

Continuous Passive Motion (CPM) Machine for Ankle Rehabilitation

Design And Fabrication Project Endsem Report

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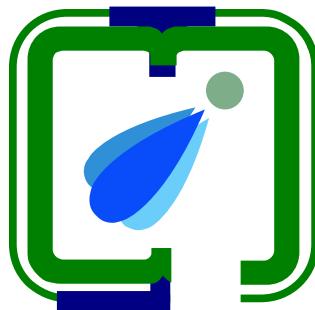
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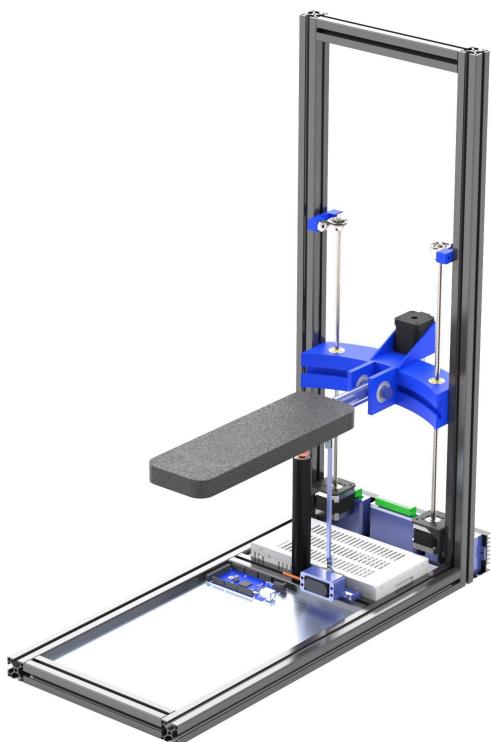
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Introduction

A Continuous Passive Motion (CPM) Machine is a medical device used for rehabilitation of joints after surgery, injury, or extended immobility. It is designed to move a joint, such as the ankle, knee, or shoulder, through a controlled and repetitive range of motion without requiring the patient's muscular effort.



How it Works ?

The ankle is secured on the platform, and the motorized system gently moves the joint through a controlled range of motion. This repetitive movement helps maintain flexibility, reduce stiffness, and promote healing by improving circulation and preventing joint adhesions.

Applications: Recovery after ankle surgery, Healing from ankle sprains and strains, Easing joint stiffness from arthritis.



Ankle Structure And Rehabilitation Principles



The ankle includes three joints: the talocrural joint, the subtalar joint, and the inferior tibiofibular joint.

Due to the unique anatomy of the ankle, if the gravity center is unbalanced, it is easy to cause the ankle joint /eversion. It will lead to internal and external ligament injury, partial avulsion tear or complete rupture, and even fracture.

After a sprain of the ankle, it is necessary to make a timely rehabilitation treatment, otherwise the injured part is prone to swelling and pain, and then it causes recurrent ankle injury.

Continuous passive motion (CPM), which is used for rehabilitation of lower extremity surgery or joint after injury, is a new effective method.



User Study

Target Audience

Patients

Primary users of CPM therapy devices, mainly adults aged 18–60 recovering from injuries or surgeries. Athletes use them for acute recovery, while middle-aged and older adults benefit from joint condition healing under supervision.

Physiotherapists

Key secondary users with at least two years of musculoskeletal rehab experience. They recommend, monitor, and educate patients on CPM use, specializing in post-op care, sports rehab, and chronic pain management.

Healthcare Providers & Institutions

Includes orthopedic clinics, rehab centres, and hospitals integrating CPM into recovery protocols. Key stakeholders—orthopaedic surgeons and sports medicine clinics—seek cost-effective, reliable, and easy-to-maintain devices.

*questionnaires & semi-structured interviews

Participant Demographics

- 20 patients (aged 22–55)
- 4 physiotherapists (experience: 2–10 years)

Rehabilitation Challenges

60% of patients found it hard to perform consistent rehabilitation exercises at home due to pain or lack of guidance.

80% of physiotherapists reported non-compliance as the biggest hurdle in rehabilitation success.

Device Preferences

85% of patients prioritized comfort during use.

75% of patients preferred a portable and home-friendly design.

