Homework 4
Due Tuesday, October 27, 2015

Answer all questions in Part A. Answer 1 question from Part B and complete the exercise in Part C.

Part A

A1. The following are names for the portions of the wave family to which light belongs:

FM radio, visible, ϒ rays, infrared, AM radio, X-rays

Arrange them in order of increasing frequency.

A2. The spectrum of radiation is said to be continuous when
- a. there are no breaks or gaps in the spectrum, that is, no absorption or emission lines.
- b. its emission lines are regularly spaced.
- c. its absorption lines are regularly spaced.
- d. all the spectrum lines of an element are present.

A3. UT is building the Extremely Large Telescope whose primary mirror will be made of 8-meter mirrors. How many of these mirrors shall we need in order to have the light gathering power of a single mirror 32 meters in diameter?

A4. The Stefan-Boltzmann law states the flux of radiation from a blackbody is proportional to
a. 1/T b. T^4 c. $1/T^4$ d. T^2 e. $1/T^2$

A5. Consider two stars having the same surface temperature, but one has a radius four times that of the other. The more luminous body radiates how much more than the other one?
a. 2 b. 4 c. 8 d. 16 e. 256

A6. The spectra of all
- a. ions of all elements are different from one another.
- b. ions of a given element are the same.
- c. elements of a given ion are the same.
- d. ions of a given isotope are the same.

A7. Which ion has no line spectrum?
a. He^+ b. neutral helium c. H^+ d. C^{+2}

A8. The parallax of a star is 0.25 seconds of arc. How far away is it?
- a. 25 light years
- b. 25 parsecs
- c. 4 light years
- d. 4 parsecs
- e. 0.4 parsecs

A9. Stars UT-X and UT-Y have parallaxes of 0.1 and 0.025 arc seconds respectively. If the stars are equally luminous, how much brighter will UT-X appear than UT-Y?

A10. The hydrogen lines are strongest in stellar spectral class
- a. A
- b. B
- c. O
- d. F
- e. M

A11. What characterizes the spectrum of an M star?
- a. hydrogen
- b. singly ionized calcium
- c. doubly ionized calcium
- d. molecules (TiO)
- e. ionized helium

A12. If a star in the process of formation begins to increase its temperature, what will happen to the peak wavelength of its emitted radiation?
- a. It will move toward longer wavelengths (e.g., visible to IR).
- b. It will remain constant, since the chemical state of the gas will not change.
- c. It will not change, since it is not dependent upon temperature.
- d. It will move toward shorter wavelengths (e.g. IR to visible).

A13. Six stars have the following spectral types; order them by decreasing surface temperature:
O5V, M3III, A2V, G2V, K0II, G5V

A14. A red giant's size is that of
- a. the Sun.
- b. the Earth.
- c. the earth's orbit.
- d. the state of Kansas.
- e. a typical city.

A15. Main sequence stars have masses between
- a. 0.001 and 1000 $M_{\odot}$
- b. 1 and 2 $M_{\odot}$
- c. 0.08 and 120 $M_{\odot}$
- d. 1/1000 and 10^6 $M_{\odot}$

A16. The mass luminosity relation $L \propto M4$ applies to:
- a. all stars
- b. white dwarfs
- c. main sequence stars
- d. red giants

A17. The star cluster UT 301 contains 5 main sequence stars of spectral types G, O, M, A, and K. Assume all stars are at the same distance.
- Which star is the hottest?
- Which star is the reddest?
- Which star is the brightest?
- Which star is the most massive?
- Which star is most like our Sun?

A18. What is the age of the Sun? Give answer to nearest billion years.

A19. Assume that the lifetime of the Sun is 10 billion years. What do you estimate to be the lifetime of a star of 10 solar masses? Show all working.

A20. The two most abundant elements in the Sun are ____________ and _____________.

Part B [Answer **ONE**!]
In answering a question, imagine you are an author of a book for junior high students. Do not simply copy or paraphrase the text's glossary. Be imaginative!

