

**UNIVERSITY OF TORONTO**  
**Faculty of Arts and Science**  
**DECEMBER 2012 EXAMINATIONS**  
**AST101H1F**

**Duration – 3 hours**  
**No Aids Allowed**

**NAME:** \_\_\_\_\_ **UTORID: (e.g.smitha4)** \_\_\_\_\_

**STUDENT NUMBER:** \_\_\_\_\_

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**Instructions:**

1. ON THIS PAGE: Fill in your identifying information above. Make sure you fill in your name AS IT APPEARS ON ROSI.
2. ON THE SCANTRON SHEET: Fill in your last name, first initial, and student number in the spaces given and, using pencil, darkly shade in the corresponding bubbles. Then sign the card.
3. For each multiple choice question, mark your answer *in pencil* on the Scantron card by darkly shading the appropriate bubble. All answers to multiple choice questions must be transferred to the Scantron card. **UNDER NO CIRCUMSTANCES WILL ANSWERS TO MULTIPLE CHOICE QUESTIONS WRITTEN ON THIS PAPER BE ACCEPTED FOR MARKS.**
4. Answer short answer questions in the spaces provided.
5. Answers to short-answer questions which are written in pencil will not be re-marked.
6. Mark values are indicated with each question.
7. Make sure that your exam paper has 19 pages.

<b>Question</b>	<b>Marks</b>
A1-A50	/50
B1	/6
B2	/6
B3	/5
B4	/4
B5	/5
B6	/5
B7	/4
<b>Total</b>	<b>/85</b>

**PART A: For each question, choose the MOST CORRECT answer and TRANSFER YOUR ANSWERS TO THE SCANTRON SHEET WHEN YOU ARE DONE (1 mark each)**

1. The spectra of most distant galaxies show redshifts. That means that their spectral lines:
  - (a) are brighter in the red part of the spectrum
  - (b) have energies which are higher than normal
  - (c) are all located in the red part of the spectrum
  - (d) are observed at wavelengths that are longer than normal \*
  
2. The difference between fusion and fission is that:
  - (a) fusion always releases energy while fission always consumes it
  - (b) fission always releases energy while fusion always consumes it
  - (c) fission is the splitting of nuclei while fusion is the joining of nuclei \*
  - (d) fission converts protons into neutrons while fusion converts neutrons into protons
  
3. Interstellar dust clouds emit mainly infrared light. Why can't we see this light in the sky with our naked eyes?
  - (a) Our eyes are not big enough to resolve infrared light.
  - (b) Our galaxy is unusually free of dust.
  - (c) Earth's atmosphere absorbs 100% of incoming infrared light.
  - (d) Our eyes are not sensitive to infrared light. \*
  - (e) Infrared light is damaging to the eye, so we should never look at it directly.
  
4. Why does the Sun appear almost white to our eyes?
  - (a) Because the Sun is mainly emitting white wavelengths of light.
  - (b) Because the Sun is emitting a few emission lines of green light, a few of blue, and a few of red; our eye combines them all to make white light.
  - (c) Because the Sun is emitting approximately equal amounts of nearly every colour of visible light. \*
  - (d) Because the Sun is very bright, and very bright things always appear whitish to the eye.
  
5. Compared to jovian planets, we should expect terrestrial planets to have:
  - (a) thicker atmospheres
  - (b) higher masses
  - (c) fewer rings \*
  - (d) higher proportions of helium
  - (e) moons with higher orbital inclinations

