Passage VI

The energy, as measured in joules (J), that an object has by virtue of its position with respect to nearby masses is called *gravitational potential energy* (GPE), while energy of motion is called *kinetic energy* (KE). An object falling toward the earth has both gravitational potential energy and kinetic energy. An object's *total mechanical energy* (TME) is the sum of GPE and KE. Objects in motion lose total mechanical energy because of friction.

Experiment 1

A steel marble weighing 1 kilogram (kg) was placed on a track and allowed to roll as shown in Figure 4. A series of photogates (timing devices useful for measuring events which happen faster than can be timed by hand) were used to determine the speed of the marble at various positions on the track. The speed of the marble was used to calculate its kinetic energy. The results are given in Table 7.

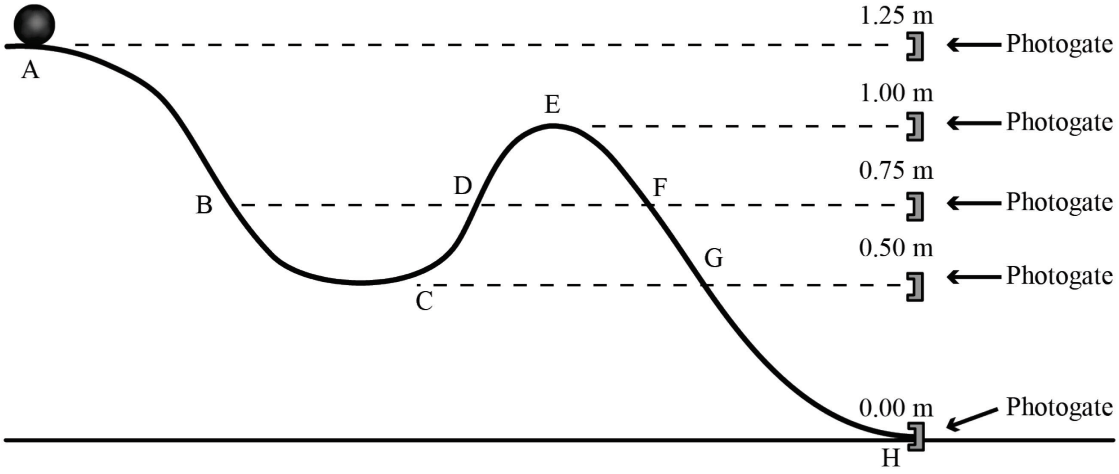


Figure 4

Table 7				
	Height (m)	GPE (J)	KE (J)	TME (J)
A	1.25	12.25	0.0	12.25
B	0.75	7.35	4.8	12.15
C	0.50	4.90	7.2	12.10
D	0.75	7.35	4.5	11.85
E	1.00	9.80	1.9	11.70
F	0.75	7.35	4.3	11.65
G	0.50	4.90	7.2	12.10
H	0.00	0.00	11.5	11.50

Experiment 2

Students constructed a pendulum by hanging a 1 kg mass ("pendulum bob") from the end of a cord 2 meters long. The bob was pulled to the side and released at a height of 0.2 meters. The students allowed the bob to swing through ten cycles before stopping its motion. Using a photogate and timer, the students determined the speed of the bob at five selected points along its path for both the first (Figure 5) and tenth swings.