70% of physiotherapists considered adjustability in motion range critical.

Features Ranking

Patients

1. Comfort padding
2. Adjustable motion settings
3. Ease of use
4. Progress tracking

Concerns

Patients:

50% cited concerns about cost.

30% were worried about setup complexity.

Physiotherapists:

40% emphasized the need for fail-safes to prevent overextension during unsupervised use.



User Study



I'm worried about the price—most devices are too expensive.

I often skip my exercises because they're painful and hard to keep track of without supervision.



Portability would make it easier to integrate into both home and clinic settings.



Adjustable motion settings are essential; every patient's recovery path is different.

Stakeholder Verbatims

Safety is a top concern. Unsupervised use should not lead to overstrain or injury.



If I could track my progress visually, I'd feel more motivated to continue.



A comfortable, easy-to-use device that I can use at home would be a game-changer.

Patients often struggle with consistency, so a progress tracker could help keep them on track.





User Study

Insight Synthesis

Pain Points in Rehabilitation

Lack of supervision and guidance leads to inconsistent exercise routines among patients.

Physiotherapists struggle with ensuring compliance in home-based rehabilitation programs.

User Priorities

Comfort is the most critical factor for patients, followed by ease of use.

Physiotherapists emphasize the need for adjustable motion ranges and safety features.

Feature Opportunities

Progress tracking (e.g., through a mobile app or display) is a desired feature to enhance engagement.

Portability is valued equally by patients and physiotherapists for flexibility in usage.

Concerns to Address

Cost remains a significant barrier for patients, requiring consideration during the design phase.

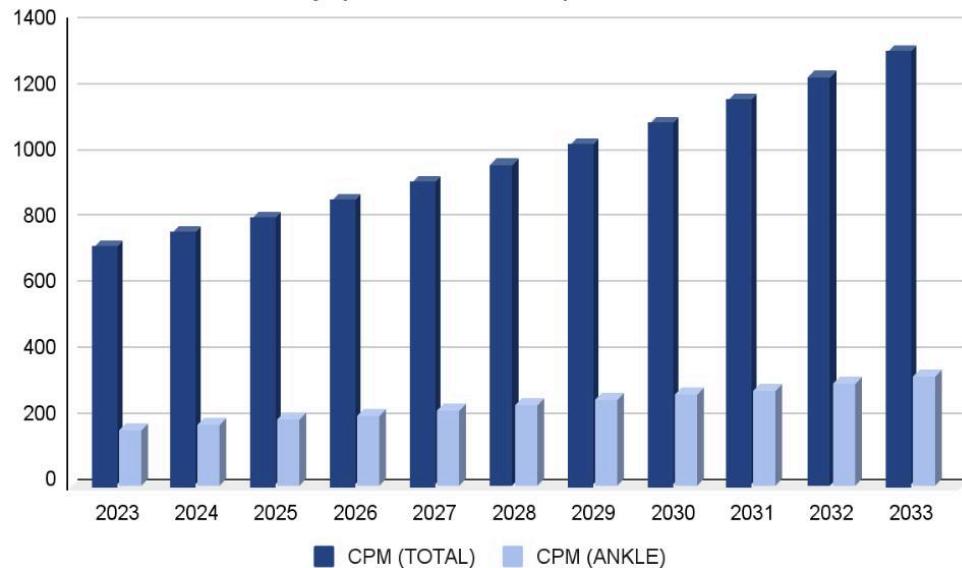
Setup complexity should be minimized to ensure adoption by a wide range of users.

Safety and Usability

Safety features, such as auto-stop to prevent overextension, are necessary for unsupervised usage at home..



Market Analysis Report For CPM Devices



Growth Rate(GR)

Global GR: 6.2% CAGR (2024–30)

India's GR: 5.3% CAGR.

Growth Rate (Global > India)

- Limited Awareness
- High Cost
- Low Adoption of Technology
- Healthcare system strain

Market Size Projection

2024 Market Size

Global: ₹6,367.8 Cr.

India: ₹439.9 Cr.

2033 Market Size

Global: ₹10,922.8 Cr.

India: ₹763.6 Cr.

73.5% of athletes reported chronic ankle instability.