6. Compared to X-rays, radio waves have:
- (a) higher frequency and lower energy
  - (b) lower frequency and higher energy
  - (c) lower frequency and lower energy \*
  - (d) higher frequency and higher energy
7. Which of these pairs of objects are closest to one another in overall chemical composition?
- (a) the atmosphere of Venus and the outermost layers of Jupiter
  - (b) the core of Earth and a Kuiper Belt object
  - (c) the crust of Earth and the crust of the Moon \*
  - (d) the atmosphere of Earth and the atmosphere of Mars
  - (e) the surface of Mercury and the surface of Jupiter's moon, Io
8. Recently, astronomers announced the discovery of a terrestrial planet orbiting the star Alpha Centauri B, which is about 4 light years from the Sun. What can we conclude from this information?
- (a) Alpha Centauri is not part of the Milky Way.
  - (b) It would take the space shuttle almost 400 years to get to Alpha Centauri.
  - (c) Alpha Centauri must be a Sun-like star.
  - (d) Any intelligent lifeforms on the newly-discovered planet could already be listening to our radio transmissions. \*
  - (e) It would be impossible to take a picture of this planet using a telescope situated on Earth.
9. When Felix Baumgartner stepped off the platform hanging from his high-altitude balloon, he fell to Earth. However, when an astronaut steps out of the International Space Station, she doesn't fall. Why?
- (a) The space station is much higher than the balloon, where gravity is much weaker.
  - (b) The space station is in free-fall, but the balloon was not.
  - (c) The space station is in orbit around the Earth, but the balloon was not. \*
  - (d) The astronaut doesn't have to deal with air resistance, but Felix did.
  - (e) The astronaut uses a jet pack, but Felix used a parachute.
10. Roughly how many constellations of the zodiac does the Sun move through in six months?
- (a) none
  - (b) 2
  - (c) 3
  - (d) 6 \*
  - (e) 12

11. How many third-quarter moons should we see in an average year?
- (a) 1
  - (b) 3
  - (c) 4
  - (d) 10
  - (e) 12 \*
12. When someone in Thunder Bay (longitude 89 degrees W) sees a full moon, what phase will someone in Paris (longitude 2 degrees W) see at the same time?
- (a) full \*
  - (b) first-quarter
  - (c) new
  - (d) third-quarter
13. When you wear a blue shirt, why does it look blue?
- (a) it is emitting blue light
  - (b) it is reflecting mainly blue light \*
  - (c) it is absorbing mainly blue light
  - (d) it is transmitting mainly blue light
  - (e) it is very cold
14. All of the following statements are true. Which one explains why there isn't a solar eclipse at every new Moon?
- (a) The Moon is the primary cause of tides on Earth.
  - (b) The orbital plane of the Moon is tilted by about 5 degrees to the ecliptic plane. \*
  - (c) The Moon rotates synchronously with its revolution about Earth.
  - (d) The sidereal month is shorter than the lunar month.
  - (e) The nodes of the Moon's orbit precess with an 18-year period.
15. Which of the following is **NOT** implied by Kepler's Laws of planetary motion?
- (a) Uranus should take less time to orbit the Sun than Neptune does.
  - (b) The orbit of Earth should be an ellipse.
  - (c) Mercury moves fastest in its orbit when it is closest to the Sun.
  - (d) Planetary orbits are all close to circular. \*
  - (e) Each planet orbits with the Sun at one focus of its orbit.

16. Which of the following statements is both true **AND** falsifiable?
- (a) Earth is the smallest planet in the solar system.
  - (b) The Moon looks nicest when it is full.
  - (c) The highest tides occur during first-quarter and third-quarter moons.
  - (d) Jupiter has planetary rings which are not as bright as Saturn's. \*
  - (e) Mars used to support life.
17. Which of the following emits a continuous spectrum of light?
- (a) a tube of hydrogen gas heated to 2000 K
  - (b) the metal filament of an incandescent light bulb \*
  - (c) a fluorescent light bulb, which works by exciting a gas
  - (d) a laser
  - (e) the microwave-emitting device in a microwave oven
18. Betelgeuse is a bright red star in the constellation of Orion, easily visible to the naked eye. Which of the following can you conclude based only on Betelgeuse's red colour?
- (a) Betelgeuse's surface is cooler than that of the Sun. \*
  - (b) Betelgeuse is much brighter than the Sun.
  - (c) Betelgeuse is moving away from us very rapidly.
  - (d) Betelgeuse is much more massive than the Sun.
  - (e) Betelgeuse is emitting far more high-energy light than the Sun is.
19. Laboratory measurements show that a sample of a particular gas shows a spectral line at a wavelength of 424 nanometers. If we observe a nearby galaxy and find the same spectral line at a wavelength of 421 nanometers, what can we conclude?
- (a) The galaxy is moving toward us. \*
  - (b) The galaxy is moving away from us.
  - (c) The galaxy is hotter than the laboratory sample of hydrogen.
  - (d) The galaxy is colder than the laboratory sample of hydrogen.
  - (e) The galaxy is very young.
20. If the redshift of star A is 10% greater than that of star B, what can you conclude about the two stars? (Assume the redshifts of both stars are positive.)
- (a) Star A is moving away from us slower than star B
  - (b) Star A is moving toward us slower than star B.
  - (c) Star A is moving toward us faster than star B.
  - (d) Star A is moving away from us faster than star B. \*
  - (e) Either (b) or (d).

