SCHEME FOR PHYSICS Internal Assessment Test 2 – June 2025

Sub:	Physics for CSE stream				Sub Code:	BPHYS102	Branch:	CSE-CSDS-ECE
Date:	18/6/2025	Duration:	90 mins	Max Marks: 50	Sem/Sec:	II Sem / I to H		OBE

Answer any FIVE FULL Questions

Given: $c = 3 \times 10^{8}$ m/s; $h = 6.625 \times 10^{-34}$Js; $k = 1.38 \times 10^{-23}$ J/K; $m_e = 9.1 \times 10^{-31}$kg; $e = 1.6 \times 10^{-19}$C

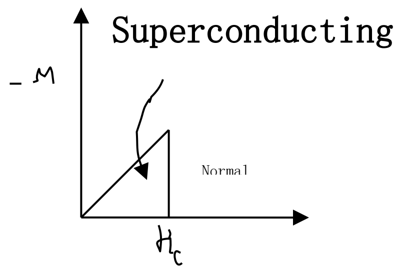
		MARKS	CO	RBT
1 (a)	4 differences :4 mark Diagram: 2 mark	[06]	CO1	L2
(b)	Formula - 1Mark Calculation -2 Mark Accurate result - 1 mark	[04]	C01	L3
2 (a)	3 figures : 3 mark Explanation of 3 concepts : 3 mark	[06]	C01	L2
(b)	Formula - 1Mark Calculation -2 Mark Accurate result - 1 mark	[04]	C01	L3
3 (a)	Definition : 1 mark Explanation with cooper pairs formation : 4 mark Diagram : 1mark	[06]	C01	L2
(b)	Failure 1 with formular : 2 mark Failure 2 with formular : 2 mark	[04]	C01	L3
4 (a)	Diagram : 1mark Truth Table ; 1 mark 4 input states: 4 mark	[6]	C01	L2
(b)	Formula - 1Mark Calculation -2 Mark Accurate result - 1 mark	[4]	C01	L2
5 (a)	Matrix for S and T gates - 2 Mark Derivation : 2 mark Proof : 2 mark	[6]	C01	L2
(b)	4 differences – 4 mark	[4]	C03	L3
6 (a)	diagram: 2mark Explanation : 2 mark Calculation :1 mark Accuracy : 1 mark	[6]	C03	L2
(b)	Hadamard Gate formula ; 1mark Proof : 4 mark	[4]	C01	L3
7 (a)	Three matrices : 3 mark Operation on $\|0\rangle$ and $\|1\rangle$: 3 mark	[6]	C01	L2
(b)	Walk definition: 1mark Discussion on Types : 3 mark	[4]	C01	L3
8 (a)	Proton decay details: 3 mark Calculation : 2 mark Conclusion : 1 mark	[6]	C01	L2
8 (b)	Definition of Qbit: 1Mark Diagram: 1 mark Definition 1 mark	[4]	C01	L3

DETAILED SOLUTION

Detailed Solutions to IAT-2 PHYSICS

1A

Type 1 Superconductors:



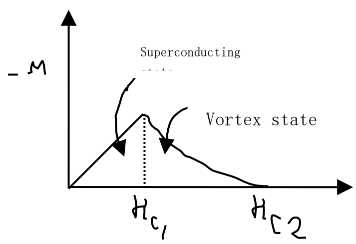
These are pure superconductors.

When kept in magnetic field, initially they continue to exhibit superconductivity and the negative magnetic moment increases. At critical magnetic field there is a sharp transition to normal state due to the penetration of magnetic flux lines. The transition is sharp.

These possess low critical magnetic fields. Their critical temperatures also low.They are generally pure metals.

Ex: Al, Pb

Type 2 superconductor:



These are generally alloys.

When kept in magnetic field, initially they continue to exhibit superconductivity and the negative magnetic moment increases. At lower critical magnetic field H_{C1}, the flux lines start penetrating .As the magnetic field is increased, the super conductivity coexists with magnetic field and this phase is known as mixed state(vortex state). At higher critical magnetic field H_{C2}, the penetration is complete and the material transforms to normal state. They possess higher critical magnetic fields. Their critical temperatures are high.