Market Segments of Different CPMs

Knee - 50%

Hip - 14.2%

Ankle - 24%

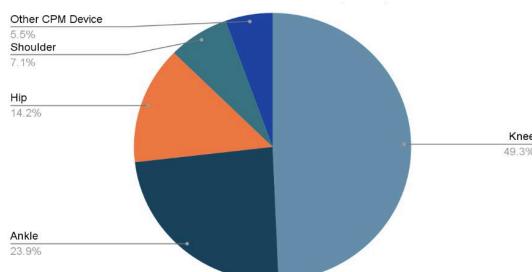
Shoulder - 7.1%

Chronic ankle Instability has high prevalence in spots like –

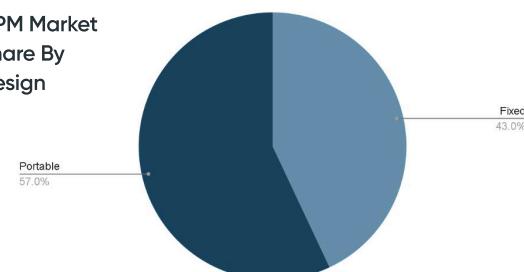
- Soccer (61%)
- Basketball (65%)
- Volleyball (46%)
- Netball (46%)
- Baseball (34%) and Others (10-20%).

Market Segmentation by User

More than **60%** of total purchase are made by hospitals and physiotherapy centers.



CPM Market Share By Design





Common Complications After Surgeries Or Injuries And The Role Of Continuous Passive Motion (CPM)

Some of the most common complications include joint stiffness, muscle atrophy, pain and swelling, blood clots, and delayed healing. Continuous Passive Motion (CPM) therapy plays a crucial role in mitigating these complications, promoting faster and more effective recovery.

Joint stiffness:

It occurs due to inflammation, immobility, or scar tissue formation. This can severely limit the range of motion and delay rehabilitation.

Pain and swelling:

Pain and swelling, often caused by post-operative inflammation or trauma, are significant barriers to recovery. CPM devices indirectly reduce pain by preventing stiffness and improving circulation.

Muscle atrophy:

This condition weakens the muscles and delays rehabilitation progress. While CPM primarily targets joint movement rather than muscle activation, its use complements active therapies, allowing patients to transition to muscle-strengthening exercises more effectively.



Comparison Of CPM With Other Rehabilitation Methods

Convenience

- **CPM Machine:** Can be used independently at home, offering flexibility and round-the-clock rehabilitation, especially for bedridden or post-operative patients.
- **Physical Therapy:** Requires scheduled appointments and often involves traveling to a clinic, which may be inconvenient or costly for some patients.

Effort Required

- **CPM Machine:** The CPM machine operates passively, requiring no physical effort from the patient. The joint is moved mechanically, allowing the patient to rest while the machine performs repetitive movements. This is especially advantageous for individuals who are weak, in pain, or unable to actively engage in exercises.
- **Physical Therapy:** Involves active participation from the patient, such as performing exercises, stretches, or engaging in therapist-guided movements. This can be challenging for patients with limited strength, pain, or mobility.

Consistency

- **CPM Machine:** Provides consistent, repetitive joint motion that minimizes human error or variations.
- **Physical Therapy:** While effective, the outcomes depend on the therapist's skills and the patient's adherence to prescribed exercises.



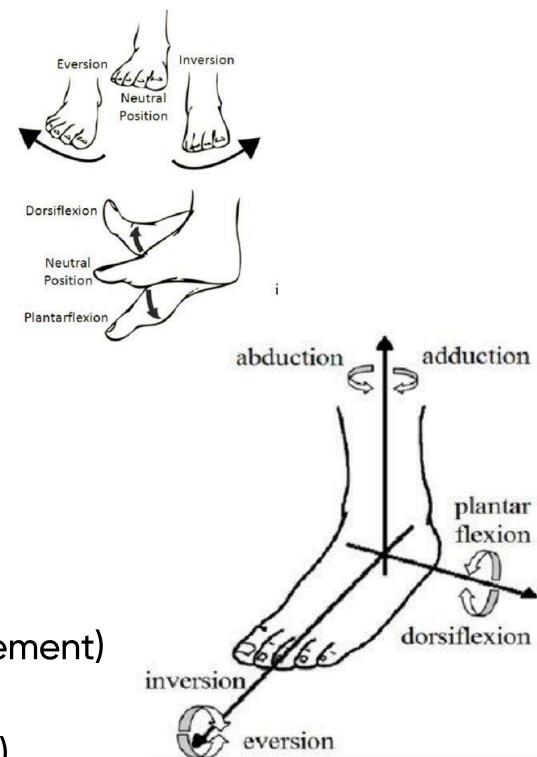
Comparison Of CPM With Other Rehabilitation Methods