21. Suppose we discover a planet orbiting a distant star. Which of the following measurements would allow us to determine the chemical composition of the planet's atmosphere most accurately?
- (a) Taking the spectrum of the star the planet orbits.
  - (b) Carefully measuring the overall colour of the planet.
  - (c) Measuring the redshift and blueshift of the planet as it orbits the star.
  - (d) Taking the spectrum of the planet's atmosphere. \*
  - (e) Bouncing radio waves off the planet and gathering the reflected light to look for absorption lines.
22. The cores of terrestrial planets are mostly made of metals such as iron and nickel, while their crusts tend to be made of lighter elements, such as silicon and oxygen. Why?
- (a) over billions of years, convection carries metals to the cores of terrestrial planets
  - (b) terrestrial worlds are made almost entirely of these metals, so it is natural to find them in large quantities in their cores
  - (c) the cores of terrestrial planets contain radioactive elements which produce these metals
  - (d) collisions of asteroids with terrestrial planets have enriched their surfaces with lighter elements
  - (e) heavier elements tended to sink to the centres of terrestrial planets, back when they were molten \*
23. Which of the following most accurately describes the structure of planets like Jupiter and Saturn?
- (a) A large rock surrounded by thin layers of liquid and gas.
  - (b) A small rock surrounded by a thin layer of liquid and a thick layer of gas.
  - (c) A large rock surrounded by a thick layer of gas.
  - (d) A small rock surrounded by a thick layer of gas.
  - (e) A small rock surrounded by a thick layer of liquid and a thick layer of gas. \*
24. Planets like Mercury show evidence of heavy bombardment by meteors while planets like Earth and Venus do not. Why not?
- (a) Mercury orbits in a part of the solar system rich with asteroids; Earth and Venus do not.
  - (b) Mercury has neither plate tectonics nor volcanoes to erase its craters; Earth and Venus do. \*
  - (c) Mercury has no atmosphere to shield it from meteors; Earth and Venus do.
  - (d) Mercury has no magnetic field to deflect small meteors; Earth and Venus do.
  - (e) Mercury has a powdery surface which craters easily; Earth and Venus are made of sturdier rock.

25. Roughly how often is Earth (surface or atmosphere) hit by impactors capable of producing Hiroshima-scale explosions?
- (a) about once a year \*
  - (b) about once every thousand (1000) years
  - (c) about once every million years (1,000,000) years
  - (d) about once every hundred million (100,000,000) years
  - (e) Earth has never been hit by such an impactor
26. The chemical composition of Jupiter is closest to that of:
- (a) Earth
  - (b) the Moon
  - (c) Pluto
  - (d) the Sun \*
  - (e) a comet
27. What is the main mechanism by which planets lose heat to space?
- (a) radiation \*
  - (b) convection with the interstellar medium
  - (c) radioactivity
  - (d) conduction with the interstellar medium
  - (e) differentiation
28. Which of the following factors is MOST responsible for determining whether a terrestrial planet will be geologically active?
- (a) the strength of its magnetic field
  - (b) its chemical composition
  - (c) the thickness of its atmosphere
  - (d) its size \*
  - (e) its distance from the Sun
29. Why should we be surprised to find that Mercury has a magnetic field?
- (a) Mercury was not thought to contain magnetic minerals.
  - (b) Mercury's interior was thought to have solidified long ago. \*
  - (c) Mercury has no atmosphere to generate a magnetic field.
  - (d) Mercury is tidally locked to the Sun, so it can't rotate and generate a magnetic field.
  - (e) Heavy bombardment by asteroids should have disrupted Mercury's magnetic field long ago.