Ex: Nb_3Ge, $YBa_2Cu_3O_7$

TYPE I	TYPE II
Pb $40x10^3$A/m	Pb - Bi $100x10^3$A/m

1B

$$f(E) = \frac{1}{e^{\frac{E-E_F}{kT}} + 1}$$

For energy levels above Fermi level, probability is of the order of 1%. So E-E_F is positive

$$e^{\frac{E-E_F}{kT}} = \frac{1}{f(E)} - 1$$

$$f(E) = 0.01$$

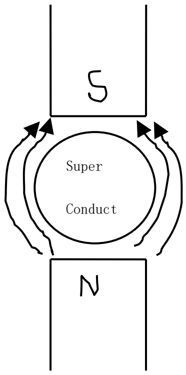
$$E - E_F = KTln\left(\frac{1}{0.01} - 1\right) = 1.902x10^{-20}J = 0.1189eV$$

$$E = E_F + 0.1189eV = 5.5 + 0.1189 = 5.619eV$$

2A MESISSENER EFFECT

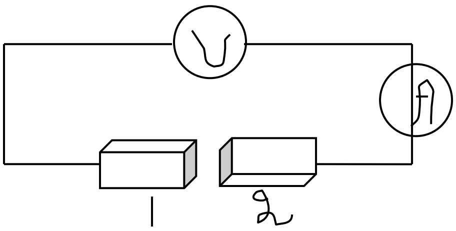
When a superconductor is placed in a magnetic field, it prevents entry of magnetic flux lines . This effect is known as **Meisseners effect.**

When a superconductor is kept in magnetic field, the surface current induced by the operation of Lenz’ s law. This generates opposite magnetic field and external field lines are prevented from entering the material. This effect is reversible. This is the principle of MAGLEV.



Josephson junction

It consists of an an insulator, sandwiched between two superconducting layers of which becomes a superconductor when cooled below critical temeperature. The insulating layer is so thin (a few nanometres) that Cooper pairs can tunnel through it and couple the superconducting wavefunctions on either side of the barrier. Most of the circuits for superconducting qubits consist of Josephson junctions and other components like capacitors connected by superconducting leads .



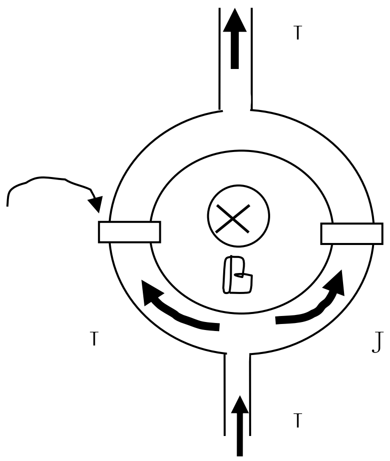
SQUIDS :(Superconducting quantum interference devices)

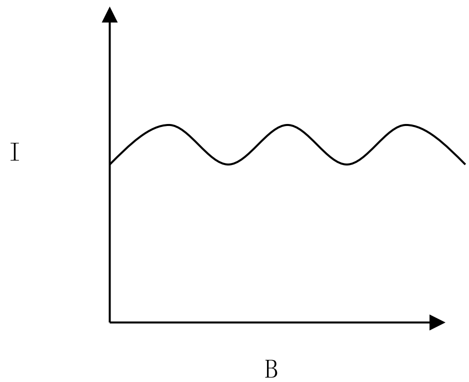
SQUID is a bi junction quantum interferometer formed from two Josephson’ s junctions. Principle of working is FLUX quantization.

Ex: DC SQUID:

It uses a pair of DC Josephson junctions. When magnetic field is applied normal to the plane of junction,, current is induced in the SQUID which opposes the external magnetic field. Magnetic Flux through the SQUID is quantized .The current through the SQUID varies periodically with the external magnetic field.