Cost

- **CPM Machine:** Involves a one-time purchase or rental fee, making it cost-effective for prolonged use. Renting a CPM device typically costs between ₹500 to ₹1,000 per day, making it a practical option for short-term recovery needs. For patients requiring longer-term use, purchasing a device is an option, with prices ranging from ₹30,000 to ₹1,50,000.
- **Physical Therapy:** This can be expensive due to repeated session costs, particularly for long-term rehabilitation.

Technical Specifications

Motion	Angle Range
Dorsiflexion	0°-30°
Plantar flexion	0°-40°
Adduction	0°-20°
Abduction	0°-30°
Eversion	0°-20°
Inversion	0°-30°

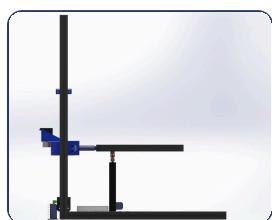
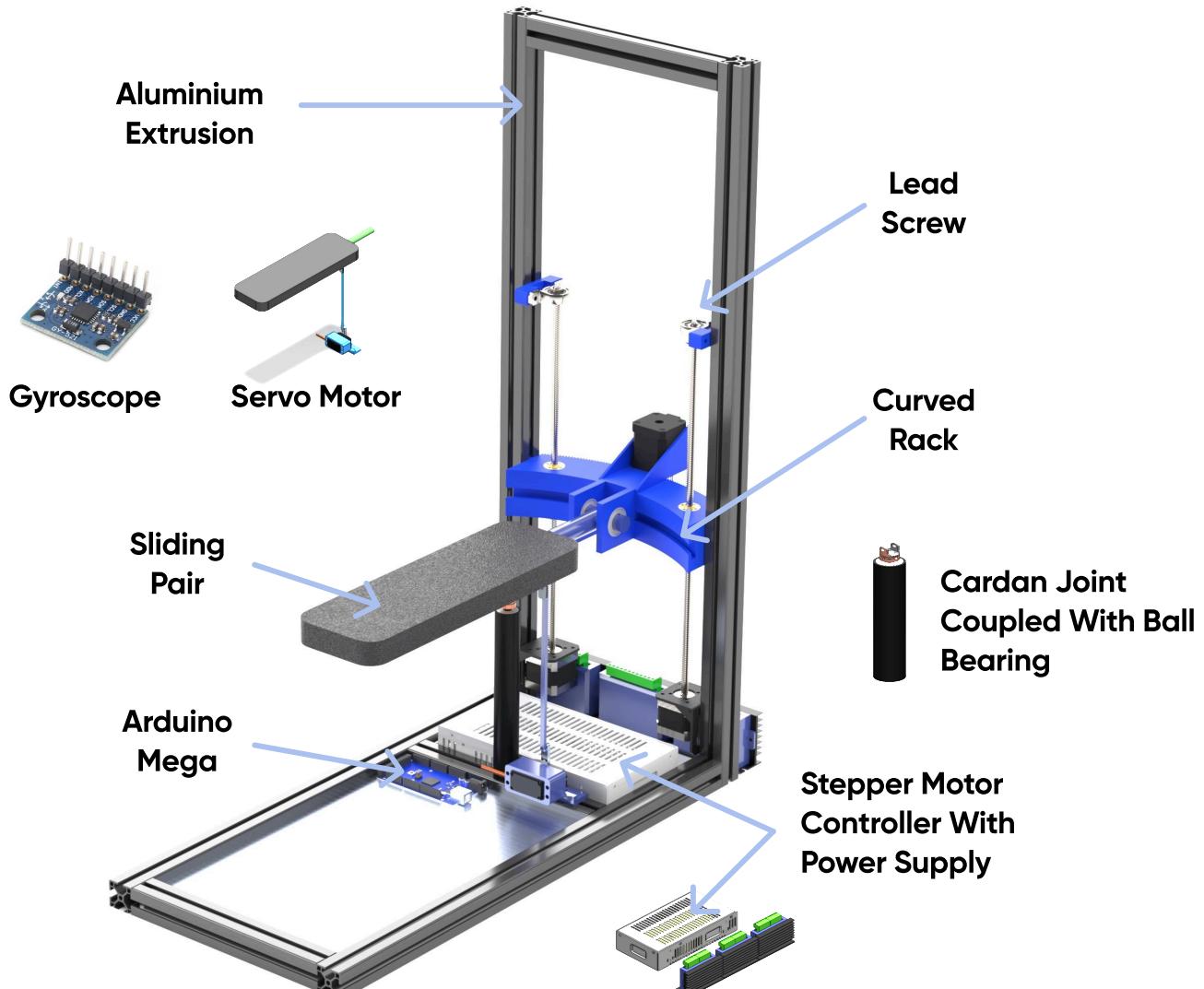


