kg) is moving at a speed of 1 m/s directly at a second steel ball that also has a mass of 1 kilogram (kg) but is at rest (speed zero) at a point that is directly north of the first ball. What happens after the first steel ball strikes the second one head-on? (Neglect friction, air resistance, gravity, and deformations of the balls.) (a) The first ball stops dead, and the second ball moves north at 1 m/s. (b) The two balls collide and move north at the same speed of 1 m/s. (c) The two balls collide and stop, held together by gravity. (d) The first ball bounces of the second ball and the two balls move apart, each at 1 m/s. (e) The first ball excuses itself and avoids the second ball. A

Question 11: In empty space far, far away from any star, planet, or gas, two protons are released at speed zero with a separation of 1 millimeter. What happens? (a) Nothing. (b) They fly apart in opposite directions along the B line that connects them because their electric repulsion is much greater then their gravitational attraction. (c) They fly towards each other along the line that connects them. (d) They orbit each other in perfect circles, never colliding. (e) They collide and change into a deuteron and a positron and an anti-neutrino.

Question 12: In empty space far, far away from any star, planet, or gas, a proton and an electron are released at speed zero with a separation of 1 millimeter. What happens? (a) Nothing. (b) They fly apart in opposite directions along the line that connects them. (c) They fly towards each other along the line that connects them, and, after radiating some photons, they settle down to form a hydrogen atom. (d) They orbit each other in perfect circles, never colliding or radiating. (e) They collide and change into a neutron and an anti-neutrino. C

Question 13: In empty space far, far away from any star, planet, or gas, a neutron is released at speed zero. What happens next? (a) Nothing: it remains at rest forever. (b) It remains at rest for a while, but with a random delay of the order of 15 minutes, it decays into a proton, an electron, and an anti-neutrino. The (anti-)neutrino moves off at nearly the speed of light, the electron at a slower speed, and the proton at a yet slower speed, so that the total momentum of the three particles is zero, equal to that of the neutron. (c) It gradually stops spinning because it runs out of angular momentum. (d) It quickly decays into the three quarks of which it is composed. (e) It turns into a helium nucleus. B

Question 14: In the spring of 1964, Penzias and Wilson turned on their 20-foot horn antenna tuned to 7.35 centimeter (cm) microwave radiation and pointed it at the sky. What did they detect? (a) Radiation from the Andromeda galaxy. (b) Radio noise from pigeon droppings. (c) Cosmic microwave background radiation that for the most part was photons emitted about 380,000 years after the big bang when the universe first became transparent. (d) One of the New Jersey radio stations owned by Clear Channel Communications. (e) The cosmic neutrino background radiation at a temperature of about 2 K°. C

Question 15: After the big bang, what happened? (a) The temperature rose and the density of the universe dropped. (b) The temperature and the density of the universe dropped as the universe expanded. (c) The temperature dropped and the density of the universe rose as the universe expanded. (d) All the stable elements were formed in equal parts by weight in the first four minutes? (e) The temperature and the density of the universe rose and fell in a wave-like manner as the universe expanded. B

Question 16: Gold sells for around $1122 per ounce. Where was it made? (a) South Africa. (b) Switzerland. (c) The sun. (d) In the big bang. (e) In very massive stars as they underwent supernova explosions billions of years ago. E

Question 17: Suppose we use a vacuum pump to suck nearly all the air out of an empty gallon-size metal can. What happens next? (a) Nothing: the vacuum is stable. (b) Atmospheric pressure (15 pounds per square inch at sea level) will collapse the can. (c) The can will rise like a balloon. (d) The can will get warm. (e) The can will grow cold. B

Question 18: Consider a circular coil 10 inches in diameter made of many turns of copper wire. Imagine two very strong electromagnets with the north pole of one only an inch or so from the south pole of the other. The magnets are on a stand about three feet above the ground. Suppose we rapidly swing the coil on a long aluminum swivel from a height of six feet so that it shoots between the poles of the magnets. Suppose the ends of the coil of copper wire are connected to a tiny light bulb. What happens when the coils and bulb shoot between the poles of the magnets? (a) The bulb lights as the leading edge of coil passes between the poles and again as the trailing edge of the coil passes the poles. The reason is that changing magnetic fields induce electric fields around them. (b) The bulb explodes. (c) All the lights go out. (d) The coil speeds up as it shoots between the poles of the magnets. (e) Time goes backward. A

Question 19: Suppose two identical green lasers are shining directly at us from far away. Suppose the first one is moving toward us at very high speed, and that the second one is moving away from us at very high speed. What do we see before we duck? (a) The lasers both look the same because the speed of light is constant. (b) The lasers are both red-shifted. (c) The first laser is blue-shifted — its photons arrive with a slightly higher frequency and energy — and the second laser is red-shifted — its photons arrive with a slightly lower frequency and energy. (d) The lasers are both blue-shifted. (e) The second laser is blue-shifted — its photons arrive with a slightly higher frequency and energy — and the first laser is red-shifted — its photons arrive with a slightly lower frequency and energy. C

Question 20: Which quantities are conserved? (a) Energy and momentum, but not angular momentum or charge. (b) Energy, momentum, and angular momentum, but not charge. (c) Energy, momentum, angular momentum, and charge, and (at least approximately) baryon number and lepton number. (d) Energy, momentum, angular momentum, charge, and the number of neutrons. (e) Taxes. C