$\varphi = \frac{nhc}{2e}$





2B

$$H_c = H_o\left(1 - \left(\frac{T}{T_c}\right)^2\right)$$

$6.2x10^4 = H_o\left[1 - \left(\frac{6}{T_c}\right)^2\right] \cdots .(1)$

$2.8x10^4 = H_o\left[1 - \left(\frac{9}{T_c}\right)^2\right] \cdots .(2)$

(1) /(2)

T_C= 10.87K

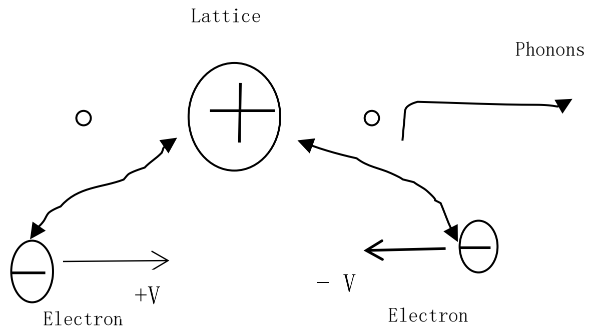
H_o=8.92x10^4 A/m

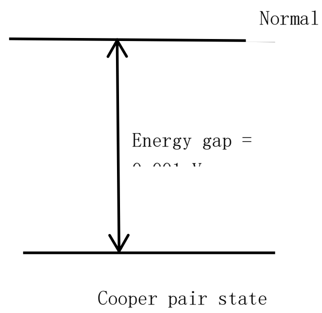
3A

SUPERCONDUCTIVITY: It is a phenomenon in which some materials loose their resistance completely below certain temperature. (1 mark)

BCS Theory :[Bardeen , Cooper, Schrieffer]

1. When the temperature of the material is reduced below critical temperature, electrons attain lower energy state than the normal energy creating an energy gap of few milli electron volt.
2. Positively charged lattice ion attracts a pair of electrons with equal and opposite spin and momentum through a feeble attractive interaction known as electron-lattice-electron interaction constituting cooper pairs.
3. Cooper pairs interact through exchanging Phonons.
4. All the cooper pairs are in same energy state and possess common wavefunction and Energy.
5. When a potential differnce applied, the current is constituted by flow of cooper pairs and are not scattered as the energy required to break it up is large enough. This reduces the resistance.





6. When the temperature / magnetic field is increased beyond critical limit, cooper pairs breakup and normal state is restored.

3B

Failures of Classical free electron theory:

1. Prediction of low specific heats for metals:

Classical free electron theory assumes that conduction electrons are classical particles similar to gas molecules. Hence,they are free to absorb energy in a continuous manner. Hence metals possessing more electrons must have higher heat content. This resulted in high specific heat given by the expression

$C_V = 10^{-4} R$.

This was contradicted by experimental results which showed low specific heat for metals.

2. Temperature dependence of electrical conductivity:

From the assumption of kinetic theory of gases

$$\frac{3}{2}kT = \frac{1}{2}mv^2$$

$$\therefore v \propto \sqrt{T}$$

Also mean collision time τ is inversely proportional to velocity,

$$\tau \propto \frac{1}{v}$$

$$\tau \propto \frac{1}{\sqrt{T}}$$

$$\therefore \sigma = \frac{ne^2\tau}{m} \Rightarrow \sigma \propto \frac{1}{\sqrt{T}}$$

