Passage V

A projectile is any object that is thrown or otherwise projected into the air. Once in the air, the only force assumed to be acting on the projectile is gravity. The effect of air resistance is assumed to be negligible. The path followed by a projectile is the trajectory.

A student performs a series of experiments using a spring launch (see Figure 3).

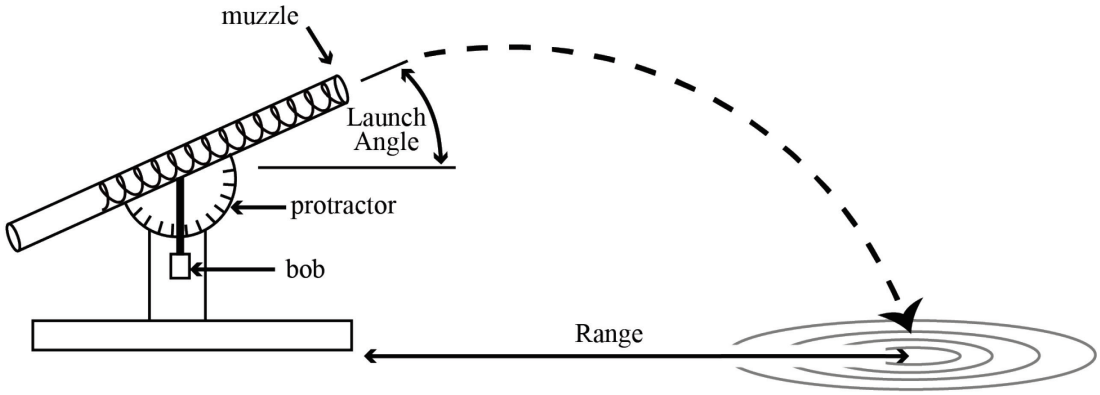

Figure 3

Experiment 1

The student launched the projectile at various angles, using the protractor to measure the angle degree, while the muzzle velocity of the projectile was held constant at 10.0 meters per second (m/s). Both the spring launch and the point of impact of the projectile were at ground level. The horizontal distance covered, or range, was measured. The results are given in Table 4.

Table 4

Launch Angle (degrees above horizontal)	Range (m)
10°	3.5
20°	6.6
30°	8.8
45°	10.2
60°	8.8
70°	6.6
80°	3.5

Experiment 2

In a second experiment, the student varied the muzzle velocity while keeping the angle of launch constant at 45°. The results are given in Table 5.

Table 5	
Muzzle Velocity (m/s)	Range (m)
10	10.2
15	23.0
20	40.8
25	63.8

Experiment 3

The student launched projectiles with the spring launch positioned at different heights above the ground while keeping the angle of launch at 45° and the muzzle velocity at 10 m/s. The range was measured horizontally from a point at ground level directly below the spring launch to the point of impact at ground level. The results are given in Table 6.

Table 6	
Height above ground (m)	Range (m)
1	11.1
2	11.9
3	12.6
4	13.3

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.

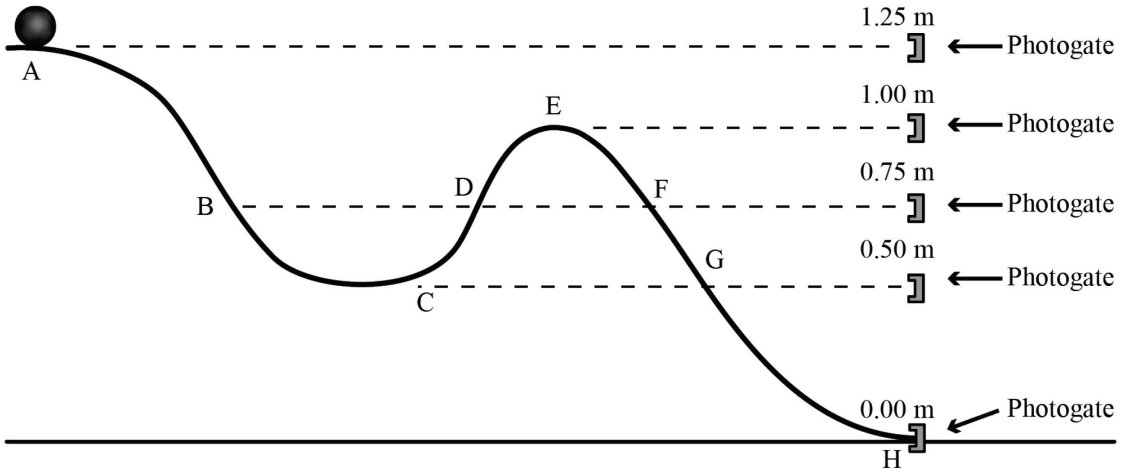

Figure 4

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.

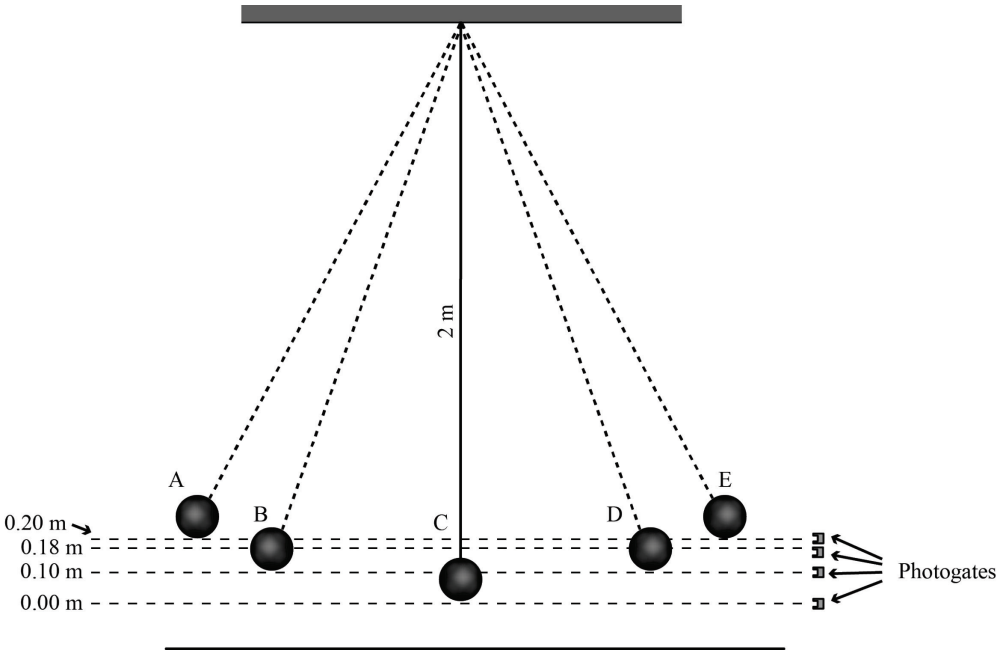

Figure 5

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