

Can waves be created with Yoga poses? (How to Apply Physics at Home during COVID time)

Yadi Liu

BHCC, Science and Engineering Department, Boston, MA, USA

Dipti Sharma

BHCC, Science and Engineering Department, Boston, MA, USA

ABSTRACT

It is always good to see how Physics can be applied in real-world applications and in everyday life activities. This experimental work shows the application of Physics in Yoga. Yoga is a group of exercises that are performed physically, mentally, and spiritually which originated in ancient India. Yoga is a good combination of Arts, Sciences, and Philosophy. Today, the entire world is following Yoga as a set of exercises in the form of poses to keep their body healthy, calm, and happy. Have you ever thought that the human body can follow circular motion? Let's think about it. If you notice and look at your own body parts, you will find that most of the parts of the human body are connected to one end and free to another end, for example, a finger, an arm, a leg, head, hair, etc. Based on the Physical concept of circular motion, any object can move in the circular motion or follow part of the circle if it is connected to one end and free to the other end and given the required radial acceleration to move. This is an honor project conducted as hands on activities at home during COVID time during spring 2021 semester. It reports that how waves can be formed using yoga poses following Physical concepts of circular motion and other linear motion. It also shows how Physics can be applied as hands on activities with Yoga and the concept of Physics were used during COVID time.

Keywords: Physics, Waves, Yoga, Exercises, Body movement, Speed, Energy, Work, Momentum, Interdisciplinary project, Honor Project, Application of Physics concepts in daily life, Hands on Activity performed at home during COVID!

INTRODUCTION

Physics as the natural science "is one the most fundamental scientific disciplines, and its main goal is to understand how the universe behaves" [1]. There are many branches existing in physics both macro and micro, such as mechanics, quantum, electromagnetism, thermodynamics, nuclear, and so on. By applying the rules and concepts of physics, people are able to learn and predict what's happening in our daily life.

Yoga as "one of the systems of orthodox Hindu philosophy" [2], originated in ancient India thousands of years ago. The word yoga "is derived from a Sanskrit word 'Yoj' which means union or join" [3]. Thus, yoga refers to uniting the external body and internal mind in order to approach a balanced being. According to the Yoga Sutras from the Indian scholar Patanjali, yoga contains eight "limbs" Yama (restraints), Niyama (observances), Asana (posture), Pranayama (breath control), Pratyahara (withdrawal of the senses), Dharana (concentration), Dhyana

(meditation) and Samadhi (pure contemplation) [4]. Nowadays, more and more people start to recognize and credit yoga as a healthy lifestyle. Although modern yoga posture or asana has developed into various forms and schools, the ancient wisdom and its essence are in succession, which is “an anaerobic regimen combining stretching and contortion with breathing techniques and mental exercises” [5]. Hatha yoga is the most popular and commonly practiced worldwide form of yoga [6]. It “places special emphasis on physical postures, which are integrated with breath control and meditation” [6]. Regular Hatha yoga practice is benefited in maintaining our body, mind, and spirit balanced and connected.

Yoga is deeply linked to quantum physics since our body same as another physical object is made of atoms and subatomic particles. So, Pranayama and Dhyana of yoga that is breath, meditation, and concentration are generating “contracted energy swirling around in vast amounts of empty space” [7]. Nevertheless, matter and energy are not independent in the physical world, which is exactly the connection of mind and body in yoga. “Quarks as the packets of energy have shown us that everything in the physical world can be conceived as essential energy” [8], which furthers the unitary and continuum of matter and energy. That’s how yoga practice not only enhances physical health but also provides pure bliss to maintain consciousness over the mind. The scientific understanding of “the universe as a whole” [9] provides a tight junction between the state of being and inner consciousness. As for the linkage between macro physics and quantum physics, yoga asana practice manages to soothe our mind and culminates in the tranquility of inner space as well.

“In physics, oscillation that is propagated from a source” [10]. Wave is fostered as the propagation spread from one place to another in a constant and systematized manner. Yoga asana “in combination with pranayama, causing energy to flow without obstruction and ensuring its even distribution through the body” [6]. In general, yoga asana allows energy to flow unimpeded and evenly in and out of the body. The simple, repetitive, and rhythmic movement of each yoga asana produces waves. “In the simplest waves, the disturbance oscillates periodically with a fixed frequency and wavelength” [11]. Wavelength is measured by the distance between the peaks (or troughs) of continuous waves. Wave frequency is the number of waves generated in a given time. The wave period is the time it takes for the wave to oscillate for one complete period. The maximum value of crest height or trough depth is the amplitude of the wave [10]. The properties of each distinct wave are yielded from diverse yoga poses.

This project will discuss in detail the connection between macro physics and the third “limb” yoga asana. How macro physics such as speed, force, kinetic energy, momentum, and jerk are present in every yoga movement will be examined. And how does the repeating yoga pose involve circular motions and the created waves forms will be exhibited. Ten yoga poses will be illustrated, and the calculated data will be compared. The results of the connection between physics and each yoga pose will be presented and discussed. (All of the poses illustrated later in this project are derived from Hatha yoga).

MATERIALS

Self-body, yoga mat, ruler, tape measure, weight scale, stop-watch, calculator, and laptop. A total of 10 yoga poses was picked to perform to observe their effects to find Physics behind them.

Pose No.	1	2	3	4	5
Pose Name	Cactus Arm	Head Rotation	Shoulder Rotation	Standing Side Bend	Bean Pulverizing
Pose No.	6	7	8	9	10
Pose Name	Butterfly	Leg Lifting	Cobra	Upper Facing Dog	Bicycle

THEORY

Theories applied were from both General Physics I and Physics II [12-13]. Theories from Physics I are Newton's second law of motion, kinetic energy, and momentum. Theories from Physics II are simple harmonic motion and waves. Simple harmonic motion is a special type of vibratory motion, and its restoring force is proportional to the displacement from equilibrium. A wave can be described as a disturbance that travels through a medium, transporting energy from one location to another without transporting matter. Waves have properties of intensity, wavelength, frequency, and amplitude. The theoretical formulas are using here where the meaning of each symbol are T = Time period, L = length of the body part used in poses, g = gravity of Earth, f = frequency of the movement, w = angular speed, A = amplitude of the movement, v = maximum possible speed of the movement, a = acceleration during movement, j = jerk in the movement, F = radial force required and used in the movement, K = kinetic energy of the body part in the movement, U = potential energy of the body part in the movement, Y = equation of the wave followed for each pose.