B1.
- a. Describe, with the aid of a well-labeled diagram, the method of trigonometric parallax.
- b. Explain why this method would benefit from a telescope placed
  - i. in orbit about the Earth, and
  - ii. in orbit around Jupiter.
- c. Define clearly the distance unit called a parsec.

B2.
- a. Describe the steps in the argument that leads to its conclusion that the Sun must have a hot core ($T \sim 15$ million K) AND that it must currently be generating energy in the core. (It is not necessary to describe the source of the energy.)
- b. Explain clearly why nuclear fusion occurs only in very hot gases.
- c. How long does it take for electromagnetic radiation emitted at the Sun's center to reach the surface? How long does it take for radiation to travel the same distance in free space? Explain clearly why these two times differ by such a very large factor. (The velocity of light is 300,000 km/sec. The radius of the Sun is 700,000 km.)

B3. Consider two perfect blackbodies of the same size. One has its maximum radiation at 2000Å while the other peaks at 20,000Å.
- a. What is the temperature ratio of these blackbodies?
- b. What is the ratio of the total radiation given off (at all wavelengths) by the two blackbodies?
- c. Which blackbody appears blue? Which red?
- d. Which blackbody emits more red light?
- e. Sirius B, a white dwarf, has a surface temperature T = 24,000 K and a luminosity 0.01 that of the Sun. Calculate its radius in terms of solar radius. Assume the Sun to have a surface temperature of 6000 K.

B4.

a. In your own words, describe the Bohr model for the hydrogen atom. Identify the particles comprising the atom. Where are these particles? Describe what is happening as the atom is ionized by interaction with radiation, and then later on the ion and the free electron recombine.

b. Argue that the absorption by the so-called Balmer series of hydrogen will appear most strongly in the spectra of A-type stars, while being much weaker in stars that either are much hotter or much cooler.

c. Why will cold hydrogen gas not be ionized by a beam of red light?

Part C

I challenge you to plot up two samples of stars on the blank H-R diagram at the end of these notes.

Sample One: the stars within 12 light years of the Earth

Sample Two: the 20 brightest stars

The blank diagrams show luminosity (in solar units, L) versus the color B-V. Luminosity is given on a log scale. B-V is a numerical measure (in magnitudes) of the color: crudely the ratio of blue to red light. Large B-V denotes a red star. Small B-V denotes at blue star.

On the diagram labeled “Nearest Stars,’ I’ve placed 61 Cyg. On the diagram labeled ‘Brightest Stars,’ I’ve placed Regulus.

These two examples should help you place the other stars. It is not necessary to write the names of the stars besides the points.

After completing the two diagrams, please answer the following questions:

1. Describe in your own words the key differences between the HR diagrams of the two samples.
2. Main sequence stars of spectral types K and M are the commonest stars in the Galaxy. Why are there none in the sample of the brightest stars?
3. Red giants such as Arcturus and Betelgeuse are very rare—in large part because they are in phase of their lives, which is short-lived. These rare stars are well represented in Sample 2 but there are none in Sample 1. Why do red giants turn up in Sample 2 but not in Sample 1?

Sample One: Stars Within 12 Light Years

Star Designation	Distance (ly)	Spectral Type	B-V Color	Luminosity ($L_\odot$)
Sun	0.0	G2 V	+0.65	1.0
Alpha Centauri	4.3	G2 V	+0.68	1.5
Barnard’s Star	5.9	M5 V	+1.74	0.00044
Wolf 359	7.6	M8 V	+2.01	0.00002
BD +36°2147	8.2	M2 V	+1.51	0.0052
Luyten 726-8	8.5	M6 V	+1.85	0.00006
Sirius	8.6	A1 V	+0.00	29.0
Ross 154	9.5	M5 V	+1.70	0.0004
Ross 248	10.2	M6 V	+1.91	0.0001
Epsilon Eridani	10.7	K2 V	+0.88	0.30
Luyten 789-6	10.8	M6 V	+1.76	0.00012
Ross 128	10.8	M5 V	+1.96	0.00033
61 Cygni	11.2	K5 V	+1.17	0.083
Epsilon Indi	11.2	K5 V	+1.05	0.13
Tau Ceti	11.3	G8 V	+0.72	0.39
Procyon	11.4	F5 IV-V	+0.42	7.0
Σ 2398	11.5	M4 V	+1.54	0.0028
BD +43°44	11.6	M1 V	+1.56	0.0058
CD -36°15693	11.7	M2 V	+1.48	0.012
G51-15	11.9	M? V	+2.06	0.00001