30. Earth has a very active carbon cycle which keeps its atmosphere free of excess carbon, while Venus does not. Why doesn't Venus have a carbon cycle?
- (a) Venus does not have continuous plate tectonics to help return carbon to its interior.
  - (b) Venus' atmosphere is acidic and carbon won't dissolve in acid.
  - (c) Venus has no oceans to trap carbon.
  - (d) Venus doesn't have enough carbon to have a carbon cycle.
  - (e) Both (a) and (c). \*
31. Volcanoes on Earth are constantly pumping CO<sub>2</sub> into the atmosphere. What happens to that CO<sub>2</sub> to prevent it from building up over long (million-year) timescales?
- (a) It dissolves into water vapour in the air, rains into the oceans, is turned into rock, and carried back into the Earth by plate tectonics. \*
  - (b) It is heated by ultraviolet rays from the Sun and broken apart into C and O<sub>2</sub>. The light C atoms escape into space and the O<sub>2</sub> is breathed by animals.
  - (c) It is absorbed by rocks on Earth's continents and reacts with them chemically to become oil and natural gas.
  - (d) It is absorbed by plants, which then die and become fossils, recycling the carbon back into the ground.
  - (e) It reacts with chemicals such as nitrogen and sulphur in Earth's atmosphere and produces acid rain.
32. On Venus, the runaway greenhouse effect has occurred despite the absence of humans on the planet. Why, then, do we think global warming on Earth is caused by human activity?
- (a) Because the temperature increase is highest on the parts of the planet where there are a lot of people.
  - (b) Because the temperature has begun to increase in proportion to the size of the hole in our ozone layer, which itself correlates strongly with the release of ozone-depleting chemicals made by humans.
  - (c) Because global warming has gotten worse a lot faster in the last decade.
  - (d) Because the temperature increase correlates strongly with the increase in human production of greenhouse gases. \*
  - (e) Because as the total population of the Earth goes up, so does its average temperature.
33. Several pieces of evidence suggest that water was once abundant on Mars. Which of the following discoveries has not actually been made yet?
- (a) channels cut into the surface of Mars which appear to have been carved by water
  - (b) the presence of water frozen into the soil on Mars
  - (c) the presence of ice caps on Mars
  - (d) deposits of ice found in the bottoms of deep craters
  - (e) underground streams on Mars \*

34. Imagine that a new planet is discovered orbiting a star (not the Sun). This star is almost exactly like the Sun and the planet orbits it at 1 AU. This planet is found to be about half the mass of Earth. From this information, we can conclude that the planet is **likely**:
- (a) to be completely free of water.
  - (b) to have a thin atmosphere. \*
  - (c) to be extremely hot.
  - (d) to be highly geologically active.
  - (e) to support life.
35. If you were to stand at the North Pole at the instant of the summer solstice, you could see:
- (a) all of the stars on the celestial sphere.
  - (b) about three-quarters of the stars on the celestial sphere.
  - (c) about half of the stars on the celestial sphere.
  - (d) about a quarter of the stars on the celestial sphere.
  - (e) none of the stars on the celestial sphere (except the Sun) because it would be day time. \*
36. Most of the Sun's energy is produced by:
- (a) combustion
  - (b) fusion \*
  - (c) diffusion
  - (d) fission
  - (e) differentiation
37. Light takes about 8 minutes to go from the surface of the Sun to the Earth. How long does it take to travel from the core of the Sun to the surface of the Sun?
- (a) about a second
  - (b) about a minute
  - (c) about 8 minutes
  - (d) more than an hour
  - (e) hundreds of thousands of years \*
38. Which of the following equations best explains how the Sun generates energy?
- (a)  $E = mc^2$  \*
  - (b)  $F = GMm/r^2$
  - (c)  $P^2 = a^3$
  - (d)  $F = ma$
  - (e)  $E = GMm/r$

39. What would eventually happen if the Sun's core were suddenly heated slightly above its current temperature?

- (a) The density of the core would decrease, causing the core to cool down and expand until it stabilized at a new, larger size.
- (b) The core would heat up, causing it to release so much energy that it would shrink even more.
- (c) The core would first expand and cool off and be heated less by nuclear reactions; then it would slowly contract and heat up to its current size and temperature. \*
- (d) The core would cool, the pressure would fall, and gravity would crush the core until it became a black hole.
- (e) The expansion of the core would mean it would generate more energy overall, causing the Sun to become a red giant.