However experimental studies show that $\sigma \propto \frac{1}{T}$

3. Dependence of electrical conductivity on electron concentration:

As per free electron theory, $\sigma \propto n$

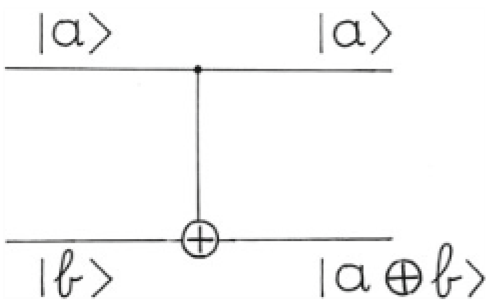
The electrical conductivity of Zinc and Cadmium are 1.09 x 10^{7} /ohm m and .15 x 10^{7} /ohm m respectively which are very much less than that for Copper and Silver for which the values are 5.88x10^{7} /ohm m and 6.2 x 10^{7} /ohm m. On the contrary, the electron concentration for zinc and cadmium are 13.1x10^{28} /m^3 and 9.28 x10^{28} /m^3 which are much higher than that for Copper and Silver which are 8.45x10^{28} /m^3 and 5.85 x10^{28} /m^3.

These examples indicate that $\sigma \propto n$ does not hold good.

4A

CONTROLLED NOT GATE

a and b are two inputs. a is called control qubit and b the target qubit. Target qubit flips if and only if a= 1. If a = 0, the second qubit remains unchanged.



INPUT CONTROL BIT	INPUT TARGET BIT	OUTPUT CONTROL BIT	OUTPUT TARGET BIT
X_1	X_o	Y_1	y_o
0	0	0	0
0	1	0	1
1	0	1	1
1	1	1	0

$$\begin{bmatrix} \mathbf{1} & \mathbf{0} & \mathbf{0} & \mathbf{0} \\ \mathbf{0} & \mathbf{1} & \mathbf{0} & \mathbf{0} \\ \mathbf{0} & \mathbf{0} & \mathbf{0} & \mathbf{1} \\ \mathbf{0} & \mathbf{0} & \mathbf{1} & \mathbf{0} \end{bmatrix}$$

4B

$$P(k=0) = \frac{\lambda^k e^{-\lambda}}{k!} = 0.135$$

$$P(k=2) = 0.270$$

5A

PHASE GATE S gate: It is P gate with $\Phi = \pi/2$. It represents rotation of 90^0 about Z axis.

$$S = \begin{bmatrix} 1 & 0 \\ 0 & e^{\frac{i\pi}{2}} \end{bmatrix} = \begin{bmatrix} 1 & 0 \\ 0 & i \end{bmatrix}$$

Truth Table

INPUT	OUTPUT

$\alpha\|0\rangle + \beta\|1\rangle$	$\alpha\|0\rangle + i\beta\|1\rangle$
0	$\|0\rangle$
1	$i\|1\rangle$

T gate : It is P gate with Φ = π/4

$$T = \begin{bmatrix} 1 & 0 \\ 0 & e^{\frac{i\pi}{4}} \end{bmatrix} = \begin{bmatrix} 1 & 0 \\ 0 & \frac{1+i}{\sqrt{2}} \end{bmatrix}$$

INPUT CONTROL BIT	INPUT CONTROL BIT	INPUT TARGET BIT	OUTPUT CONTROL BIT	OUTPUT CONTROL BIT	OUTPUT CONTROL BIT	
0	0	0	0	0	0	
0	0	1	0	0	1	
0	1	0	0	1	0	
0	1	1	0	1	1	
1	0	0	1	0	0	
1	0	1	1	0	1	
1	1	0	1	1	1	
1	1	1	1	1	0	

INPUT	OUTPUT
0	$\|0\rangle$
1	$(\frac{1}{\sqrt{2}} + \frac{i}{\sqrt{2}})\|1\rangle$
$\alpha\|0\rangle + \beta\|1\rangle$	$\alpha\|0\rangle + \beta\|1\rangle = \alpha\|0\rangle + \beta\frac{1+i}{\sqrt{2}}\|1\rangle$

To Show that $T^2 = S$

$$T^2 = \begin{bmatrix} 1 & 0 \\ 0 & \frac{1}{\sqrt{2}} + i\frac{1}{\sqrt{2}} \end{bmatrix} \mathrm{X} \begin{bmatrix} 1 & 0 \\ 0 & \frac{1}{\sqrt{2}} + i\frac{1}{\sqrt{2}} \end{bmatrix} = \begin{bmatrix} (1X1) + (0) & (1X0) + 0 \\ 0 + 0 & 0 + i \end{bmatrix} = S$$

5B

The field of statistics is divided into two major divisions: descriptive and inferential. Each of these segments is important, offering different techniques that accomplish different objectives. Descriptive statistics describe what is going on in a population or data set. Inferential statistics, by contrast, allow scientists to take findings from a sample group and generalize them to a larger population. The two types of statistics have some important differences.