Equations used:

$$T = 2\pi\sqrt{L/g};$$

$$f = 1/T;$$

$$w = 2\pi f;$$

$$v = A\omega;$$

$$a = A\omega^2;$$

$$j = A\omega^3;$$

$$F = am;$$

$$K = 1/2mv^2;$$

$$U = mv;$$

$$Y(t) = A \sin (\omega t).$$

RESULTS AND CALCULATIONS

Pose 1: Cactus Arm Pose

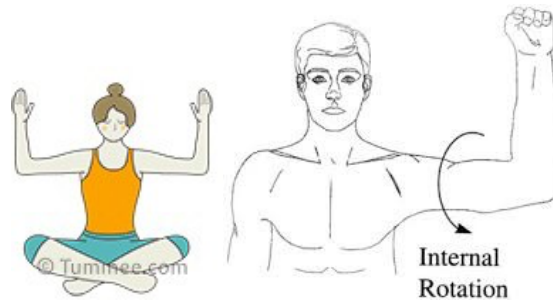


Figure 1 Cactus Arm [14 & 15]

Table 1-1 Raw data

Description: Forearms with hands weight: $(1.38\% + 0.56\%) \times 2 = 3.88\%$ of total body weight 48 kg
 $*3.88/100 = 1.86 \text{ kg}$ [16]

	Length forearm (m)	Weight forearm (kg)	n	t (s)				
	0.43	1.86	5	6.56	6.75	6.89	6.23	6.10
				Average: 6.51				
t exp	1.30 s							
t th	1.31 s							
% error	0.76 %							

Table 1-2 Calculated data:

	Experimental data
f (Hz)	0.77
ω (rad/s)	4.84
A (m)	0.43
v (m/s)	2.08
a (m/s ²)	10.07
j (m/s ³)	48.75
F (N)	18.73
KE (J)	4.02
P (kg*m/s)	3.87

CALCULATION

Example for pose 1: other poses will follow the same procedure for calculations:

$$t_{\text{exp}} = t/5 = 1.30\text{s}$$

$$t_{\text{th}} = 2 \pi \sqrt{(L/g)} = 2 \pi \sqrt{(0.43\text{m}/9.81 \text{ m/s}^2)} = 1.31\text{s}$$

$$\begin{aligned} \% \text{ error} &= [(t_{th} - t_{exp})/t_{th}] * 100 = 0.76 \% \quad f_{exp} = 1/t = 0.77 \text{ Hz} \\ \omega_{exp} &= 2 \pi f = 4.84 \text{ rad/s} \quad A = 0.43 \text{ m} \\ v &= A \omega = 0.43 * 4.84 = 2.08 \text{ m/s} \\ a &= A \omega^2 = 10.07 \text{ m/s}^2 \quad j = A \omega^3 = 48.75 \text{ m/s}^3 \\ F &= a m = 10.07 \text{ m/s}^2 * 1.86 \text{ kg} = 18.73 \text{ N} \quad \text{Kinetic energy (KE)} = 1/2 m v^2 \text{ (J)} = 4.02 \text{ J} \\ \text{Momentum (P)} &= m v \text{ (kg*m/s)} = 1.86 \text{ kg} * 1.93 \text{ m/s} = 3.87 \text{ kg*m/s} \end{aligned}$$

Pose 2: Head Rotation Pose

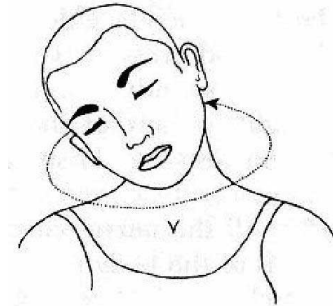


Figure 2 Head Rotation [17]

Table 2-1 Raw data

Head and neck weight: 8.20 % of total body weight 48 kg * 8.20% / 100 = 3.94 kg [16]

Length neck and head (m)	Weight (kg)	n	t (s)				
0.29	3.94	5	5.46	5.90	6.19	6.33	5.91
			Average: 5.96				

t exp	1.19 s
t th	1.08 s
% error	10.2 %

Table 2-2 Calculated data:

	Experimental data
f (Hz)	0.840
ω (rad/s)	5.28
A (m)	0.29
v (m/s)	1.53
a (m/s ²)	8.08
j (m/s ³)	42.69
F (N)	31.84
KE (J)	4.61
P (kg*m/s)	6.03

CALCULATION

$$t_{exp} = t/5 = 1.19 \text{ s}$$

$$t_{th} = 2\pi\sqrt{L/g} = 2\pi\sqrt{(0.29\text{m}/9.81 \text{ m/s}^2)} = 1.08$$

$$\% \text{ error} = [(t_{th} - t_{exp})/t_{th}] * 100 = 10.2 \% \quad f_{exp} = 1/t = 0.840 \text{ Hz}$$

$$\omega_{exp} = 2\pi f = 5.28 \text{ rad/s} \quad A = 0.29 \text{ m}$$

$$v = A\omega = 0.43 * 4.48 = 1.53 \text{ m/s}$$

$$a = A\omega^2 = 8.08 \text{ m/s}^2 \quad j = A\omega^3 = 42.69 \text{ m/s}^3$$

$$F = a m = 8.08 * 3.94\text{kg} = 31.84 \text{ N}$$

$$\text{Kinetic energy (KE)} = 1/2mv^2 \text{ (J)} = 4.61 \text{ J}$$

$$\text{Momentum (P)} = mv \text{ (kg*m/s)} = 3.94 \text{ kg} * 1.53 \text{ m/s} = 6.03 \text{ kg*m/s}$$

Pose 3: Shoulder Rotation Pose**Figure 3 Shoulder Rotation [18]****Table 3-1 Raw data**

Full arms weight: 4.49% x2 = 8.98% of total body weight 48kg [16]

$$*8.98/100 = 4.31 \text{ kg}$$

	Length upper arm (m)	Weight (kg)	n	t (s)				
	0.28	4.31	5	5.33	5.52	5.59	5.12	5.25
				Average: 5.36				
t exp	1.07 s							
t th	1.06 s							
% error	0.94 %							

Table 3-2 Calculated data:

	Experimental data
f (Hz)	0.93
ω (rad/s)	5.84
A (m)	0.28
v (m/s)	1.64
a (m/s ²)	9.55
j (m/s ³)	55.78
F (N)	41.07
KE (J)	5.80
P (kg*m/s)	7.07

CALCULATION

$$t_{exp} = t/5 = 1.07 \text{ s}$$

$$t_{th} = 2 \pi \sqrt{L/g} = 2 \pi \sqrt{(0.28\text{m}/9.81 \text{ m/s}^2)} = 1.06 \text{ s}$$

$$\% \text{ error} = [(t_{th} - t_{exp}) / t_{th}] * 100 = 0.94 \% \quad f_{exp} = 1 / t = 0.93 \text{ Hz}$$

$$\omega_{exp} = 2 \pi f = 5.84 \text{ rad/s} \quad A = 0.28 \text{ m}$$

$$v = A \omega = 0.28 * 5.84 = 1.64 \text{ m/s}$$

$$a = A \omega^2 = 9.55 \text{ m/s}^2 \quad j = A \omega^3 = 55.78 \text{ m/s}^3$$

$$F = a m = 9.55 * 4.31 \text{ kg} = 41.07 \text{ N}$$

$$\text{Kinetic energy (KE)} = 1/2 mv^2 \text{ (J)} = 5.80 \text{ J}$$

$$\text{Momentum (P)} = mv \text{ (kg*m/s)} = 4.31 \text{ kg} * 1.64 \text{ m/s} = 7.07 \text{ kg*m/s}$$

Pose 4: Standing Side Bend Pose

Yoga Sequence Builder



Figure 4 Standing Side Bend [19]

Table 4-1 Raw data

Full arms + head + trunk weight: $2 * 4.49\% + 6.68\% + 42.58\% = 58.24\%$ of total body weight 48kg
 $* 58.24 / 100 = 27.96 \text{ kg}$ [16]

	Length (m)	Weight (kg)	n	t (s)				
	1.11	27.96	5	11.09	10.18	10.56	10.79	10.34
				Average: 10.59				
t exp	2.12 s							
t th	2.11 s							
% error	0.47 %							

Table 4-2 Calculated data:

	Experimental data
f (Hz)	0.47
ω (rad/s)	2.95
A (m)	1.11
v (m/s)	3.27
a (m/s ²)	9.65
j (m/s ³)	28.50
F (N)	270.09
KE (J)	149.49
P (kg*m/s)	91.43

