Experiment 20.3. To determine the frequency of an electrically maintained tuning fork by Melde's experiment.

Apparatus. Electrically maintained tuning fork, a stand with clamp, pulley, a light weight pan, a weight box, a balance, a battery of two cells, a key, a rheostat, connecting wires etc.

Theory. A string can be set in to vibrations by means of an electrically maintained tuning fork, thereby producing stationary waves due to reflection of waves at the pulley. The end of the string where it is fixed to the prong of the tuning fork and the position where it touches the pulley are nodes
(i) For the transverse arrangement the frequency $n$ is given by

$$
n=\frac{1}{2 l} \sqrt{\frac{T}{m}}
$$

where $l$ is the length of the thread in fundamental mode of vibration, $T$ the tension applied to the thread and $m$ the mass per unit length of the thread.

If $p$-loops are formed in the length $l$ of the thread, then

$$
n=\frac{p}{2 l} \sqrt{\frac{T}{m}}
$$

(ii) For the longitudinal arrangement. When $p$-loops are formed the frequency $n$ is given by

$$
n=\frac{p}{l} \sqrt{\frac{T}{m}}
$$

## Procedure. Transverse arrangemient.

1. Find the weight of the pan $P$ and arrange the apparatus as shown in Fig. 20.5.
2. Place a load of 4 to 5 gm in the pan attached to the end of the string passing over the pulle Excite the tuning fork by putting the plug in the key $K$.
3. Adjust the position of the pulley so that the string is set into resonant vibrations and well defined loops are obtained. If necessary, adjust the tension by adding weights in the pan slowly and gradually. For finer adjustment add milligram weights so that the nodes are reduced to points.
4. Measure the length of say 4 loops formed in the middle part of the string. If $L$ is the distan $t^{2}$ in which 4 loops are formed then distance between two consecutive nodes $l=\frac{L}{4}$.
5. Note down the weight placed in the pan and calculate the tension $T$. Tension $T=\left(\omega \mathrm{w}\right.$. in $\mathrm{n}^{\text {nd }}$ pan $+w t$. of pan) $g$
6. Repeat the experiment twice by changing the weight in the pan in steps of one gram and altering the position of the pulley each time to get well defined loops.
7. Measure one metre length of the thread and find its mass to find the value of $m$, the mass per unit length.
8. Longitudinal arrangement. Set the apparatus as shown in Fig. 20.6. and proceed with the adjustments and measurements as explained above.

Observations.

| Mass of the pan | $=$ | gm |
| :--- | :--- | :--- |
| Mass of one metre of thread | $=$ | kg |
| Mass per metre | $m=$ | gm |
|  |  | $=\mathrm{kg}$ |


| Mode of vibration | No. | $\begin{aligned} & \text { No. of } \\ & \text { loops }(p) \end{aligned}$ | Length of corresponding thread L (in metre) | Length of each loop $\frac{L}{\prime \prime}=1 \text { metre }$ | Mass in the pan W in kg | Tension $T=$ $(w+W) g$ | $\begin{gathered} \text { Frequency } \\ n \end{gathered}$ |
| :---: | :---: | :---: | :---: | :---: | :---: | :---: | :---: |
| Transverse (A) | $\begin{aligned} & 1 \\ & 2 \\ & 3 \end{aligned}$ |  |  |  |  |  |  |
| $\begin{aligned} & \text { Longitudinal } \\ & (B) \end{aligned}$ | 1 <br> 2 <br> 3 |  |  |  |  |  |  |

Mean frequency $n=$ vib. $/$ sec
Calculations. A. Transverse arrangement.

$$
n=\frac{1}{2 l} \sqrt{\frac{T}{m}}
$$

B. Longitudinal arrangement

$$
n=\frac{1}{l} \sqrt{\frac{T}{m}}
$$

Precautions. 1. The thread should be uniform and inextensible.
2. The thread should be horizontal and in alignment with the tuning fork. In transverse rrangement the thread should be stretched in line with the length of the prong so that the vibrations $f$ the tip of the prong are at right angle to it. In the longitudinal arrangement the thread should be in ne with the line of vibration of the prong.
3. Well defined loops should be obtained by adjusting the tension with milligram weights.
4. Friction in the pulley should be least possible as otherwise it causes the tension to be less than re actual applied tension.
5. The loops in the central part of the thread should be counted for measurements. The nodes at ie tip of the prong and at the pulley should be neglected as these have some motion.

Sources of error. 1. The friction at the pulley and sparking at the platinum points cannot be tally eliminated.
2. There is a change in frequency due to the clamping screw at the tip of the prong of the luning rk.

Experiment 24.4. To verify the laws of vibrating strings by Melde's experiment that is to how that $\lambda^{2} / \Gamma=$ constant.

Apparatus. Same as in Experiment 20.3.