Descriptive Statistics

Descriptive statistics is the type of statistics that probably springs to most people’s minds when they hear the word “statistics.” In this branch of statistics, the goal is to describe. Numerical measures are used to tell about features of a set of data. There are a number of items that belong in this portion of statistics, such as:

- The average, or measure of the center of a data set, consisting of the mean, median, mode, or midrange
- The spread of a data set, which can be measured with the range or standard deviation
- Overall descriptions of data such as the five number summary
- Measurements such as skewness and kurtosis
- The exploration of relationships and correlation between paired data
- The presentation of statistical results in graphical form

These measures are important and useful because they allow scientists to see patterns among data, and thus to make sense of that data. Descriptive statistics can only be used to describe the population or data set under study: The results cannot be generalized to any other group or population.

Types of Descriptive Statistics

There are two kinds of descriptive statistics that social scientists use:

Measures of central tendency capture general trends within the data and are calculated and expressed as the mean, median, and mode. A mean tells scientists the mathematical average of all of a data set, such as the average age at first marriage; the median represents the middle of the data distribution, like the age that sits in the middle of the range of ages at which people first marry; and, the mode might be the most common age at which people first marry.

Measures of spread describe how the data are distributed and relate to each other, including:

- The range, the entire range of values present in a data set

- The frequency distribution, which defines how many times a particular value occurs within a data set
- Quartiles, subgroups formed within a data set when all values are divided into four equal parts across the range
- Mean absolute deviation, the average of how much each value deviates from the mean
- Variance, which illustrates how much of a spread exists in the data
- Standard deviation, which illustrates the spread of data relative to the mean

Measures of spread are often visually represented in tables, pie and bar charts, and histograms to aid in the understanding of the trends within the data.

Inferential Statistics

Inferential statistics are produced through complex mathematical calculations that allow scientists to infer trends about a larger population based on a study of a sample taken from it. Scientists use inferential statistics to examine the relationships between variables within a sample and then make generalizations or predictions about how those variables will relate to a larger population.

It is usually impossible to examine each member of the population individually. So scientists choose a representative subset of the population, called a statistical sample, and from this analysis, they are able to say something about the population from which the sample came. There are two major divisions of inferential statistics:

- A confidence interval gives a range of values for an unknown parameter of the population by measuring a statistical sample. This is expressed in terms of an interval and the degree of confidence that the parameter is within the interval.
- Tests of significance or hypothesis testing where scientists make a claim about the population by analyzing a statistical sample. By design, there is some uncertainty in this process. This can be expressed in terms of a level of significance.

Techniques that social scientists use to examine the relationships between variables, and thereby to create inferential statistics, include linear regression analyses, logistic regression analyses, ANOVA, correlation analyses, structural equation modeling, and survival analysis. When conducting research using inferential statistics, scientists conduct a test of significance to determine whether they can generalize their results to a larger population. Common tests of significance include the chi-square and t-test. These tell scientists the probability that the results of their analysis of the sample are representative of the population as a whole.