CALCULATION

$$t_{\text{exp}} = t/5 = 2.12 \text{ s}$$

$$t_{\text{th}} = 2\pi\sqrt{L/g} = 2\pi\sqrt{(1.11\text{m}/9.81 \text{ m/s}^2)} = 2.11 \text{ s}$$

$$\% \text{ error} = [(t_{\text{th}} - t_{\text{exp}})/t_{\text{th}}] * 100 = 0.47 \% \quad f_{\text{exp}} = 1/t = 0.47 \text{ Hz}$$

$$\omega_{\text{exp}} = 2\pi f = 2.95 \text{ rad/s} \quad A = 1.11 \text{ m}$$

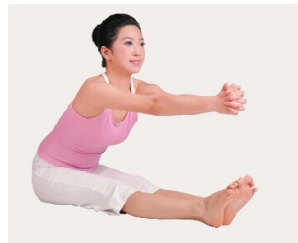
$$v = A\omega = 1.11 * 2.95 = 3.27 \text{ m/s}$$

$$a = A\omega^2 = 9.66 \text{ m/s}^2 \quad j = A\omega^3 = 28.50 \text{ m/s}^3$$

$$F = a m = 9.65 * 27.96 \text{ kg} = 270.09 \text{ N}$$

$$\text{Kinetic energy (KE)} = 1/2 mv^2 \text{ (J)} = 149.49 \text{ J}$$

$$\text{Momentum (P)} = mv \text{ (kg*m/s)} = 27.96 \text{ kg} * 3.27 \text{ m/s} = 91.43 \text{ kg*m/s}$$

Pose 5: Bean Pulverizing Pose**Figure 5 Bean Pulverizing [20]****Table 5-1 Raw data**

Full arms + head + truck weight: $2*4.49\% + 6.68\% + 42.58\% = 53.75\%$ of total body weight 48kg
 $*53.75/100 = 27.96 \text{ kg [16]}$

	Length (m)	Weight (kg)	n	t (s)				
	1.11	27.96	5	10.59	10.96	10.89	10.39	10.01
				Average: 10.57				
t exp	2.11 s							
t th	2.11 s							
% error	0 %							

Table 5-2 Calculated data:

	Experimental data
f (Hz)	0.47
ω (rad/s)	2.95
A (m)	1.11
v (m/s)	3.27
a (m/s ²)	9.66
j (m/s ³)	28.50
F (N)	270.09
KE (J)	149.49
P (kg*m/s)	91.43

CALCULATION

$$t_{\text{exp}} = t/5 = 2.11\text{s}$$

$$t_{\text{th}} = 2\pi\sqrt{L/g} = 2\pi\sqrt{(1.11\text{m}/9.81\text{ m/s}^2)} = 2.11\text{ s}$$

$$\% \text{ error} = [(t_{\text{th}} - t_{\text{exp}})/t_{\text{th}}] * 100 = 0\% \quad f_{\text{exp}} = 1/t = 0.47\text{ Hz}$$

$$\omega_{\text{exp}} = 2\pi f = 2.95\text{ rad/s} \quad A = 1.11\text{ m}$$

$$v = A\omega = 1.11 * 2.95 = 3.27\text{ m/s}$$

$$a = A\omega^2 = 9.66\text{ m/s}^2 \quad j = A\omega^3 = 28.50\text{ m/s}^3$$

$$F = am = 9.66\text{ m/s}^2 * 27.96\text{ kg} = 270.09\text{ N} \quad \text{Kinetic energy (KE)} = 1/2mv^2\text{ (J)} = 149.49\text{ J}$$

$$\text{Momentum (P)} = mv\text{ (kg*m/s)} = 27.96\text{ kg} * 3.27\text{ m/s} = 91.43\text{ kg*m/s}$$

Pose 6: Butterfly Pose



Figure 6 Butterfly [21]

Table 6-1 Raw data

Thighs + shanks + feet weight: (14.78%+ 4.81%+1.29%) x2 = 20.88%x2 = 41.76% of total body weight 48kg *41.76/100 = 20.04 kg [16]

Experiment 1	Length (m)	Weight (kg)	n	t (s)				
	0.09	20.04	5	2.66	2.96	2.87	2.79	3.01
				Average: 2.86				
t exp	0.57 s							
t th	0.60 s							
% error	5.00 %							

Experiment 2	Length (m)	Weight (kg)	n	t (s)				
	0.44	20.04	5	6.59	6.95	6.43	6.56	6.50
				Average: 6.61				
t exp	1.32 s							
t th	1.33 s							
% error	0.75 %							

Table 6-2 Calculated data:

	Experimental data 1	Experimental data 2
f (Hz)	1.75	0.76
ω (rad/s)	11.02	4.76
A (m)	0.09	
r (m)		0.44
v (m/s)	$v = A \omega = 0.99$	$v = r \omega = 2.09$
a (m/s ²)	10.93	9.97
j (m/s ³)	120.44	47.45
F (N)	219.04	199.80
KE (J)	9.82	43.77
P (kg*m/s)	19.84	41.88

CALCULATION

$$t_{\text{exp}} = t/5 = 0.57 \text{ s}$$

$$t_{\text{th}} = 2 \pi \sqrt{L/g} = 2 \pi \sqrt{0.09 / 9.81 \text{ m/s}^2} = 0.60 \text{ s}$$

$$\% \text{ error} = [(t_{\text{th}} - t_{\text{exp}}) / t_{\text{th}}] * 100 = 5.00 \% \quad f_{\text{exp}} = 1 / t = 1.75 \text{ Hz}$$

$$\omega_{\text{exp}} = 2 \pi f = 11.02 \text{ rad/s} \quad A = 0.09 \text{ m}$$

$$v = A \omega = 0.09 * 11.02 = 0.99 \text{ m/s}$$

$$a = A \omega^2 = 10.93 \text{ m/s}^2 \quad j = A \omega^3 = 120.44 \text{ m/s}^3$$

$$F = a m = 10.93 * 20.04 \text{ kg} = 219.04 \text{ N}$$

$$\text{Kinetic energy (KE)} = 1/2 m v^2 \text{ (J)} = 9.82 \text{ J}$$

$$\text{Momentum (P)} = m v \text{ (kg*m/s)} = 20.04 \text{ kg} * 0.99 \text{ m/s} = 19.84 \text{ kg*m/s}$$

$$t_{\text{exp}} = t/5 = 1.32 \text{ s}$$

$$t_{\text{th}} = 2 \pi \sqrt{L/g} = 2 \pi \sqrt{0.44 / 9.81 \text{ m/s}^2} = 1.33 \text{ s}$$

$$\% \text{ error} = [(t_{\text{th}} - t_{\text{exp}}) / t_{\text{th}}] * 100 = 0.75 \% \quad f_{\text{exp}} = 1 / t = 0.76 \text{ Hz}$$

$$\omega_{\text{exp}} = 2 \pi f = 4.76 \text{ rad/s}$$

$$\mathbf{r \text{ (half of leg's length)} = 0.44 \text{ m}}$$

$$\mathbf{v^2 = r \omega = 0.44 * 4.76 \text{ rad/s} = 2.09 \text{ m/s}}$$

$$a = r \omega^2 = 9.97 \text{ j} = r \omega^3 = 47.45$$

$$F = a m = 9.97 * 20.04 \text{ kg} = 199.80 \text{ N} \quad \text{KE} = 1/2 m v^2 \text{ (J)} = 43.77 \text{ J}$$

$$P = 20.04 \text{ kg} * 2.09 \text{ m/s} = 41.88 \text{ kg*m/s}$$

Pose 7: Leg Lifting Pose



Figure 7 Leg Lifting [22]