Sample Two: The 20 Brightest Stars

Star Designation	Constellation Designation	Distance (ly)	Spectral Type	B-V Color	Luminosity ($L_{\odot}$)
Sirius	α CMa	8.6	A1 V	+0.00	29
Canopus	α Car	120	F0 II	+0.15	2200
Arcturus	α Boo	35	K1 III	+1.28	370
Rigel Kent	α Cen	4.3	G2 V	+0.68	1.5
Vega	α Lyr	25	A0 V	+0.00	63
Capella	α Aur	40	G5 III	+0.80	140
Rigel	β Ori	850?	B8 I	-0.03	120,000
Procyon	α CMi	11.4	F5 IV-V	+0.42	6.6
Achemar	α Eri	125	B3 V	+0.16	6,000
Betelgeuse	α Ori	650?	M1 I	+1.85	120,000
Hadar	β Cen	360?	B1 III	-0.23	61,000
Altair	α Agl	16.1	A7 V	+0.22	10.6
Aldebaran	α Tau	60	K5 III	+1.54	300
Acrux	α Cru	400?	B1 IV	-0.26	71,000
Antares	α Sco	300?	M2 I	+1.83	16,000
Spica	α Vir	260?	B1 III	-0.23	23,000
Pollux	β Gem	35	K0 III	+1.00	50
Fomalhaut	α PsA	22	A3 V	+0.09	15
Deneb	α Cyg	1600?	A2 I	+0.09	90,000
Mimosa	β Cru	500?	B0 III	-0.23	82,000
Regulus	α Leo	70	B7 V	-0.11	310
Adhara	ε CMa	650?	B2 II	-0.21	72,000
Castor	α Gem	50	A1 V	+0.03	55
Shaula	λ Sco	330?	B2 IV	-0.22	13,000
Gacrux	γ Cru	230?	M4 III	+1.59	8,700
Bellatrix	γ Ori	300?	B2 III	-0.22	17,000
El Nath	β Tau	120	B7 III	-0.13	240
Miaplacidus	β Car	160	A2 IV	+0.00	550
Alnilam	ε Ori	1500?	B0 I	-0.19	550,000
Al Nair	α Cru	55	B7 IV	-0.13	150