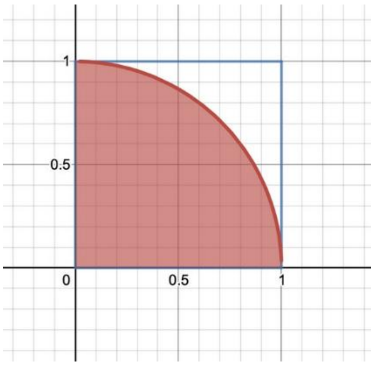
6A

Monte-Carlo Method

Monte Carlo methods vary, but tend to follow a particular pattern:

1. Define a domain of possible inputs
2. Generate inputs randomly from a probability distribution over the domain
3. Perform a deterministic computation on the inputs
4. Aggregate the results

Monte Carlo method applied to approximating the value of π. For example, consider a quadrant inscribed in a unit square. Given that the ratio of their areas is $\pi/4$, the value of π can be approximated using a Monte Carlo method:



1. Draw a square, then Inscribe a quadrant within it
2. Uniformly scatter a given number of points over the square
3. Count the number of points inside the quadrant, i.e. having a distance from the origin of < 1
4. The ratio of the inside-count and the total-sample-count is an estimate of the ratio of the two areas, $\pi/4$.
   Multiply the result by 4 to estimate π./

In this procedure the domain of inputs is the square that circumscribes the quadrant. We generate random inputs by scattering grains over the square then perform a computation on each input (test whether it falls within the quadrant). Aggregating the results yields our final result, the approximation of π.

There are two important considerations:

1. If the points are not uniformly distributed, then the approximation will be poor.
2. There are many points. The approximation is generally poor if only a few points are randomly placed in the whole square. On average, the approximation improves as more points are placed.

Uses of Monte Carlo methods require large amounts of random numbers, and their use benefited greatly from Pseudo random number generators, which were far quicker to use than the tables of random numbers that had been previously used for statistical sampling.

6B

HADAMARD GATE : It creates superposed states.

MATRIX $$H = \frac{1}{\sqrt{2}}\begin{bmatrix}1 & 1\\1 & -1\end{bmatrix}$$

It is Hermitian and also satisfies unitary condition.

$$H[H^{+}]^{T} = I$$
$$[H^{+}] = \frac{1}{\sqrt{2}}\begin{bmatrix}1 & 1\\1 & -1\end{bmatrix}$$
$$[H^{+}]^{T} = \frac{1}{\sqrt{2}}\begin{bmatrix}1 & 1\\1 & -1\end{bmatrix}$$

$$H[H^{+}]^{T} = \frac{1}{2}\begin{bmatrix}(1X1)+(1X1) & (1X1)+(1X-1)\\(1X1)+(-1X1) & (1X1)+(-1X-1)\end{bmatrix} = \begin{bmatrix}1 & 0\\0 & 1\end{bmatrix}$$

$$\mathrm{H}|0\rangle = \frac{1}{\sqrt{2}}(|0\rangle + |1\rangle) = \frac{1}{\sqrt{2}}\left\|\begin{matrix}1\\1\end{matrix}\right\|, \quad \mathrm{H}|1\rangle = \frac{1}{\sqrt{2}}(|0\rangle - |1\rangle) = \frac{1}{\sqrt{2}}\left\|\begin{matrix}1\\-1\end{matrix}\right\|.$$

Truth Table

INPUT	OUTPUT
$[0\rangle$	$\frac{1}{\sqrt{2}}[\|0\rangle + \|1\rangle)$
$\|1\rangle$	$\frac{1}{\sqrt{2}}[\|0\rangle - \|1\rangle)$
$\alpha\|0\rangle + \beta\|1\rangle$	$\frac{1}{\sqrt{2}}\alpha(\|0\rangle + \|1\rangle) + \frac{1}{\sqrt{2}}\beta(\|0\rangle - \|1\rangle)$

7A

PAULI MATRICES

$$\sigma_x = \begin{bmatrix}0 & 1\\1 & 0\end{bmatrix}$$
$$\sigma_y = \begin{bmatrix}0 & -i\\i & 0\end{bmatrix}$$
$$\sigma_z = \begin{bmatrix}1 & 0\\0 & -1\end{bmatrix}$$