Table 7-1 Raw data For one leg

Thighs + shanks + feet weight: $(14.78\% + 4.81\% + 1.29\%) \times 2 = 20.88\% \times 2 = 41.76\%$ of total body weight $48\text{kg} \times 41.76/100 = 20.04\text{ kg}$ [16]

	Length one leg and the tilt foot (m)	Weight (kg)	n	t (s)				
	0.98	20.04	5	9.88	9.96	10.22	9.20	10.48
				Average: 9.95				
t exp	1.99 s							
t th	1.98 s							
% error	0.51 %							

Table 7-2 Calculated data:

	Experimental data
f (Hz)	0.50
ω (rad/s)	3.14
A (m)	0.98
v (m/s)	3.08
a (m/s ²)	9.66
j (m/s ³)	30.34
F (N)	193.59
KE (J)	95.05
P (kg*m/s)	61.72

CALCULATION

$$t_{\text{exp}} = t/5 = 1.99 \text{ s}$$

$$t_{\text{th}} = 2\pi \sqrt{L/g} = 2\pi \sqrt{(0.98\text{m}/9.81 \text{ m/s}^2)} = 1.98 \text{ s}$$

$$\% \text{ error} = [(t_{\text{th}} - t_{\text{exp}})/t_{\text{th}}] \times 100 = 0.51 \% \quad f_{\text{exp}} = 1/t = 0.50 \text{ Hz}$$

$$\omega_{\text{exp}} = 2\pi f = 3.14 \text{ rad/s}$$

$$A = 0.98 \text{ m}$$

$$v = A \omega = 0.98 \text{ m} \cdot 3.14 = 3.08 \text{ m/s} \quad a = A \omega^2 = 9.66 \text{ m/s}^2$$

$$j = A \omega^3 = 30.34 \text{ m/s}^3$$

$$F = a m = 9.66 \cdot 20.04 \text{ kg} = 193.59 \text{ N}$$

$$\text{Kinetic energy (KE)} = 1/2 m v^2 \text{ (J)} = 95.05 \text{ J}$$

$$\text{Momentum (P)} = m v \text{ (kg} \cdot \text{m/s)} = 20.04 \text{ kg} \cdot 3.08 \text{ m/s} = 61.72 \text{ kg} \cdot \text{m/s}$$

Pose 8: Cobra Pose

Mass is whole upper body arm *2

Do next to the wall (use sticky note to mark the starting and ending point, then measure vertically - A).

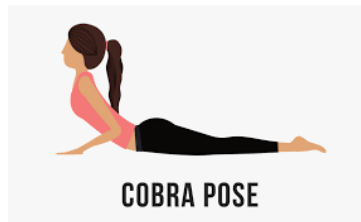


Figure 8 Cobra [23]

Table 8-1 Raw data

Full arms + head + truck weight: $2 \cdot 4.49\% + 6.68\% + 42.58\% = 53.75\%$ of total body weight 48kg
 $\cdot 53.75/100 = 27.96 \text{ kg}$ [16]

	Length (m)	Weight (kg)	n	t (s)				
	0.31	27.96	5	6.16	5.69	5.64	5.21	5.26
				Average: 9.99				
t exp	1.12 s							
t th	1.12 s							
% error	0 %							

Table 8-2 Calculated data:

	Experimental data
f (Hz)	0.89
ω (rad/s)	5.59
A (m)	0.31
v (m/s)	1.73
a (m/s ²)	9.69
j (m/s ³)	54.15
F (N)	270.93
KE (J)	41.84
P (kg·m/s)	48.37

CALCULATION

$$t_{exp} = t/5 = 1.12 \text{ s}$$

$$t_{th} = 2\pi\sqrt{L/g} = 2\pi\sqrt{(0.31\text{m}/9.81 \text{ m/s}^2)} = 1.12 \text{ s}$$

$$\% \text{ error} = [(t_{th} - t_{exp}) / t_{th}] * 100 = 0 \% \quad f_{exp} = 1/t = 0.89 \text{ Hz}$$

$$\omega_{exp} = 2\pi f = 5.59 \text{ rad/s} \quad A = 0.31 \text{ m}$$

$$v = A\omega = 0.31 * 5.59 = 1.73 \text{ m/s}$$

$$a = A\omega^2 = 9.69 \text{ m/s}^2 \quad j = A\omega^3 = 54.15 \text{ m/s}^3$$

$$F = am = 9.69 \text{ m/s}^2 * 27.96 \text{ kg} = 270.93 \text{ N} \quad \text{Kinetic energy (KE)} = 1/2mv^2 \text{ (J)} = 41.84 \text{ J}$$

$$\text{Momentum (P)} = mv \text{ (kg*m/s)} = 27.96\text{kg} * 1.73 \text{ m/s} = 48.37 \text{ kg*m/s}$$

Pose 9: Upper Facing Dog Pose



Figure 9 Upper Facing Dog [24]

Table 9-1 Raw data

Full arms + head + truck weight: $2*4.49\% + 6.68\% + 42.58\% = 53.75\%$ of total body weight 48kg
 $*53.75/100 = 27.96 \text{ kg}$ [16]

	Length (m)	Weight (kg)	n	t (s)				
	0.63	27.96	5	7.95	7.68	8.07	8.18	7.70
				Average: 7.92				
t exp	1.58 s							
t th	1.59 s							
% error	0.63 %							

Table 9-2 Calculated data:

	Experimental data
f (Hz)	0.63
ω (rad/s)	3.96
A (m)	0.63
v (m/s)	2.49
a (m/s ²)	9.88
j (m/s ³)	39.12
F (N)	276.24
KE (J)	86.68
P (kg*m/s)	69.92

CALCULATION

$$t_{exp} = t/5 = 1.58 \text{ s}$$

$$t_{th} = 2\pi\sqrt{L/g} = 2\pi\sqrt{(0.63\text{m}/9.81\text{ m/s}^2)} = 1.59 \text{ s}$$

$$\% \text{ error} = [(t_{th} - t_{exp}) / t_{th}] * 100 = 0.63 \% \quad f_{exp} = 1/t = 0.63 \text{ Hz}$$

$$\omega_{exp} = 2\pi f = 3.96 \text{ rad/s} \quad A = 0.63 \text{ m}$$

$$v = A\omega = 0.63 * 3.96 = 2.49 \text{ m/s}$$

$$a = A\omega^2 = 9.88 \text{ m/s}^2 \quad j = A\omega^3 = 39.12 \text{ m/s}^3$$

$$F = a m = 9.88 \text{ m/s}^2 * 27.96 \text{ kg} = 276.24 \text{ N} \quad \text{Kinetic energy (KE)} = 1/2 mv^2 \text{ (J)} = 86.68 \text{ J}$$

$$\text{Momentum (P)} = mv \text{ (kg*m/s)} = 27.96 \text{ kg} * 2.49 \text{ m/s} = 69.62 \text{ kg*m/s}$$