Degrees of Motion

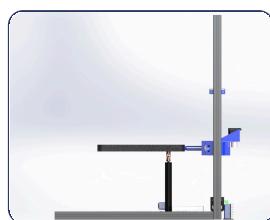
- Dorsiflexion & Plantar flexion (Pitch movement)
- Inversion & Eversion (Role movement)
- Abduction & Adduction (Yaw movement)



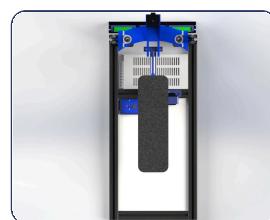
Mechanical Design Of CPM Machine



Side View 1



Side View 2



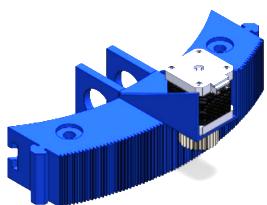
Top View



Front View



Components



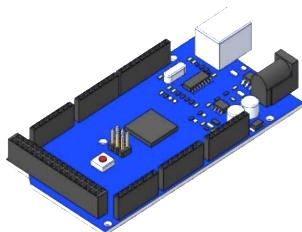
3D Printed Curved Rack

It is designed to provide Yaw motion to the CPM machine, gear teeth are provided in accordance with the spur gear.



Lead Screw

Used to provide translatory motion to curved rack in order to provide pitch rotation to foot pedal.



Arduino mega

Can be used as the central control unit in an Ankle Continuous Passive Motion (CPM) Machine. Drives the Actuators, Smooth & Precise Motion and Adjustable Speed & Range of Motion



Aluminum Extrusion

It is used to make the frame for the CPM machine and it is used because of its lightweight, cost efficiency, and good strength.



Cardan Joint coupled with ball bearing

Used to provide multiple degrees of freedom to the footplate of the CPM machine.

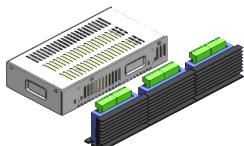


Components



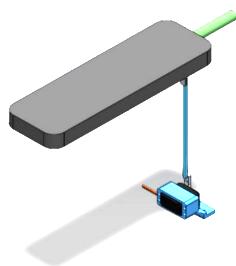
Sliding Pair

Used to provide the pitch movement to the ankle i.e. Dorsiflexion.



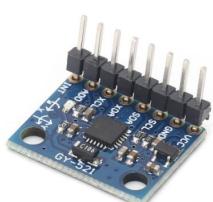
Stepper Motor Controller with Power Supply

A Stepper Motor is responsible for precisely controlling the movement of the foot platform.



Servo Motor

It is attached to the footplate and it is used to provide inversion and eversion motion to the ankle.