σ_x is a classical not gate. When operated on a state vector say $|0\rangle$, it flips to $|1\rangle$

$$\sigma_x|0\rangle = \begin{bmatrix}0 & 1\\1 & 0\end{bmatrix}.\begin{bmatrix}1\\0\end{bmatrix} = \begin{bmatrix}0x1 + 1x0\\1x1 + 0x0\end{bmatrix} = \begin{bmatrix}0\\1\end{bmatrix}$$

$$\sigma_x|1\rangle = \begin{bmatrix}0 & 1\\1 & 0\end{bmatrix}.\begin{bmatrix}0\\1\end{bmatrix} = \begin{bmatrix}0x0 + 1x1\\1x0 + 0x1\end{bmatrix} = \begin{bmatrix}1\\0\end{bmatrix}$$

$$\sigma_y|0\rangle = \begin{bmatrix} 0 & -i \\ i & 0 \end{bmatrix} . \begin{bmatrix} 1 \\ 0 \end{bmatrix} = \begin{bmatrix} 0x1 + (-ix0) \\ ix1 + 0x0 \end{bmatrix} = \begin{bmatrix} 0 \\ i \end{bmatrix}$$

$$\sigma_y|1\rangle = \begin{bmatrix} 0 & -i \\ i & 0 \end{bmatrix} . \begin{bmatrix} 0 \\ 1 \end{bmatrix} = \begin{bmatrix} 0x0 + (-ix1) \\ ix0 + 0x1 \end{bmatrix} = \begin{bmatrix} -i \\ 0 \end{bmatrix}$$

$$\sigma_z|0\rangle = \begin{bmatrix} 1 & 0 \\ 0 & -1 \end{bmatrix} . \begin{bmatrix} 1 \\ 0 \end{bmatrix} = \begin{bmatrix} 1x1 + 0x0 \\ 0x1 \pm 1x0 \end{bmatrix} = \begin{bmatrix} 1 \\ 0 \end{bmatrix}$$

$$\sigma_z|1\rangle = \begin{bmatrix} 1 & 0 \\ 0 & -1 \end{bmatrix} . \begin{bmatrix} 0 \\ 1 \end{bmatrix} = \begin{bmatrix} 1x0 + 0x1 \\ 0x0 \pm 1x1 \end{bmatrix} = \begin{bmatrix} 0 \\ -1 \end{bmatrix}$$

7B

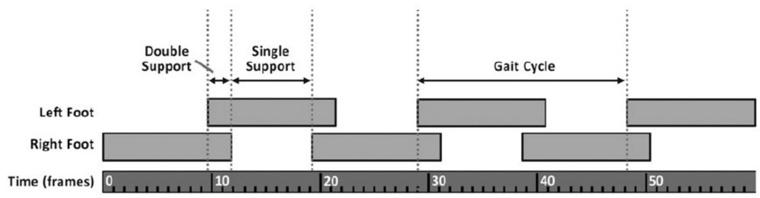
Walking

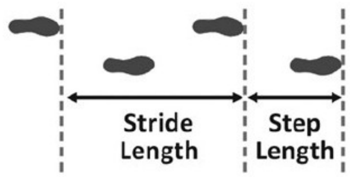
Walks feature all the basics of mechanics while including personality. The ability to animate walk cycles is one of the most important skills a character animator needs to master.

Strides and Steps

A step is one step with one foot. A stride is two steps, one with each foot. Stride length is the distance the character travels in a stride, measured from the same part of the foot. Step and stride length indicate lengthwise spacing for the feet during a walk.

Gait is the timing of the motion for each foot, including how long each foot is on the ground or in the air. During a walk, the number of feet the character has on the ground changes from one foot (single support) to two feet (double support) and then back to one foot. You can plot the time each foot is on the ground to see the single and double support times over time. A normal walking gait ranges from 1/ 3 to 2/3 of a second per step, with 1/2 second being average.





Walk Timing

Walking is sometimes called “controlled falling.” Right after you move past the passing position, your body’ s center of gravity is no longer over your base of support, and you begin to tip. Your passing leg moves forward to stop the fall, creating your next step. Then the cycle begins again. The horizontal timing for between the four walk poses is not uniform. The CG slows in going from the contact to passing position, then slows out from passing to contact. The CG also rises and falls, rising to the highest position during passing and the lowest during contact. The head is in the highest position during passing.

