
University of Toronto

Faculty of Arts and Science
April Examinations 2010

AST 121 H1 S

Duration - 3 Hours
Permitted Examination Aids: Non-Programmable Calculators

This Exam Contains 3 Pages

Instructions

- (a) Read the questions carefully
- (b) Give quantitative answers in S.I. units (kg, m etc.) unless indicated otherwise.
- (c) In some questions you will need to produce a numerical answer. It will help you in doing these questions, and help us in following what you have done, if you derive *algebraic expressions* for your answers which you then *evaluate* only at the end.
- (d) Where a non-numerical answer is required: keep it short (at most a few sentences), keep it accurate, and feel free to draw a diagram if needed.
- (e) Some useful physical constants:

speed of light:	$c = 3 \times 10^8 \text{ m s}^{-1}$
gravitational constant:	$G = 6.67 \times 10^{-11} \text{ N m}^2 \text{ kg}^{-2}$
radius of sun:	$r_{\text{sun}} = 6.96 \times 10^8 \text{ m}$

- (f) Don't forget these basic definitions for units:

$$\begin{aligned} 1 \text{ J} &\equiv 1 \text{ kg m}^2/\text{s}^2 \\ 1 \text{ W} &\equiv 1 \text{ J/s} \\ 1 \text{ pc} &\approx 3.26 \text{ light years} \\ 1 \text{ light year} &\approx 9.461 \times 10^{15} \text{ m} \end{aligned}$$

- (g) Each question is worth equal marks. Each question is divided into a number of parts [e.g. question 1 is divided into parts 1(a), 1(b), etc.], each of which is weighted equally to determine the final mark for the question.

DO SEVEN OF THE EIGHT QUESTIONS BELOW.

■ Question 1

- (i) Name all of the forces of nature.
- (ii) What is a boson?
- (iii) Which forces of nature have finite range?
- (iv) Label each of these weak force reactions as possible or impossible. If it's impossible, why?
 - (a) $e^- + \nu_\tau \rightarrow \tau^- + \nu_e$
 - (b) $e^- + e^+ \rightarrow \nu_e + \tau$
 - (c) $\nu_e + u \rightarrow d + e^-$

■ Question 2

- (i) Describe three properties that would make an astronomical object a good "standard candle".
- (ii) Name three standard candles, and indicate very roughly over what range of distances they are useful for as distance indicators. (Relative distances are fine, i.e. "useful for obtaining distances to nearby galaxies such as the Andromeda Galaxy", "useful for getting distances to very nearby stars", etc.)
- (iii) What is the "cosmological distance ladder"?
- (iv) If I tell you Hubble's constant is 75 km/s/Mpc and you measure the recession velocity of a galaxy to be 3,000 km/s, then how far away is the galaxy?

■ Question 3

- (i) Define the term *isotropy*.
- (ii) Define the term *homogeneity*.
- (iii) If the Hubble Constant has a value of 75 km/s/Mpc, about how old is the Universe?
- (iv) If the Hubble Constant has a value of 75 km/s/Mpc, about how big is the observable Universe?

■ Question 4

- (i) What is our best estimate for the present age of the Universe?
- (ii) What is the present temperature of the cosmic microwave background? What was the temperature at when the Universe was 1/3 its present size?
- (iii) What is the meaning of the term 'redshift'? How do I measure a redshift?
- (iv) How much smaller (relative to the current size) was the Universe at a redshift of 1?

■ Question 5

- (i) What is the relationship between the scale factor and time for a matter-dominated Universe?
- (ii) What is the relationship between the scale factor and time for a radiation-dominated Universe?
- (iii) What is the the relationship between the redshift and the scale factor?
- (iv) Derive the relationship between redshift and time in a radiation-dominated Universe?

■ Question 6

- (i) Why do astronomers think that the Universe may have undergone a period of "inflation" soon after the big bang? (Note: stating four problems that inflation solves will get full marks).
- (ii) Why do astronomers now believe the expansion of the Universe may be accelerating?
- (iii) What is the origin of quantum mechanical zero point energy?
- (iv) What is the Casimir Effect and how does it (possibly) relate to dark energy?

■ Question 7

- (i) When was most of the Hydrogen and Helium in the Universe produced?
- (ii) What do astronomers mean when they refer to 'First Light'?
- (iii) Why do we associate First Light with the origin of complexity?
- (iv) Name two possible sources of First Light.

■ Question 8

- (i) What chemical element marks the boundary between fusion and fission as an energetically favourable process in stars (hint: think of the binding energy diagram)?
- (ii) About how much longer will the sun live?
- (iii) Describe how the sun will die.
- (iv) Where was most of the uranium in the Universe produced and how did this wind up in the interstellar medium? Where was most of the oxygen produced and how did this wind up in the interstellar medium?

END OF EXAM.
TOTAL PAGES = (3)