Gyroscope

The MPU 6050 3-axis gyroscope is used to provide spatial feedback to the microcontroller and to keep a record of patient's exercise history



Design And Manufacturing Process Plan



Manufacturing Process Plan

- **Mechanical Design**
 - Software : Solidworks
 - Creating a 3D Model of CPM Device.
 - Ensuring to get 3 DOF.
- **Material Selection And Procurement**
 - Structural Frame - Aluminium Extrusion
 - 3D Printed Structure - PLA
 - Bearings , Fasteners , Stepper motor , Servo motor , Lead screw , Motor mount, etc. to be procured from suppliers
- **Fabrication Process**
 - **Frame Assembly**
 - Cutting and arranging aluminum extrusion structure using T-slot.
 - Mounting the stepper motor on the motor mount, either parallel to or along the vertical aluminum extrusion, in conjunction with lead screws.
 - **3D-Printing**
 - Using the 3D-Printing technique to make curved rack.
 - Servo motor mount, bearing mount, etc
 - **Assembly**
 - Integration and assembly of all parts into the frame, including 3D-printed components, motors, lead screws, and linear guides.
- **Electronics**
 - Mounting all electronic devices securely.
 - Wiring connection with stepper motors , servo , arduino etc.



Bill Of Materials

S.No	Name	Price	Unit	#	Net Price	Specification	Link
1	3D Printer Filament	999	2		1998	Teal Blue – 1.75 mm / 1 kg	https://robu.in/product/numaker
2	TB6600 Stepper Motor Controller	330.4	3		991.2	4.0A , 42V	https://robokits.co.in/motor-drive
3	Nema 17 stepper Motor with lead screw	1299	2		2598	Stepper motor with 400mm lead screw	https://novo3d.in/stepper-motor
4	Nema 17 stepper Motor	553.2	2		1106.4	Torque : 4.2 Kg-cm; Step Angle: 1.8 deg / step.	https://robokits.co.in/motors/stepper-motor
5	Connector wire stepper Motor	40	3		120	100cm , copper	https://roboticsdna.in/product/stepper-motor
6	T-Slot Aluminium(30x30, 1000mm)	738	2		1476	Extrusion Profile, 1m length	https://aws.robu.in/product/easy-profile
7	T-Slot sliding nut (M5,10piece)	150	2		300	M5	https://aws.robu.in/product/easy-nut
8	Nema 17 Stepper Motor Steel Mounting Bracket	109	3		327	Steel, Black	https://novo3d.in/nema-17-stepper-motor
9	8 mm dia Bearing	69	4		276	bearing, bore: 8mm	https://novo3d.in/kp08-bearing/
10	Power supply 6.25 A 24V	1062	1		1062	Power Supply	https://robokits.co.in/power-supply
11	M3 M4 M5 Socket head bolt set	873	1		873	Socket Head Cap Screws With Nuts and Flat Washer	https://www.amazon.in/Rpi-shop
12	MPU 6050	111	1		111	Gyro & Accelerometer	https://robu.in/product/mpu-6050
13	Arduino Mega	1072	1		1072	Atmega16U2 Mega	https://robu.in/product/atmel-mega
14	ESP 32	619	1		619	Wi-Fi and bluetooth module	https://www.amazon.in/SquadPix
15	Universal Joint	3372	1		3372	16mm Outside Diameter, 8mm Bore	https://in.rsdelivers.com/product/universal-joint
16	High Torque servo motor	1268	1		1268	180Degree , DC motor	https://roboticsdna.in/product/stepper-motor
17	Breadboard with jumper wire set	279	1		279	Wires	https://www.amazon.in/ApTechDigital
18	Radial Ball Bearing 608ZZ	100	2		200	ID: 8mm , OD: 22mm	https://robu.in/product/radial-ball-bearing
19	Aluminium Composite Pannel	799	4		3196	For covering the lower frame from the ground.	https://www.amazon.in/Aluminum-Composite-Pannel
20	6903 Deep groove bearings	525	1		525	Pitch motion providing bearing	https://www.flipkart.com/invento
21	Corner bracket for aluminium extrusion	169	5		845	to connect the aluminium extrusions	https://robu.in/product/easymech
22	Miscellaneous	5000	-		5000	For Miscellaneous expenses such as delivery charges, offline purchases, manufacturing, etc.	
	Total				27614.6		



Thank You