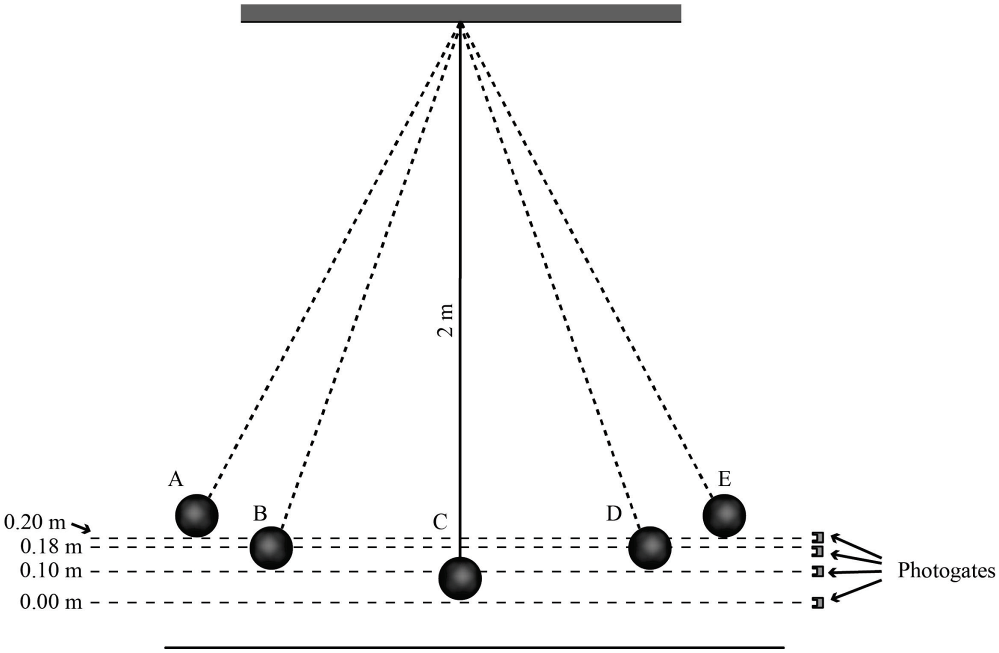


Figure 5

Note: Points A and E are the end points of the swing of the pendulum where height (*h*) has its maximum value. As the pendulum continues to swing, *h* values for points A and E will decrease because of frictional effects.

Table 8				
First Swing of Pendulum				
	Height (m)	GPE (J)	KE (J)	TME (J)
A	0.2	1.96	0.00	1.96
B	0.1	0.98	0.98	1.96
C	0.0	0.00	1.96	1.96
D	0.1	0.98	0.98	1.96
E	0.2	1.96	0.00	1.96
Tenth Swing of Pendulum				
	Height (m)	GPE (J)	KE (J)	TME (J)
A	0.18	1.76	0.00	1.76
B	0.10	0.98	0.78	1.76
C	0.00	0.00	1.76	1.76
D	0.10	0.98	0.78	1.76
E	0.18	1.76	0.00	1.76

Passage VII

A Hertzsprung-Russell (H-R) diagram is used to plot the luminosity (or true brightness) of a star versus its surface temperature. Luminosity is typically expressed in relation to the luminosity of the Sun (solar units). For example, a star with a luminosity of 2 solar units would emit twice as much energy as does our Sun. Surface temperatures of stars are expressed in kelvins (K).

Stars plotted on an H-R diagram generally fall into four main regions: main sequence, red giants, supergiants, and white dwarfs. All main sequence stars (which comprise approximately 90% of all stars) undergo hydrogen fusion in their cores. The heat and pressure created by fusion prevent gravitational forces acting inward from crushing the star.