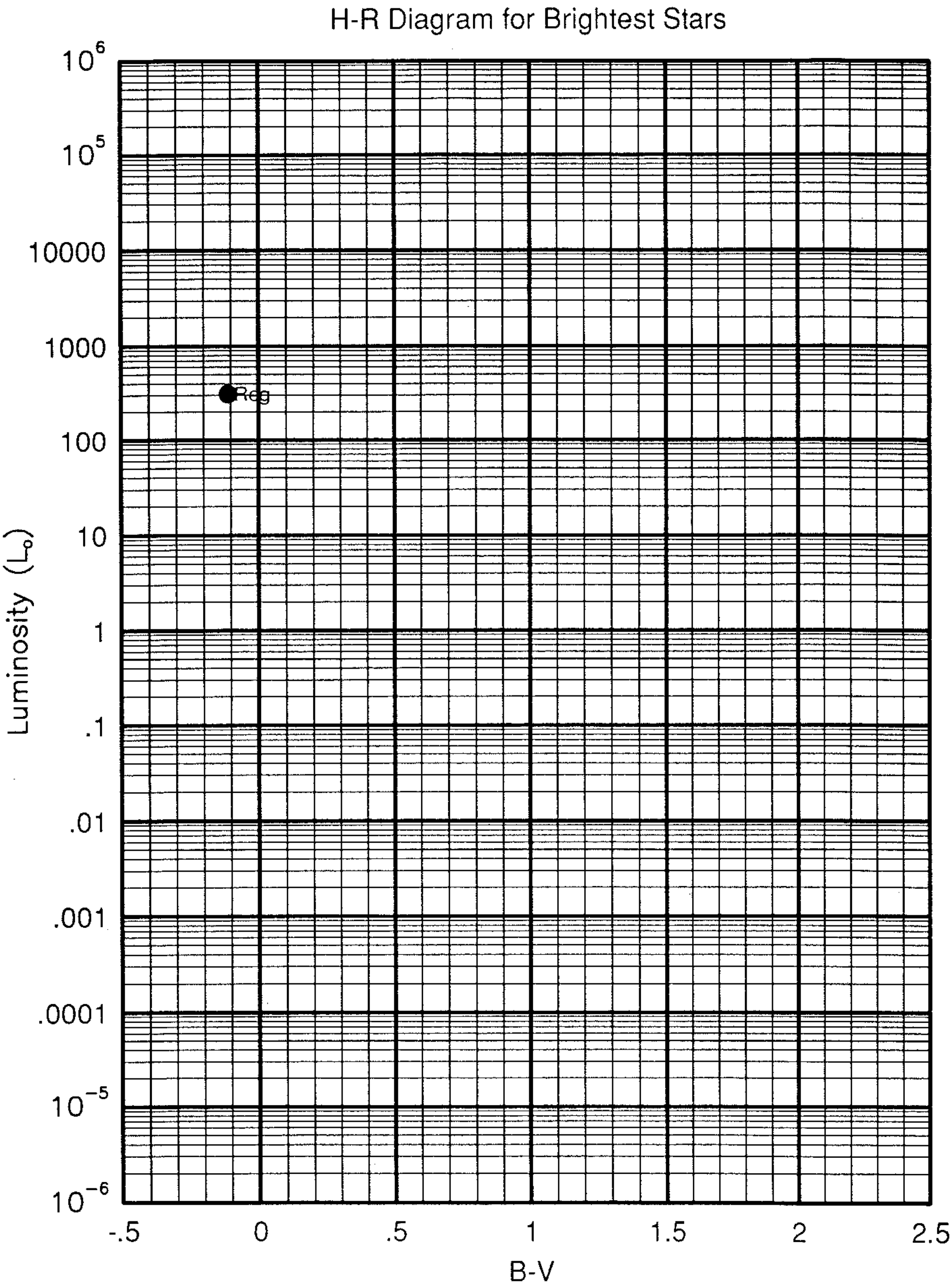
The excitement of doing science is not conveyed by the textbooks such as ours. I came across the following piece in an essay (“Blood, Birds, and the Old Road”) written by Sir Denys Wilkinson whose lectures on nuclear physics I attended long, long ago.