Pose 10: Bicycle Pose

Yoga Sequence Builder

**Figure 10 Bicycle [25]****A = half of the leg Length is full leg Table 10-1 Raw data**

Thighs + shanks + feet weight: (14.78%+ 4.81%+1.29%) x 2 = 20.88% x2 = 41.76% of total body weight 48kg *41.76/100 = 20.04 kg [16]

Length (m)	Weight (kg)	n	t (s)				
0.98	20.04	5	10.48	9.53	9.92	9.15	10.78
			Average: 9.97				

t exp	1.99 s
t th	1.98 s
% error	0.51 %

Table 10-2 Calculated data:

	Experimental data
f (Hz)	0.50
ω (rad/s)	3.14
A (m)	0.55
v (m/s)	1.73
a (m/s ²)	5.42
j (m/s ³)	17.03
F (N)	108.62
KE (J)	29.99
P (kg*m/s)	34.67

CALCULATION

$$t_{\text{exp}} = t/5 = 1.99 \text{ s}$$

$$t_{\text{th}} = 2\pi\sqrt{L/g} = 2\pi\sqrt{(0.98\text{m}/9.81 \text{ m/s}^2)} = 1.98 \text{ s}$$

$$\% \text{ error} = [(t_{\text{th}} - t_{\text{exp}})/t_{\text{th}}] * 100 = 0.51 \% \quad f_{\text{exp}} = 1/t = 0.50 \text{ Hz}$$

$$\omega_{\text{exp}} = 2\pi f = 3.14 \text{ rad/s}$$

$$A = 0.55 \text{ m (half - shank + tilted foot)}$$

$$v = A\omega = 0.55 \text{ m} * 3.14 \text{ rad/s} = 1.73 \text{ m/s} \quad a = A\omega^2 = 5.42 \text{ m/s}^2$$

$$j = A\omega^3 = 17.03 \text{ m/s}^3$$

$$F = am = 5.42 * 20.04 \text{ kg} = 108.62 \text{ N}$$

$$\text{Kinetic energy (KE)} = 1/2mv^2 \text{ (J)} = 29.99 \text{ J}$$

$$\text{Momentum (P)} = mv \text{ (kg*m/s)} = 20.04 \text{ kg} * 1.97 \text{ m/s} = 34.67 \text{ kg*m/s}$$

Following the length and weight of the body parts in each yoga poses, from the recorded time period for each set of movements, the frequency, angular frequency, amplitude, speed, acceleration, jerk, force, kinetic energy, and momentum for each yoga pose would be calculated.

DISCUSSION

The concepts applied in this project were from both General Physics I and Physics II. Based on simple harmonic motion, with measured length and weight of each involved body part, the time periods of one oscillation of each yoga pose was calculated. The percent error between the theoretical and experimental time period was determined. The calculated speed, force, kinetic energy, momentum, and jerk of each pose were summarized below.

Table 11 Summary of Result

Pose No.	Pose Name	v (m/s)	F (N)	KE (J)	P (kg*m/s)	J (m/s ³)	t Percent Error (%)
1	Cactus Arm	2.08	18.73	4.02	3.87	48.75	0.76
2	Head Rotation	1.53	31.84	4.61	6.03	42.69	10.2
3	Shoulder Rotation	1.64	41.07	5.80	7.07	55.78	0.94
4	Standing Side Bend	3.27	270.09	149.49	91.43	28.50	0.47
5	Bean Pulverizing	3.27	270.09	149.49	91.43	28.50	0
6	Butterfly	2.09	199.80	43.77	41.88	47.45	0.75
7	Leg lifting	3.08	193.59	95.05	61.72	30.34	0.51
8	Cobra	1.73	270.93	41.84	48.37	54.15	0
9	Upper Facing Dog	2.49	276.24	86.68	69.62	39.12	0.63
10	Bicycle	1.73	108.62	29.99	34.67	17.03	0.51

v--- speed in m/s

F--- force in N

KE--- kinetic energy in J

P--- momentum in kg m/s

J--- jerk in m/s³

t percent error --- the percent error between theoretical and experimental time for one oscillation

According to the calculated data among these ten yoga poses, different poses created or required different speeds, forces, kinetic energy, momentum, and jerk. The results of Standing Side Bend and Bean Pulverizing were very close to each other because these two poses required the same length and weight of body parts. Both poses required arms to be raised along with ears. The length was measured from the hipbone to the figure tip, which was 1.11m. The mass was the whole upper trunk, head, and arms, which was 27.96 kg. Besides, Standing Side Bend and Bean Pulverizing had the same maximum speed to complete one oscillation, which was 3.27 s. The head Rotation pose had the minimum speed for completing one oscillation, which was 1.53 s. Upper Facing Dog had the maximum force of 276.24 N, and Cactus Arm pose had the minimum force of 18.73 N. The maximum kinetic energy required in both Standing Side Bend and Bean Pulverizing, which was 149.49 J. The minimum kinetic energy was required in the Cactus Arm pose, which was 4.02 J. The maximum momentum was in both Standing Side Bend and Bean Pulverizing as 91.43 kg*m/s. The minimum momentum was in Cactus Arm again, which was 3.87 kg*m/s. The smallest jerk was in pose Bicycle, which was 17.03 m/s³. The shoulder Rotation pose had the largest jerk, which was 55.78 m/s³.

Overall, the percent error among all tested poses between theoretical and experimental time for one oscillation was lower than 1%. Both Bean Pulverizing and Cobra got 0% in error, which was convincible. Based on the measured length of 1.11m to perform Bean Pulverizing, the calculated theoretical time period for one set of movements was 2.11s. The average experimental time period from 5 trails was 2.11s. There was a 0% difference between the theoretical and experimental values. Bean Pulverizing had the highest speed, kinetic energy, and momentum. Its force was relatively higher than most of the tested pose, which was 270.09

N. Its jerk was relatively low as 28.50 m/s^3 . Following the measured length of 0.31m to perform Cobra, the calculated theoretical time period for one set of movements was 1.12s. The average experimental time period from 5 trails was 1.12s. There was a 0% difference between the theoretical and experimental values. Cobra had the second-highest force as 270.93 N, and the second-highest jerk as 54.15 m/s^3 . The speed to perform Cobra was the same as Bicycle, which was 1.73s. However, the mass to do Cobra requiring the whole upper trunk, head, and arms, which was 27.96 kg. The mass to do Bicycle was involved with legs and feet, which was 20.04 kg. The mass of doing Cobra was higher than the mass in Bicycle, and that's why Cobra had higher force, kinetic energy, and momentum than Bicycle.

However, the percent error in Head Rotation between time periods for one circle of movement was recorded as 10.2%. Besides, Head Rotation had the lowest speed among the ten tested poses, which was 1.53 s. The reason is in reality fast head-spinning can lead to vertigo or light headaches as human beings. Thus, the time period to perform Head Rotation in real life would be higher than the theoretical time period. The speed to do Head Rotation in real life would be lower than the theoretical value. Head Rotation is one of the yoga poses that can't conduct entirely relying on mechanics. Besides, all data was personal, which was not performing on a standard scale. Thus, the results might vary among different people, since different people have different body types, exercise paces, and breath rhythms. Although Head Rotation had the minimum speed, it had higher force, kinetic energy, and momentum than Cactus Arm. Because the body parts needed to perform Head Rotation was head and neck, and the mass was 3.94 kg. The body part needed to do Cactus Arm was the forearm, and the mass was 1.86 kg. The mass in Head Rotation was more than two times higher than the mass in Cactus Arm. Moreover, the mass in Cactus Arm was the least among these ten poses, that's why it had the minimum force, kinetic energy, and momentum.