Theory. When a string is set into resonant vibrations by the electrically maintained tuning formy stationary waves are produced. If $/$ is the distance between the two consecutive in transverse arrangement.

$$
\begin{aligned}
& n=\frac{p}{2 l} \sqrt{\frac{T}{m}}=\frac{l}{\lambda} \sqrt{\frac{T}{m}}\left(\because \frac{2 l}{p}=\lambda\right) \\
& \frac{\lambda^{2}}{T}=\left(\frac{1}{n^{2} m}\right)=k_{1} \text { (constant) }
\end{aligned}
$$

In Longitudinal arrangement.
or

$$
\begin{aligned}
n & =\frac{p}{l} \sqrt{\frac{T}{m}}=\frac{2}{\lambda} \sqrt{\frac{T}{m}} \\
\frac{\lambda^{2}}{T} & \left.=\left[\frac{4}{n^{2} m}\right]=k_{2} \text { (constant }\right)
\end{aligned}
$$

Procedure. Same as in Experiment. 20.3.
Observations. Mass of the pan $P=w \mathrm{gm}=\mathrm{kg}$.

| Mode of <br> vibration | No. | No. of loops <br> $p$ | Length of <br> corresponding <br> thread l <br> (in metre) | Wave <br> length <br> (en <br> $p$ | Mass in the <br> pan $W$ in $k g$ | Tension $T=$ <br> $(W+w) g$ | $\frac{\lambda^{2}}{T}$ |
| :---: | :---: | :---: | :---: | :---: | :---: | :---: | :---: |
| Transverse (A) | 1 |  |  |  |  |  |  |
| Longitudinal (B) | 1 |  |  |  |  |  |  |
|  | 2 |  |  |  |  |  |  |

Verification. Within the limits of experimental error $\lambda^{2} / T$ is constant. Hence the law is verified
Precautions and sources of error. Same as in Expt 20.3.
Experiment 20.5. To compare mass per unit length of two strings by Melde's experiment.
Apparatus. Same as in Expt. 20.3. Two strings whose mass per unit length is to be compared.
Theory. When a string is set into resonant vibrations by the electrically maintained turing fork. stationary waves are produced. If $T_{1}$ is the tension applied to the first string of mass per unit length $m_{1}$, then
(i) In transverse arrangement

$$
n=\frac{1}{2 l_{1}} \sqrt{\frac{T_{1}}{m_{1}}}
$$

where $l_{1}$ is the length of one loop of the string i.e. $l_{1}=\frac{L_{1}}{p_{1}}, L_{1}$ being the length of the first string and $p_{1}$ the number of loops.

Similarly for the second string of mass per unit length $m_{2}$, if $T_{2}$ is the tension applied and $l_{2}$, he length of one loop of the string i.e. $l_{2}=\frac{L_{2}}{p_{2}}, L_{2}$ being the length of the second string and $p_{2}$ the number of loops with the same tuning fork of frequency $n$, then we have

$$
n=\frac{1}{2 l_{2}} \sqrt{\frac{T_{2}}{m_{2}}}
$$

Theory. When a string is set into resonant vibrations by the electrically maintained tuning ifr, stationary waves are produced. If $l$ is the distance between the two consecutive nodes of a loop, thene In transverse arrangement.

$$
\begin{aligned}
& n=\frac{p}{2 l} \sqrt{\frac{T}{m}}=\frac{l}{\lambda} \sqrt{\frac{T}{m}}\left(\because \frac{2 l}{p}=\lambda\right) \\
& \frac{\lambda^{2}}{T}=\left(\frac{1}{n^{2} m}\right)=k_{1} \text { (constant) }
\end{aligned}
$$

In longitudinal arrangeme hu.

Or

$$
\begin{aligned}
n & =\frac{p}{l} \sqrt{\frac{T}{m}}=\frac{2}{\lambda} \sqrt{\frac{T}{m}} \\
\frac{\lambda^{2}}{T} & =\left[\frac{4}{n^{2} m}\right]=k_{2}(\text { constant })
\end{aligned}
$$

Procedure. Same as in Experiment. 20.3.
Observations. Mass of the pan $P=w \mathrm{gm}=\mathrm{kg}$.

| Mode of vibration | No. | $\begin{gathered} \text { No. of loops } \\ p \end{gathered}$ | Length of corresponding thread l (in metre) | Wave <br> length $\lambda=\frac{2 l}{p} \text { metre }$ | Mass in the pan $W$ in $k g$ | Tension $T=$ $(W+w) g$ | $\frac{i^{2}}{T}$ |
| :---: | :---: | :---: | :---: | :---: | :---: | :---: | :---: |
| Transverse ( $A$ ) | $\begin{aligned} & 1 \\ & 2 \\ & 3 \\ & \hline \end{aligned}$ |  |  |  |  |  |  |
| Longitudinal ( $B$ ) | $\begin{aligned} & 1 \\ & 2 \end{aligned}$ |  |  |  |  |  |  |