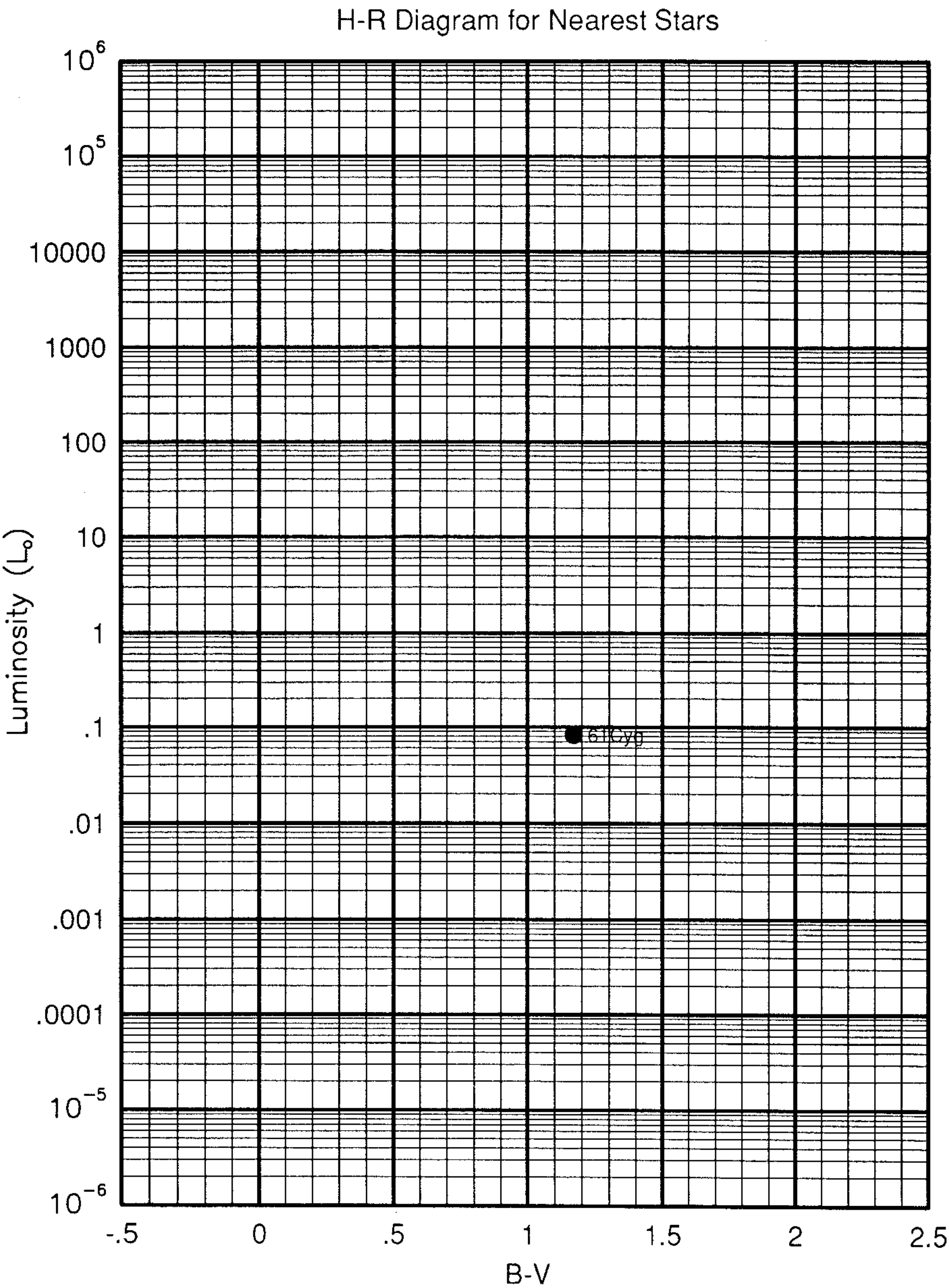
Sir Denys suffered extensively at an early time in his career from radiation sickness. His doctor ordered him to take a complete rest. He took up bird watching. I hope he conveys the excitement of experiments—when they work!

He was fascinated by how birds released far from home, find their way back. Here is his account of one experiment:

> The Manx Shearwater (*Puffinus puffinus*), a strictly pelagic bird never seen inland unless tempest-tossed, comes to land for only a few weeks per year to breed in a burrow close to the sea. We brought these birds, deprived of sensory clues, from Skokholm, their breeding island off the Welsh coast, and released them singly from the top of the Cambridge University library tower, for them totally unknown territory, and watched until each was out of sight before releasing the next. The angular distribution of their disappearances formed a tight fan pointing toward their island home 230 miles away. I have had many thrills in my life in physics, when something has worked or when I have though that I have understood something, but never that eerie feeling as when I watched those shearwaters disappear.

His next paragraph opens with the question ‘How is it done?’ We don’t know!!


H-R Diagram for Brightest Stars
Luminosity ($L_\odot$)
10^6
10^5
10000
1000
100
10
1
.1
.01
.001
.0001
10^{-5}
10^{-6}
Reg
-.5
0
.5
1
1.5
2
2.5
B-V


H-R Diagram for Nearest Stars
10^6
10^5
10000
1000
100
10
1
.1
.01
.001
.0001
10^{-5}
10^{-6}
Luminosity ($L_\odot$)
61Cyg
-.5
0
.5
1
1.5
2
2.5
B-V