WAVE FORMS OF YOGA POSES

Following the Physics of waves, the data calculated for each Yoga pose were used to make waves. According to the measured amplitude, calculated time period, and angular frequency of one oscillation of each yoga pose, the wave forms of these ten poses were created as they were shown below. The equation of the wave for each Yoga pose is also written next to the wave form. The graphs of the waveforms are plotted amplitude (m) versus time (s). Amplitude (A) is defined as the maximum displacement from the mean position during oscillation and time is defined as the time taken in the movement.

These waveforms for each Yoga Pose can be seen below with the names of Yoga pose and with their wave equations. These waveforms are drawn to the scale and they are handmade showing originality created by the first author of the paper.

Pose 1: $Y(t) = 0.43\sin(4.84t)$

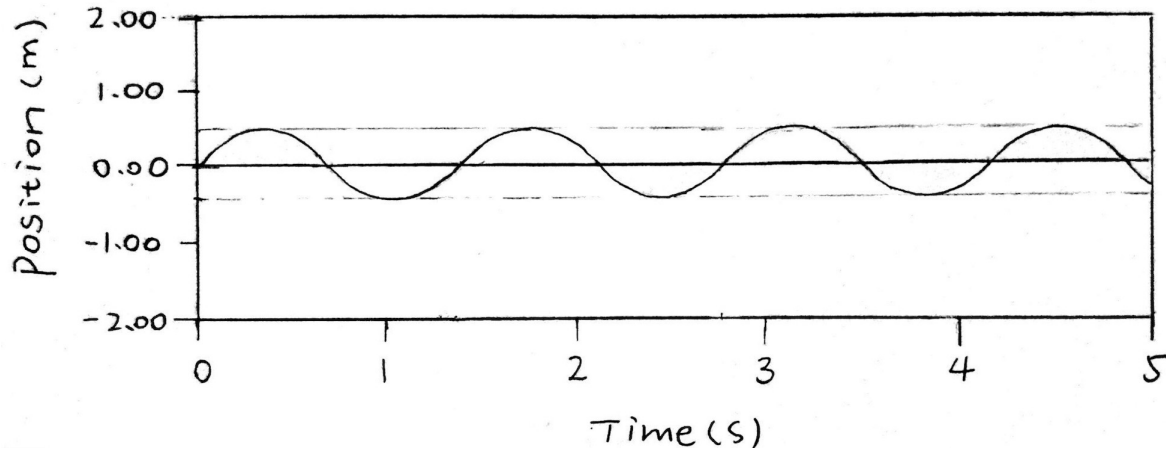


Figure 11 Wave Form of Pose 1

Pose 2: $Y(t) = 0.29\sin(5.28t)$

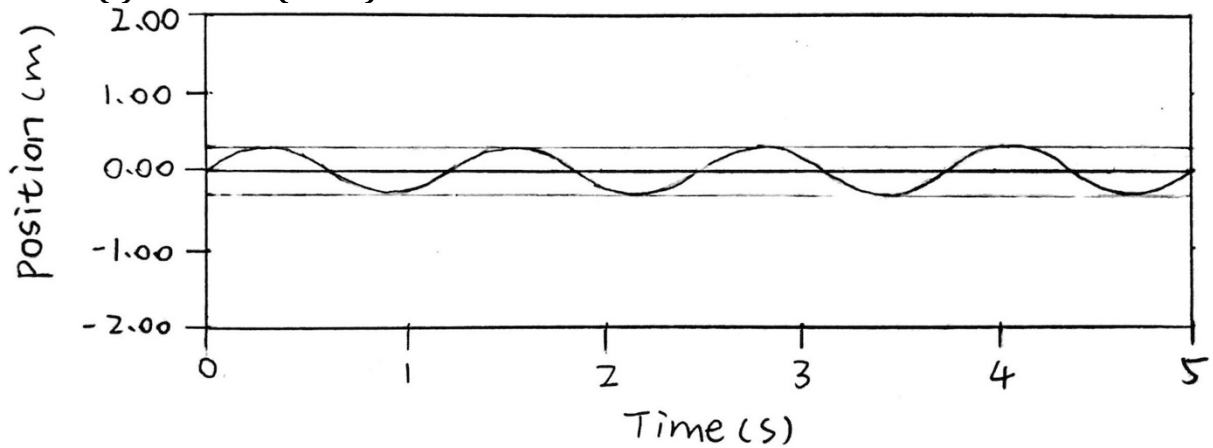


Figure 12 Wave Form of Pose 2

Pose 3: $Y(t) = 0.28\sin(5.84t)$

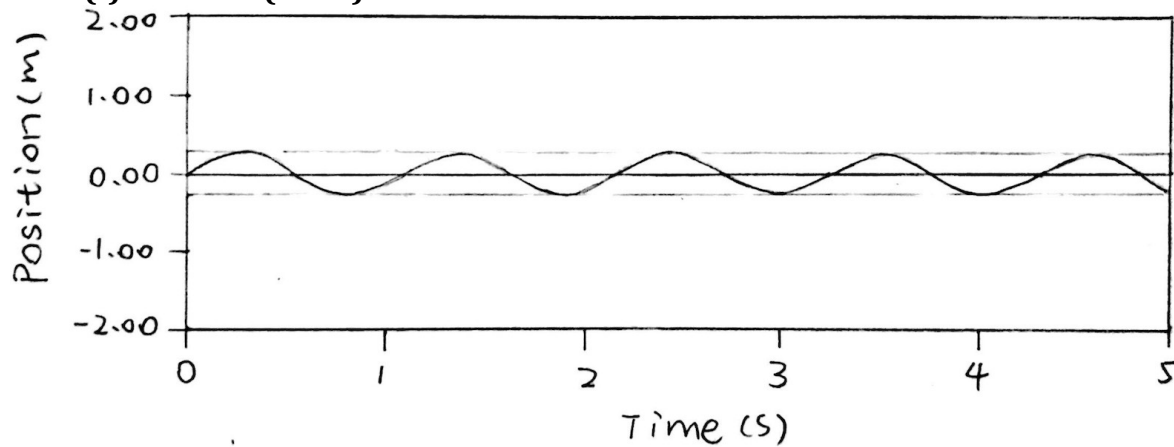


Figure 13 Wave Form of Pose 3

Pose 4: $Y(t) = 1.11\sin(2.95t)$

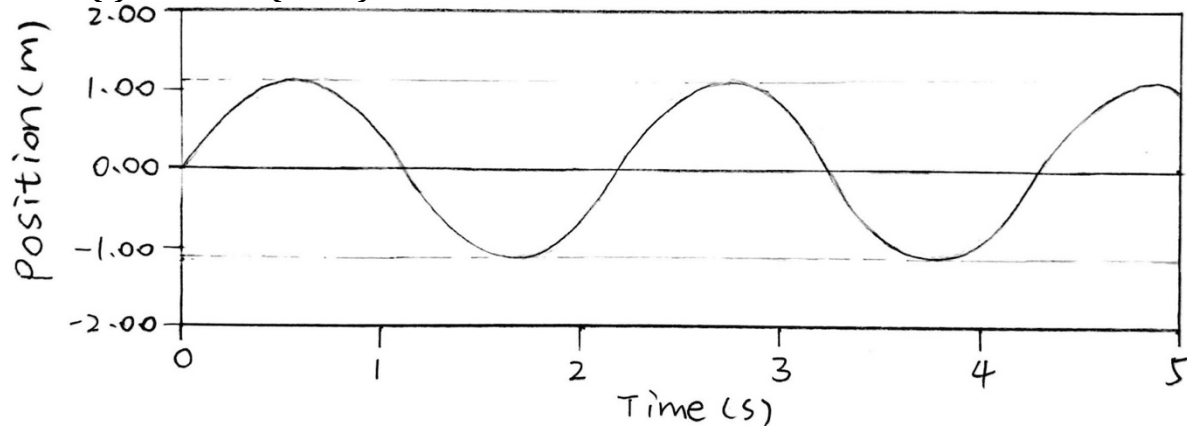


Figure 14 Wave Form of Pose 4

Pose 5: $Y(t) = 1.11\sin(2.95t)$

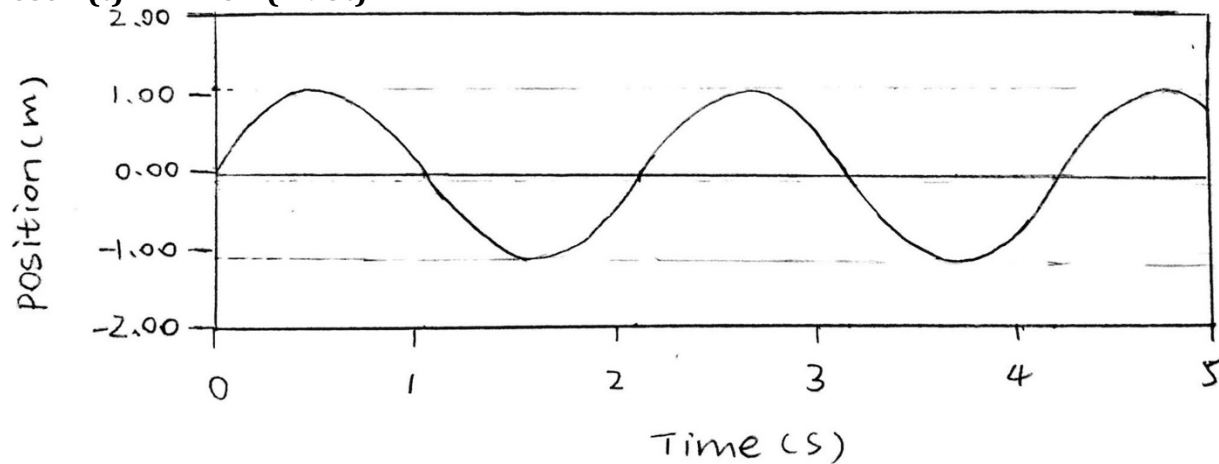


Figure 15 Wave Form of Pose 5

5:

Pose 6: $Y(t) = 0.44\sin(4.76t)$

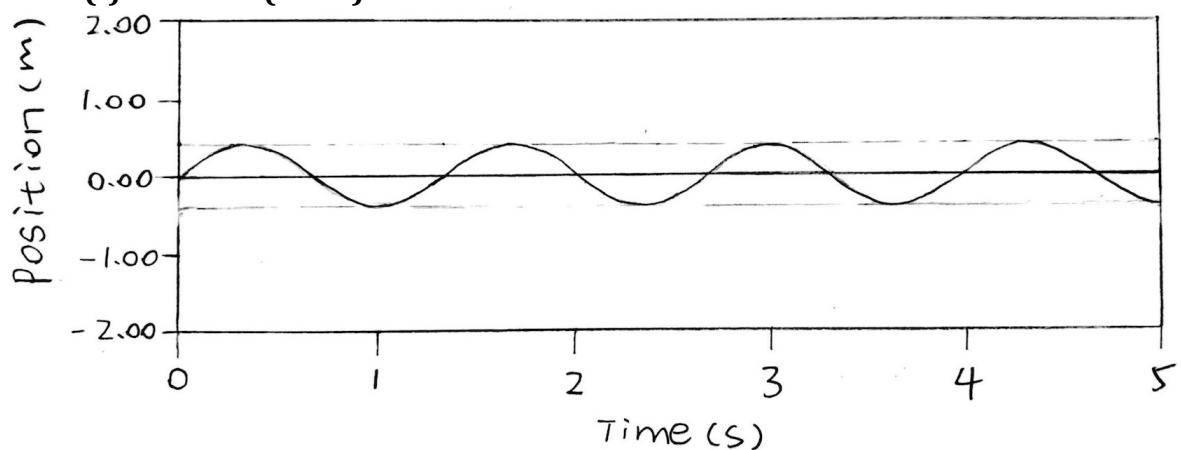


Figure 16 Wave Form of Pose 6

Pose 7: $Y(t) = 0.98\sin(3.14t)$

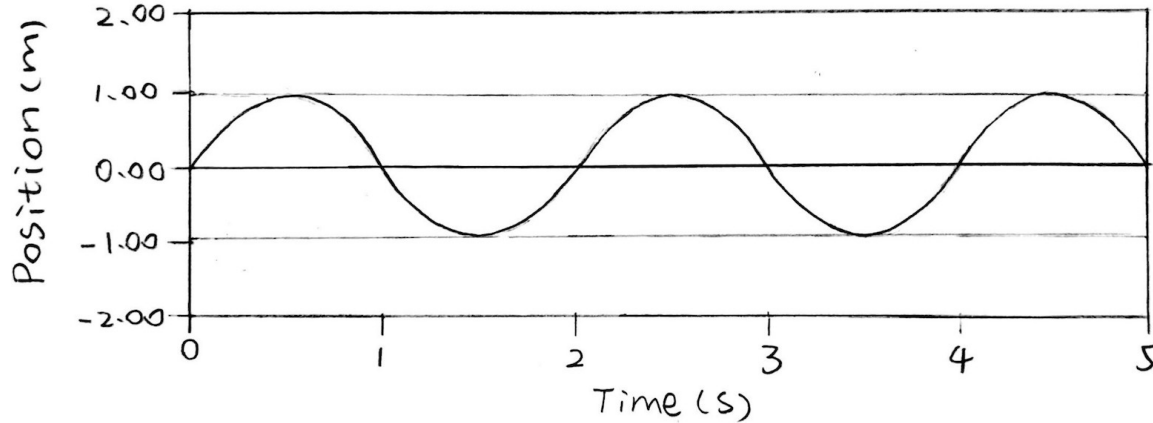


Figure 17 Wave Form of Pose 7

Pose 8: $Y(t) = 0.31\sin(5.59t)$

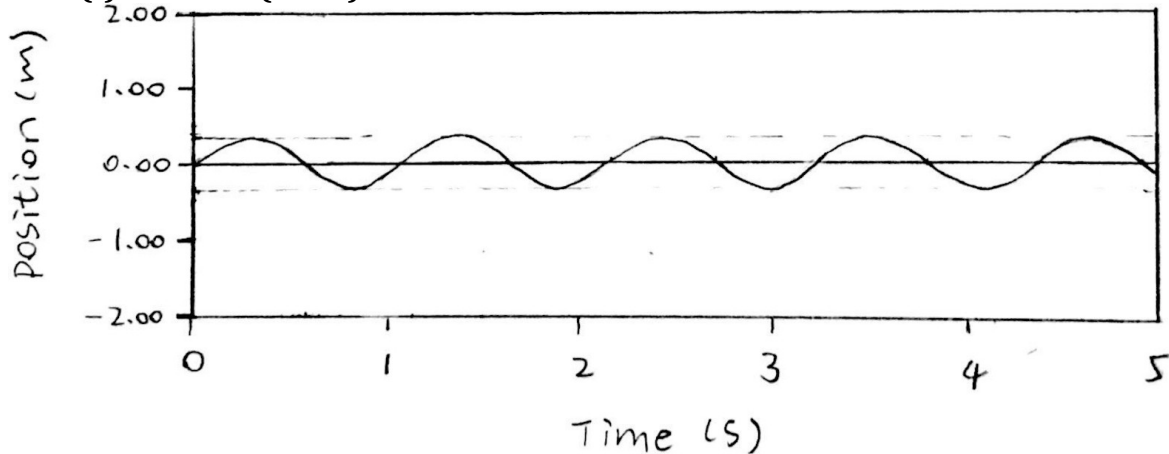


Figure 18 Wave Form of Pose 8

Pose 9: $Y(t) = 0.63\sin(3.96t)$

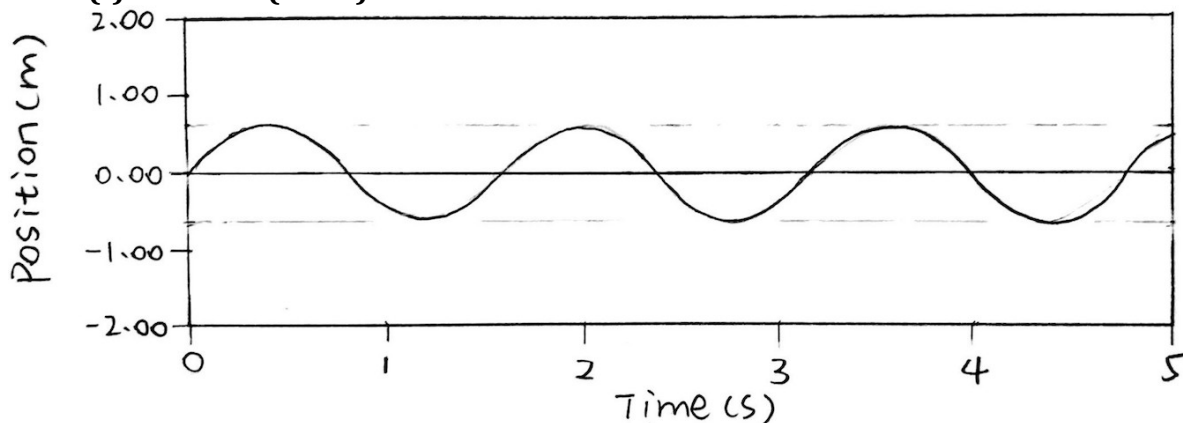


Figure 19 Wave Form of Pose 9

Pose 10: $Y(t) = 0.98\sin(3.14t)$

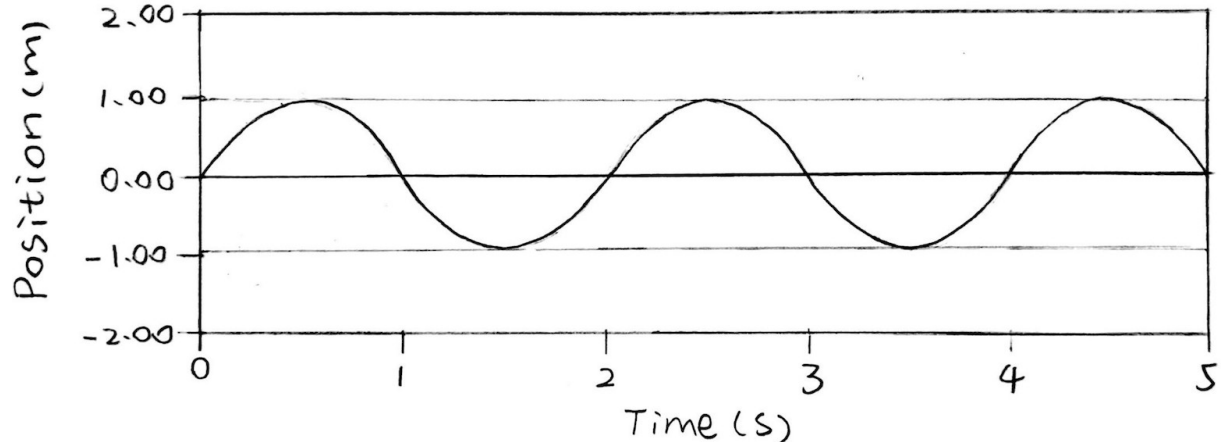


Figure 20 Wave Form of Pose 10

Yoga poses are involved in circular motions as well. Taking Bean Pulverizing and Cobra as examples, the graphs of waves were drawn based on the repeating movement. For Bean Pulverizing, following its time period 2.11s and is calculated amplitude 1.11m, the waves between time period and position could be created. Since angular frequency ω was calculated as 2.95 rad/s, the equation was $Y(t) = 1.11\sin(2.95t)$. For Cobra, following its time period 1.12s and is calculated amplitude 0.31m, the waves between time period and position were created. Since its angular frequency ω was calculated as 5.59 rad/s, the equation was $Y(t) = 0.31\sin(5.59t)$. The graphs of these yoga poses showed that the higher time period had lower angular frequency, and the lower time period had higher angular frequency. Time period and angular frequency were inversely proportional.

What's more, the waveforms illustrated that yoga is not only an exercise, it accompanied by a natural flow of breath and harmonic rhythm of repetition. The physical pace and peaceful inner space created the beautiful and coherent waves of our bodies.

CONCLUSION