40. Fifty (50) AU is closest to:

- (a) the distance between the Sun and the next star
- (b) the distance between the Sun and the center of our galaxy
- (c) the distance between Mercury and Saturn
- (d) the distance between the Sun and Neptune \*
- (e) the distance between the Milky Way and Andromeda

41. The lowest of the low tides occurs when the phase of the Moon is:

- (a) full
- (b) waxing gibbous
- (c) crescent
- (d) third quarter \*
- (e) new

42. The current number of **confirmed** exoplanets is closest to:

- (a) 0
- (b) 10
- (c) 1000 \*
- (d) 1,000,000
- (e) 100,000,000

43. The main asteroid belt is best described as:

- (a) material left over from the formation of the solar system \*
- (b) a band of rocks orbiting between Jupiter and Saturn
- (c) a ring of asteroids orbiting just beyond the orbit of Neptune
- (d) a cloud of asteroids surrounding the whole solar system
- (e) the source of short-period comets

44. The Doppler method for finding exoplanets is **least** efficient at finding:
- (a) low-mass planets with long orbital periods \*
  - (b) low-mass planets with short orbital periods
  - (c) massive planets with short orbital periods
  - (d) massive planets with long orbital periods
45. Earth's moon was probably formed by:
- (a) Direct capture of the Moon by the Earth's gravity.
  - (b) A catastrophic collision of the early Earth with a planet-sized object. \*
  - (c) Fission of a spinning body condensing from the early protosolar nebula.
  - (d) Accretion of comets onto a small captured asteroid.
  - (e) Fission of the young Earth, which split because it was spinning so quickly.
46. Which of the following correctly describes the strategy astronomers currently use when looking for extraterrestrial life?
- (a) Follow the water \*
  - (b) Organics and ice make biochemistry nice
  - (c) Turn over every rock
  - (d) Look for the fungus among us
  - (e) Shoot first, ask questions later
47. Most observatories designed to detect signals from space are built in space or on the surface of the Earth. Which of the following is typically detected using observatories underground?
- (a) gamma rays
  - (b) neutrinos \*
  - (c) anti-matter
  - (d) X-rays
  - (e) solar wind
48. Samples of rock brought back from the surface of another object in our solar system are analysed using radiometric dating. The rocks were found all over the surface of the object. It is found that a certain element in these rocks has decayed until there is only one-sixteenth (1/16) of the original amount remaining. If the half-life of the original element is 100 million years, which object are these rocks likely from?
- (a) Mars
  - (b) Venus \*
  - (c) Mercury
  - (d) the Moon
  - (e) the asteroid Eros

49. Which of the following best explains why jovian moons have been more geologically active than the Moon or Mercury?
- (a) Because of their greater distances from the Sun, the jovian moons receive much less heat from the Sun.
  - (b) The jovian moons probably have far more internal heat generated by radioactive decay than do the Moon or Mercury.
  - (c) The jovian moons are considerably larger than the Moon and Mercury and therefore have retained much more internal heat.
  - (d) Jovian moons are made mostly of ice that, when tidally heated, can melt or deform at lower temperatures than can the rock and metal that make up the Moon and Mercury. \*
50. Where on Earth would you have to stand to see the whole celestial sphere at night over the course of a year? Assume that you can stand on top of a mountain without anything blocking your horizon.
- (a) at the North Pole
  - (b) anywhere within the Arctic Circle
  - (c) on the equator \*
  - (d) somewhere on a very tall mountain, such as Hawaii, Chile, or Tibet
  - (e) nowhere—it's not possible to see the whole celestial sphere from a single point on Earth within 24 hours

**All answers to Part A questions MUST be transferred to the scantron sheet to count for marks.**

**PART B: Short answer questions. Answer ALL of the following questions in the spaces provided. Point form is acceptable where appropriate. Marks may be deducted for lack of clarity or concision.**

1. The formation of the solar system.

- (a) [3 marks] Name three separate observations about our solar system which suggest that it formed from a rotating disk of material.