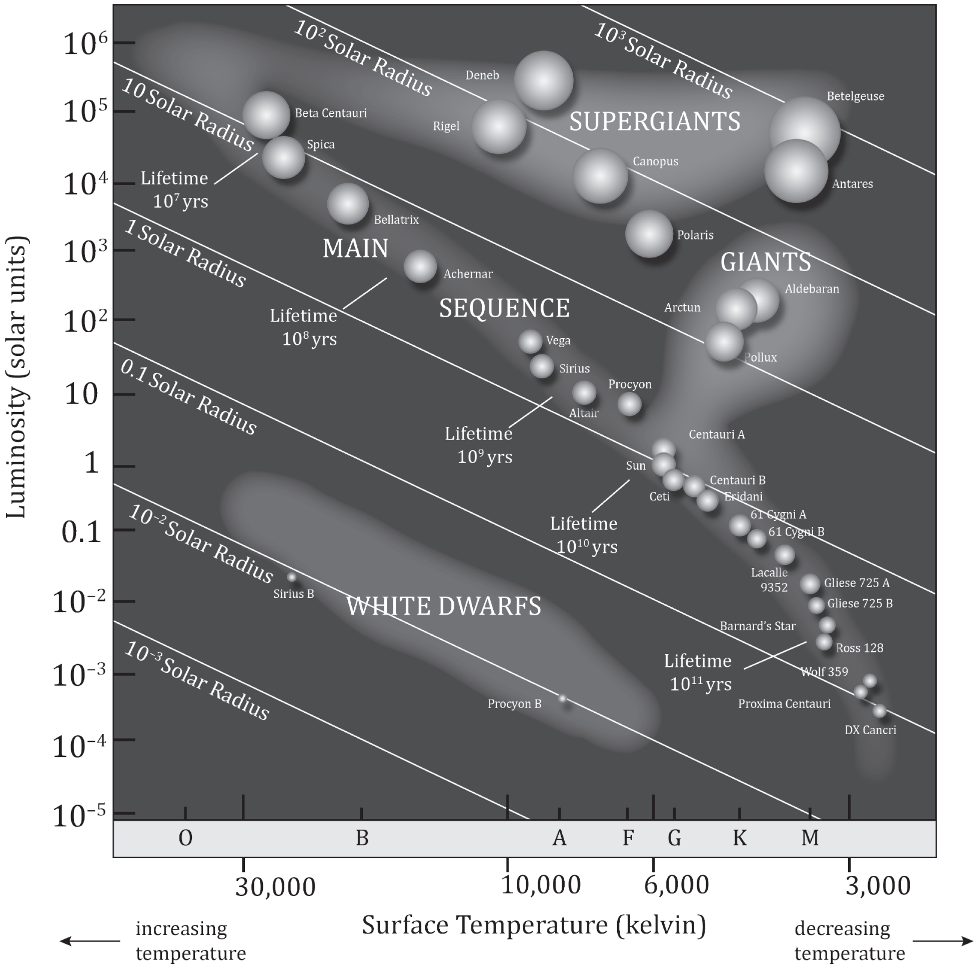


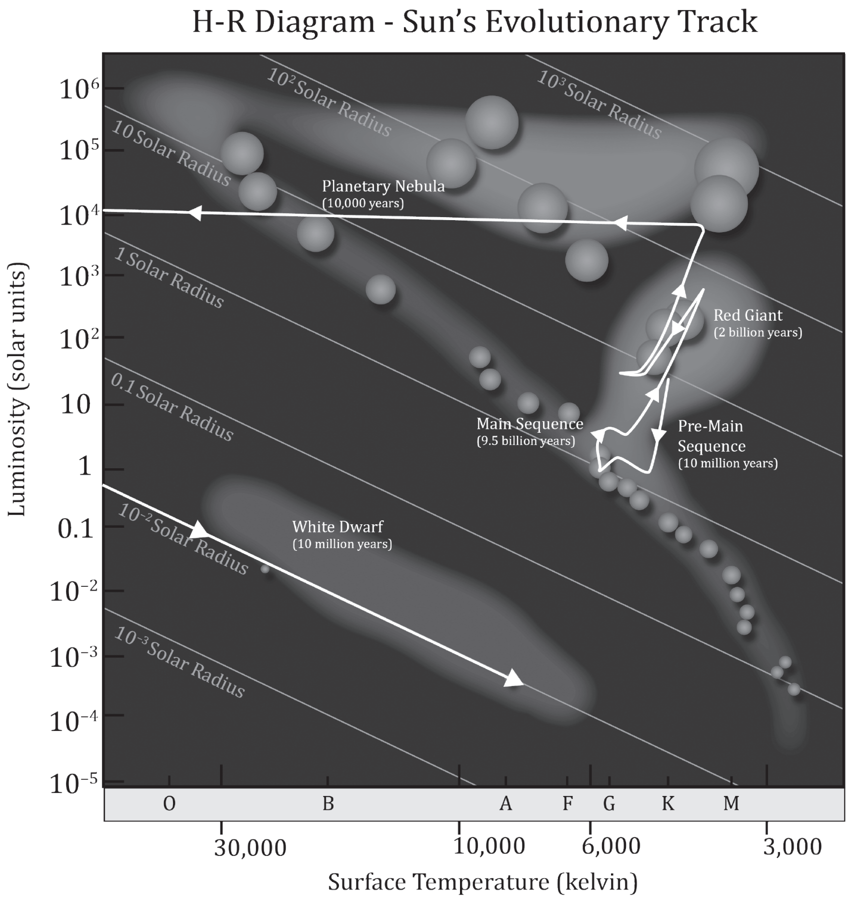
Figure 6

The evolutionary fate of main sequence stars depends on their mass. When mid-mass main sequence stars, such as the Sun, run out of hydrogen in their cores, other fusion reactions occur; and the stars expand to become red giants. When fusion stops altogether, after a brief transitory phase called a planetary nebula, the cores of mid-size stars remain as planet-sized, very hot objects called white dwarfs. From birth to death, mid-mass stars exist on the order of billions of years.

Main sequence stars with much more mass than the Sun appear in the upper left of the H-R diagram. When hydrogen fusion ceases in the cores of these rare stars, other fusion reactions support the star, and they evolve into red supergiants. Eventually, when fusion reactions in their cores cease altogether, gravity begins to crush the stars and runaway thermonuclear reactions cause the outer layers to explode in an event called a supernova. The spent cores of these stars become either neutron stars or black holes. Neither neutron stars nor black holes appear on the H-R diagram. Large mass stars exist for the shortest amount of time—just millions of years—because they burn through their fuel quickly.

Finally, the majority of all main sequence stars have much less mass than the Sun. Fusion reactions in their cores take place at a much slower rate. In fact, these stars will remain on the main sequence for trillions of years. Since the universe is only 13.8 billion years old, not a single low-mass star has yet to evolve off the main sequence.

The diagram below shows the Sun's future evolutionary journey on the H-R diagram.



H-R Diagram - Sun's Evolutionary Track

Figure 7