Physics offered a scientific method to analyze the effectiveness of each yoga pose. Based on the results of ten tested yoga poses, Standing Side Bend and Bean Pulverizing had the highest speed (3.27s), highest kinetic energy (149.49J), and momentum (91.43 kg*m/s), because the total weight of the involved body parts in these two poses was higher, which was 27.96 kg. Cactus Arm had the lowest force (18.73N), lowest kinetic energy (4.02J), and momentum (3.87 kg*m/s), since there were fewer body parts involved in this pose. Though Head Rotation had the lowest speed (1.53s), since the mass involved in head rotation (3.94kg) was higher than the Cactus arm (1.86kg), its force, kinetic energy, and momentum were slightly higher. The percent error of time period in Bean Pulverizing and Cobra was 0%. The highest percent error of time period (10.2%) was in Head Rotation because in real life fast head spinning can lead to vertigo or light headache, so this pose should be recommended to perform slower than theoretical mechanics.

All in all, it is clear that yoga is massively linked to physics. The results presented the yoga poses had certain speed, force, kinetic energy, momentum, and jerk. Waves were created in repeating poses. The harmonic motion of yoga leads to relaxation, inner peace, and bliss.

Eventually, yoga is beneficial in mental and physical health. However, with different body parts involving, the results of force, kinetic energy, momentum would be different. In addition, though the percent errors among all tested poses were low, the data was collected on a personal scale, which could be biased.

It can be seen by this project work that Yoga poses create Waves and they follow concepts of circular motion, waves, and other linear parameters of Physics. The height of crest and depth of trough shows how high and low amplitude a Yoga pose can have whereas the frequency or the number of waves in the graph shows how fast or slow Yoga poses are formed. Finally, we are able to show that Waves can be generated with Yoga poses and Yoga poses follow Physics and Yoga is one of the good applications in the real world that shows a good example of using Physics in everyday life!

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