**MANY POSSIBLE ANSWERS, INCLUDING: ALL PLANETS ORBIT IN THE SAME PLANE; ALL PLANETS ORBIT IN THE SAME SENSE; ALL PLANETS ROTATE IN THE SAME SENSE; PLANETARY ECCENTRICITIES ARE GENERALLY VERY LOW**

- (b) [1 mark] Two planets—Venus and Uranus—have properties which appear to challenge our nebular theory for the formation of the solar system. Pick **ONE** of these planets. Identify its anomalous property **and** how it can be accounted for by the nebular theory.

**VENUS—ROTATES VERY SLOWLY AND RETROGRADE**

**URANUS—ROTATION AXIS IS IN THE PLANE OF ITS ORBIT**

**IN BOTH CASES, THE SUGGESTED EXPLANATION IS AN IMPACT WITH A PLANETESSIMAL DURING THE ACCRETION PHASE IN THE EARLY SOLAR SYSTEM.**

- (c) [2 marks] Imagine astronomers find a solar system with a Sun-like star and three planets: a jovian planet orbiting at 0.8 AU, a terrestrial planet orbiting at 2.2 AU, and a dwarf planet orbiting at 6.0 AU. Would such a solar system support or challenge the nebular theory? Explain your reasoning.

**SUCH A PLANET WOULD CHALLENGE THE NEBULAR THEORY ON SEVERAL COUNTS: JOVIAN PLANETS SHOULD NOT BE ABLE TO FORM SO FAR INSIDE THE FROST LINE AND, IF THEY INSTEAD MIGRATED IN, THEY SHOULD DISPLACE OTHER PLANETS**

2. Spectroscopy.

- (a) [2 marks] Describe the steps involved in determining the chemical composition of a celestial object which is too far away to be reached by spacecraft.

**ESSENTIAL STEPS ARE:**

**RECORD SPECTRUM OF LIGHT COMING FROM THE OBJECT USING A SPECTROGRAPH**

**IDENTIFY SPECTRAL LINES**

**COMPARE SPECTRAL LINES TO A CATALOG OF KNOWN LINES TO DETERMINE THE ELEMENTS FROM WHICH THEY ORIGINATE**

- (b) [4 marks] Draw the electron energy level diagram for an atom which is capable of producing a total of **ten** spectral lines. Your diagram should be **CLEARLY LABELLED** and should include all of the following:

- i. [0.5 mark] the energy levels; label the one with the lowest energy
- ii. [1.5 marks] the set of **ten** electron transitions which correspond to the **emission** of light (these should be drawn with ten separate arrows)
- iii. [1 mark] the transition which would **emit** light of the highest frequency (label one of your arrows from part ii)
- iv. [1 mark] the transition would **absorb** light of the lowest energy (draw and label an arrow)

**DIAGRAM SHOULD HAVE FIVE HORIZONTAL LINES, WITH THE LOWEST ONE LABELED AS THE LOWEST ENERGY. LINES SHOULD BE MORE CLOSELY SPACED TOWARD THE TOP OF THE DIAGRAM. TEN VERTICAL LINES SHOULD CONNECT ALL POSSIBLE PAIRS OF HORIZONTAL LINES. HIGHEST FREQUENCY EMISSION TRANSITION IS DOWNWARD-POINTING ARROW BETWEEN BOTTOM AND TOP HORIZONTAL LINES AND LOWEST ENERGY ABSORPTION IS UPWARD-POINTING ARROW BETWEEN THE TWO MOST CLOSELY SPACED LINES (TWO TOP ONES).**

3. Exoplanets.

(a) [2 marks] Imagine that scientists announce the discovery of planet with the properties listed below. Comment on the likelihood that this planet could support life like the kinds we find on Earth. Your answer should make specific reference to the properties of the planet.