8A

Modeling the Probability for Proton Decay

The experimental search for Proton Decay was undertaken because of the implications of the Grand unification Theories. The lower bound for the lifetime is now projected to be on the order of $\tau = 10^{33}$ Years. The probability for observing a proton decay can be estimated from the nature of particle decay and the application of Poisson Statistics. The number of protons N can be modeled by the decay equation

$$N = N_0 e^{-\lambda t}$$

Here $\lambda = 1/t = 10^{-33}/$ year is the probability that any given proton will decay in a year. Since the decay constant λ is so small, the exponential can be represented by the first two terms of the Exponential Series.

$$e^{-\lambda t} = 1 - \lambda t$$
$$N = N_o(1 - \lambda t)$$

If the number of protons is 7.5 x 10^{33}protons. For one year of observation, the number of expected proton decays is then

$$N - N_o = N_o \lambda t$$
$$= 7.5x10^{33}\ protons \times 10^{-33} / year \times 1 year$$
$$= 7.5$$

Poisson distribution function tells us that the probability for zero observations of a decay is

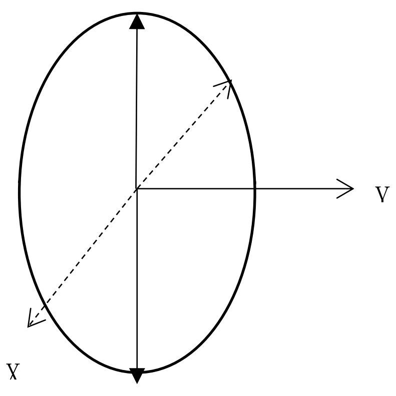
$$p(k) = \frac{\lambda^k e^{-\lambda}}{k!} \quad p(k) = \frac{3^0 e^{-3}}{o!} = 0.05$$

This low probability for a null result suggests that the proposed lifetime of 10^{33} years is too short. While this is not a realistic assessment of the probability of observations because there are a number of possible pathways for decay, it serves to illustrate in principle how even a non-observation can be used to refine a proposed lifetime.

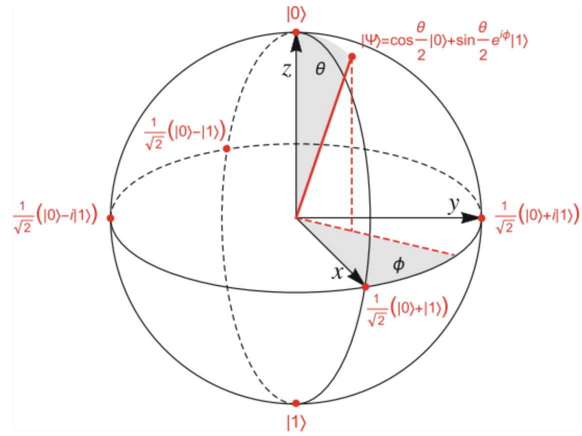
8B

BLOCK SPHERE

It represents a sphere with all the points on its surface correspond to state vectors in Hilbert space. The vector drawn to any point on the surface from the centre represents a state. In the diagram, $|\psi\rangle = c|0\rangle + d|1\rangle$ is a superposed state. $|0\rangle$ and $|1\rangle$are represented along + Z and - Z axes.



$$|\psi\rangle = c|0\rangle + d|1\rangle$$



|0⟩
$|\Psi\rangle = \cos\frac{\theta}{2}|0\rangle + \sin\frac{\theta}{2}e^{i\phi}|1\rangle$
z
θ
$\frac{1}{\sqrt{2}}(|0\rangle - |1\rangle)$
$\frac{1}{\sqrt{2}}(|0\rangle - i|1\rangle)$
y
$\frac{1}{\sqrt{2}}(|0\rangle + i|1\rangle)$
x
ϕ
$\frac{1}{\sqrt{2}}(|0\rangle + |1\rangle)$
|1⟩