Verification. Within the limits of experimental error $\lambda^{2} / T$ is constant. Hence the law is verified.
Precautions and sources of error. Same as in Expt 20.3.
Experiment 20.5. To compare mass per unit length of two strings by Melde's experiment.
Apparatus. Same as in Expt. 20.3. Two strings whose mass per unit length is to be compared.
Theory. When a string is set into resonant vibrations by the electrically maintained turing fork, stationary waves are produced. If $T_{1}$ is the tension applied to the first string of mass per unit length $m_{1}$, then
(i) In transverse arrangement

$$
n=\frac{1}{2 l_{1}} \sqrt{\frac{T_{1}}{m_{1}}}
$$

where $l_{1}$ is the length of one loop of the string i.e. $l_{1}=\frac{L_{1}}{p_{1}}, L_{1}$ being the length of the first string and p the number of loops.

Similarly for the second string of mass per unit length $m_{2}$, if $T_{2}$ is the tension applied and $h$, the length of one loop of the string i.e. $l_{2}=\frac{L_{2}}{p_{2}}, L_{2}$ being the length of the second string and $p_{2}$ the number floups wath the same tuning fork of frequency $n$, then we have

$$
n=\frac{1}{2 l_{2}} \sqrt{\frac{T_{2}}{m_{2}}}
$$

From equations (i) and (ii), we get

$$
\begin{aligned}
\frac{1}{2 l_{1}} \sqrt{\frac{T_{1}}{m_{1}}} & =\frac{1}{2 l_{2}} \sqrt{\frac{T_{2}}{m_{2}}} \\
\frac{1}{l_{1}^{2}} \frac{T_{1}}{m_{1}} & =\frac{1}{l_{2}^{2}} \frac{T_{2}}{m_{2}} \\
\frac{m_{2}}{m_{1}} & =\frac{T_{2}}{l_{2}^{2}} \cdot \frac{l_{1}^{2}}{T_{1}}=\frac{l_{1}^{2}}{l_{2}^{2}} \times \frac{T_{2}}{T_{1}}
\end{aligned}
$$

Thus knowing the values of $l_{1}, l_{2}, T_{1}$ and $T_{2}$ we can find the value of $\frac{m_{2}}{m_{1}}$.
The same relation holds true in longitudinal arrangement.
Procedure (i) Transverse arrangement. Set the apparatus as shown in Fig. 20.5 and proceed as in Expt. 20.3. Steps 1-6.
7. Repeat steps 1-6 by using the second string.
(ii) Longitudinal arrangement. 8. Set the apparatus as shown in Fig. 20.6 and repeat steps 1-6.

Observations Mass of the pan $=w=$

| Mode of vibration | String | No. | No. of <br> loops $p$ | Length <br> of <br> correspon <br> ding <br> string L | Length <br> of each <br> loop <br> $\frac{L}{p}=l$ | Mass in <br> the pan <br> $W$ | Tension <br> $T=$ <br> $(W+w) g$ | $\frac{T}{l^{2}}$ <br> (A) Transverse |
| :--- | :--- | :---: | :---: | :---: | :---: | :---: | :---: | :---: |
|  | First No. 1 | (i) <br> (ii) <br> (iii) |  |  |  |  |  |  |
|  | Second No.2 | (i) <br> (ii) <br> (iii) |  |  |  |  |  |  |
| (B) Longitudinal | First No.1 | (i) <br> (ii) <br> (iii) |  |  |  |  | $\cdots$ |  |
|  | Second No.2 | (i) <br> (ii) <br> (iii) |  |  |  |  |  |  |

Calculations (A) Transverse arrangement

$$
\begin{equation*}
\frac{m_{2}}{m_{1}}=\frac{T_{2}}{l_{2}^{2}} \times \frac{l_{1}^{2}}{T_{1}}=(i) \tag{ii}
\end{equation*}
$$

$$
\begin{equation*}
\text { mean } \frac{m_{2}}{m_{1}}= \tag{iii}
\end{equation*}
$$

(B) Longitudinal arrangement

$$
\begin{equation*}
\frac{m_{2}}{m_{1}}=\frac{T_{2}}{l_{2}^{2}} \times \frac{l_{1}^{2}}{T_{1}}=(i) \tag{ii}
\end{equation*}
$$

$$
\text { mean } \frac{m_{2}}{m_{1}}=
$$

Mean $\frac{m_{2}}{m_{1}}$ from both the modes $=$
Verification. Actual mass of 1 metre length of first string

$$
M_{1}=\quad g
$$

$\therefore \quad$ Mass per unit length of the first string $\frac{M_{1}}{100}=m_{1}=\quad \mathrm{g} / \mathrm{cm}$
Actual mass of 1 metre length of second string

$$
M_{2}=g
$$

$\therefore$ Mass per unit length of the second string $\frac{M_{2}}{100}=m_{2}=\quad \mathrm{g} / \mathrm{cm}$
Actual ratio $\frac{m_{2}}{m_{1}}=$