- i. orbits a Sun-like star which is about 3 billion years old
- ii. orbits the star at 1.1 AU
- iii. has a diameter twice that of Earth
- iv. has an atmosphere which is 70% carbon dioxide

**SUCH A PLANET IS UNLIKELY TO BE ABLE TO SUPPORT LIFE. ITS STAR SHOULD BE ABOUT AS WARM AS THE SUN AND IT IS AT A TEMPERATE DISTANCE FROM THE STAR (WITHIN THE HABITABLE ZONE). HOWEVER, THE PLANET IS LARGE AND THEREFORE LIKELY TO BE VERY VOLCANICALLY ACTIVE. THE DENSITY OF ITS ATMOSPHERE IS NOT SPECIFIED, SO IT'S HARD TO SAY WHETHER THE PLANET WOULD BE COLD (LIKE MARS) OR HOT (LIKE VENUS), BOTH OF WHICH HAVE ATMOSPHERES WHICH ARE APPROXIMATELY 95% CO<sub>2</sub>.**

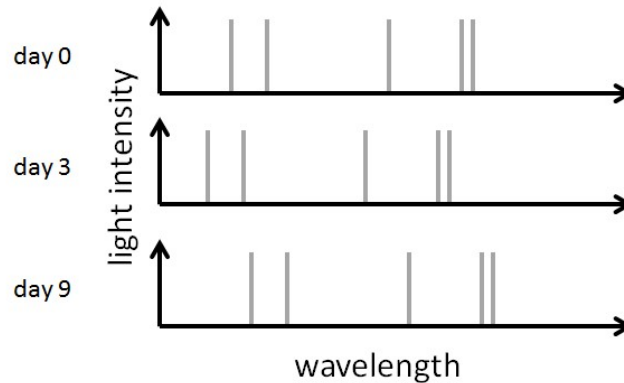
(b) [1 marks] Describe one method we could use to check for the existence of life on the planet described in part (a). Your method should only rely on current technology.

**THERE ARE MANY POSSIBLE ANSWERS. ONE IS TO USE A RADIO TELESCOPE TO CHECK FOR SIGNALS FROM INTELLIGENT LIFE ON THE PLANET.**

(c) [2 marks] Describe how, using current technology, we can measure the physical size (radius or diameter) of an exoplanet orbiting a star 70 light years from the Sun.

**BY TIMING THE PERIOD BETWEEN FIRST AND SECOND CONTACT DURING AN EXOPLANETARY TRANSIT AND COMBINING THIS INFORMATION WITH THE PLANET'S ORBITAL PERIOD (AND HENCE ORBITAL SEMIMAJOR AXIS), WE CAN MEASURE THE DIAMETER OF THE PLANET.**

4. Imagine that astronomers observing a star find that a portion of its spectrum looks as shown below (day 0). The same portion of the spectrum of the same object is shown three and nine days later. This whole sequence repeats every 12 days.



- (a) [1 mark] What could be causing the star's spectrum to change in this way? Be as specific as possible.

**THE STAR COULD BE ORBITED BY AN UNSEEN BODY WITH A PERIOD OF 12 DAYS.**

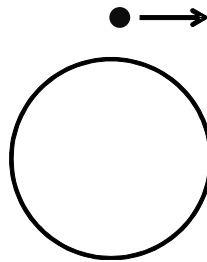
- (b) [3 marks] Draw a **CLEARLY LABELLED** diagram showing the physical process or situation which is causing the spectrum to change in this way. Make sure that your diagram accounts for why the pattern repeats every 12 days. You may need to include a few sentences of explanation.

**THE DIAGRAM SHOULD SHOW THE STAR BEING ORBITED BY AN UNSEEN BODY WHICH IS MOVING AWAY FROM US ON DAY 3, TOWARD US ON DAY 9, AND TANGENTIAL TO OUR LINE OF SIGHT ON DAYS 0 AND 6.**

5. Orbits.

(a) [2 marks] The large circle below represents the Earth. The black dot represents the point from which an object is thrown in the direction shown. On the diagram, draw and **CLEARLY LABEL** the following possible orbits of this object, always starting from the position shown. Assume that the object being thrown is the same in all cases and that it is being thrown from the same altitude in all cases. Draw all of your diagrams assuming that we are looking at the orbit of the object from a top-down perspective (i.e. from the North Celestial Pole).

- i. an elliptical orbit whose apogee (farthest excursion from Earth) is at the starting point
- ii. an elliptical orbit whose perigee (closest approach to Earth) is at the starting point
- iii. the orbit of an object whose orbit is unbound
- iv. an object in a circular orbit



(b) [2 marks] For each of the cases from part (a), state the allowed range of speeds for an object in this type of orbit. Express your answers in terms of the relevant “boundary” speeds, such as the minimum speed required to orbit.

**I.  $V_{\text{ORBITAL}} < V < V_{\text{CIRCULAR}}$**

**II.  $V_{\text{CIRCULAR}} < V < V_{\text{ESCAPE}}$**

**III.  $V \geq V_{\text{ESCAPE}}$**

**IV.  $V = V_{\text{CIRCULAR}}$**

- (c) [1 mark] In which of the cases from part (a) is the object in free-fall? Justify your answer.

**THE OBJECT IS IN FREE-FALL IN ALL CASES AS, IN EACH CASE, THE ONLY FORCE ACTING ON IT IS GRAVITY.**

6. Fermi's Paradox.

- (a) [2 marks] In your own words, state Fermi's Paradox.

**FERMI'S PARADOX STATES THAT ANY INTELLIGENT EXTRATERRESTRIAL SPECIES OUGHT TO HAVE EVOLVED TO INTELLIGENCE MILLIONS OR BILLIONS OF YEARS BEFORE HUMANS DID. IF SUCH A SPECIES COULD ACHIEVE SLOW SPACE TRAVEL (AT 0.1C) IT COULD CROSS THE GALAXY EVERY MILLION YEARS OR SO. HAVING HAD MANY SUCH OPPORTUNITIES TO CROSS—AND COLONIZE—THE GALAXY, WE ARE LEFT WITH THE PARADOX THAT THIS HAS APPARENTLY NOT HAPPENED.**

- (b) [3 marks] State three possible resolutions to the paradox. Each resolution should be independent of the others. Be concise.

**THERE IS NO EXTRATERRESTRIAL INTELLIGENT LIFE.**

**ET INTELLIGENCES ARE NOT INTERESTED IN SPACE TRAVEL.**

**ET INTELLIGENCES DELIBERATELY MASK THEIR PRESENCE FROM US.**

7. Lookback time.

- (a) [2 marks] Astronomers say that looking far away also means looking far back in time. Explain what is meant by this claim—how can it be possible to look back in time? You might wish to use a diagram, but this is not required for full marks.

**LIGHT TRAVELS AT A FINITE SPEED. THEREFORE, THE LIGHT WE SEE COMING FROM CELESTIAL OBJECTS HAS TAKEN TIME TO GET TO US. THEREFORE, WE SEE OBJECTS NOT AS THEY ARE NOW, BUT AS THEY WERE WHEN THE LIGHT WE NOW SEE LEFT THEM.**

- (b) [1 mark] How can this effect be used to study the history of the universe as a whole?

**BY STUDYING THE UNIVERSE AT GREATER AND GREATER DISTANCES, WE CAN STUDY IT AT EARLIER AND EARLIER EPOCHS.**

- (c) [1 mark] Could this effect (and present-day technology) be used to see back in time and watch the formation of the Sun? Why or why not?

**THIS EFFECT CANNOT BE USED TO SEE THE FORMATION HISTORY OF THE SUN. THE SUN IS EIGHT LIGHT MINUTES AWAY, SO WE CAN ONLY SEE IT EIGHT MINUTES INTO THE PAST . TO SEE MORE DISTANTLY INTO THE PAST OF THE SUN, WE WOULD HAVE TO TRAVEL FASTER THAN THE SPEED OF LIGHT TO OVERTAKE THE LIGHT IT SENT OUT BILLIONS OF YEARS AGO.**

**THE END**