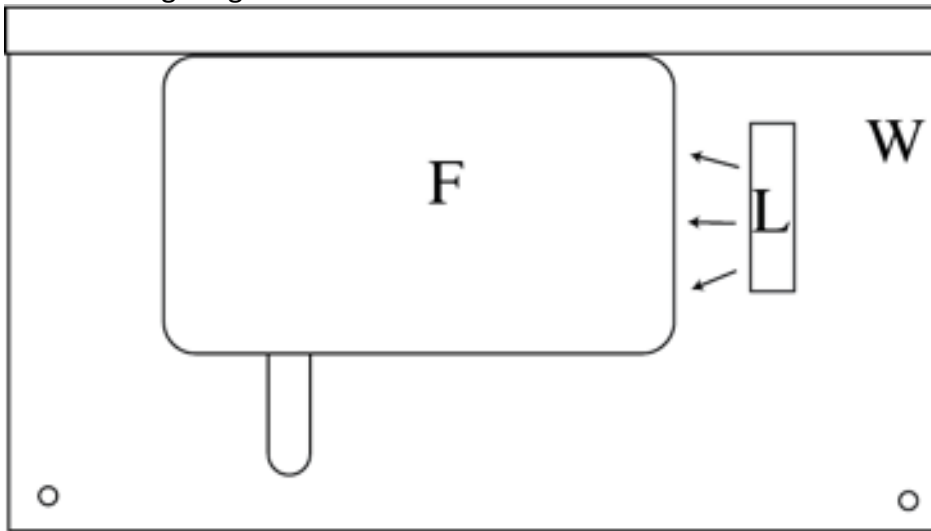Experiment 2 Solutions

Throughout the light is used in two modes when taking videos. For parts A and D, the light is set up so that it is illuminating the ferrofluid surface through the sides of the box.

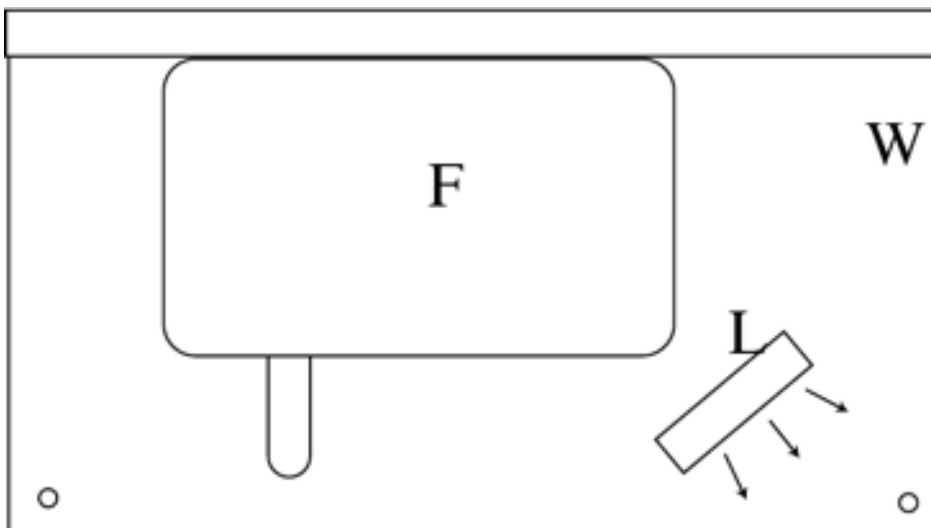This direct lighting is used in Part A and Part F.

F – box with fluid
L – light
W – wooden base

Diffuse lighting is used for other parts. In this case the light is direction up and away from the box with ferrofluid.


A1 – Direct lighting was used, so see above for diagram.
A2. Some example frames from videos are shown below.

Note that the scale on the graticule does not directly measure position.

A measurement with a ruler of the internal length of the container is
17.3 ± 0.3 cm . The distance is equivalent to 13.4 graticule squares, so there is a factor of 17.0/13.4 to convert from graticule squares to cm.
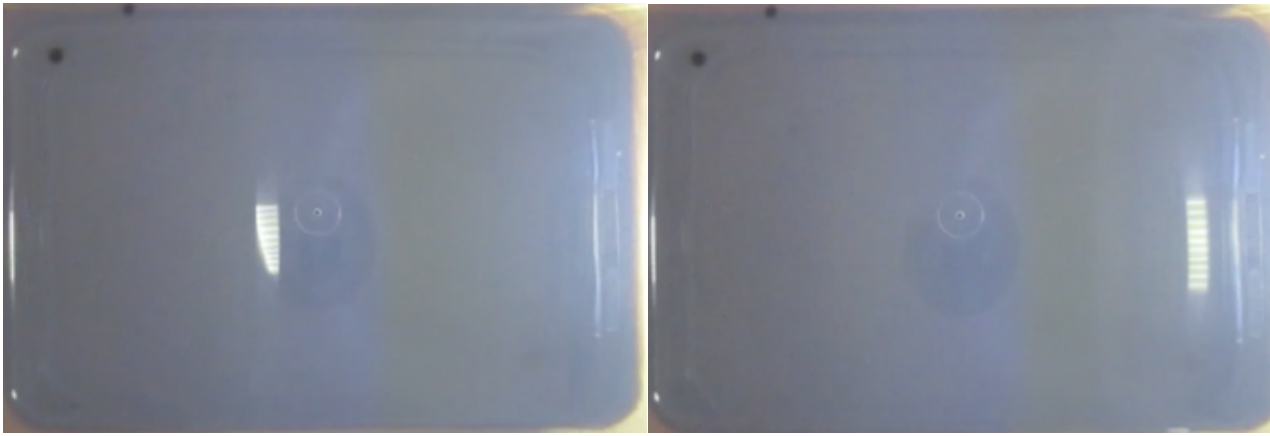
The images above show two frames from a video of a plane pulse. The videos are recorded at 25 fps by default

| Frames	Distance (graticule squares)	Distance (m)	Speed (m/s)
8	6.5	0.83	0.26
7	6.0	0.76	0.27
9	6.8	0.85	0.24

This gives $v = 0.26 \pm 0.02$ m/s

A3. The uncertainty is estimated from the spread of values.

B1. If x=0 when t=0, then $x = vt$, however, $v = \alpha\sqrt{d}$, so $x = \alpha\sqrt{d}t$.

Since the depth varies linearly, $d = y\,tan\theta$. Hence, $x = \alpha\sqrt{y\tan\theta}\,t$, or equivalently, $x^2 = \alpha^2 \tan\theta\, t^2 y$.

This approximation will be least valid when the direction of propagation varies the most from the x-direction, and when the depth is least as there are nonlinear effects. Both of these happen for small y, in other words, $y < k$ for some constant k.
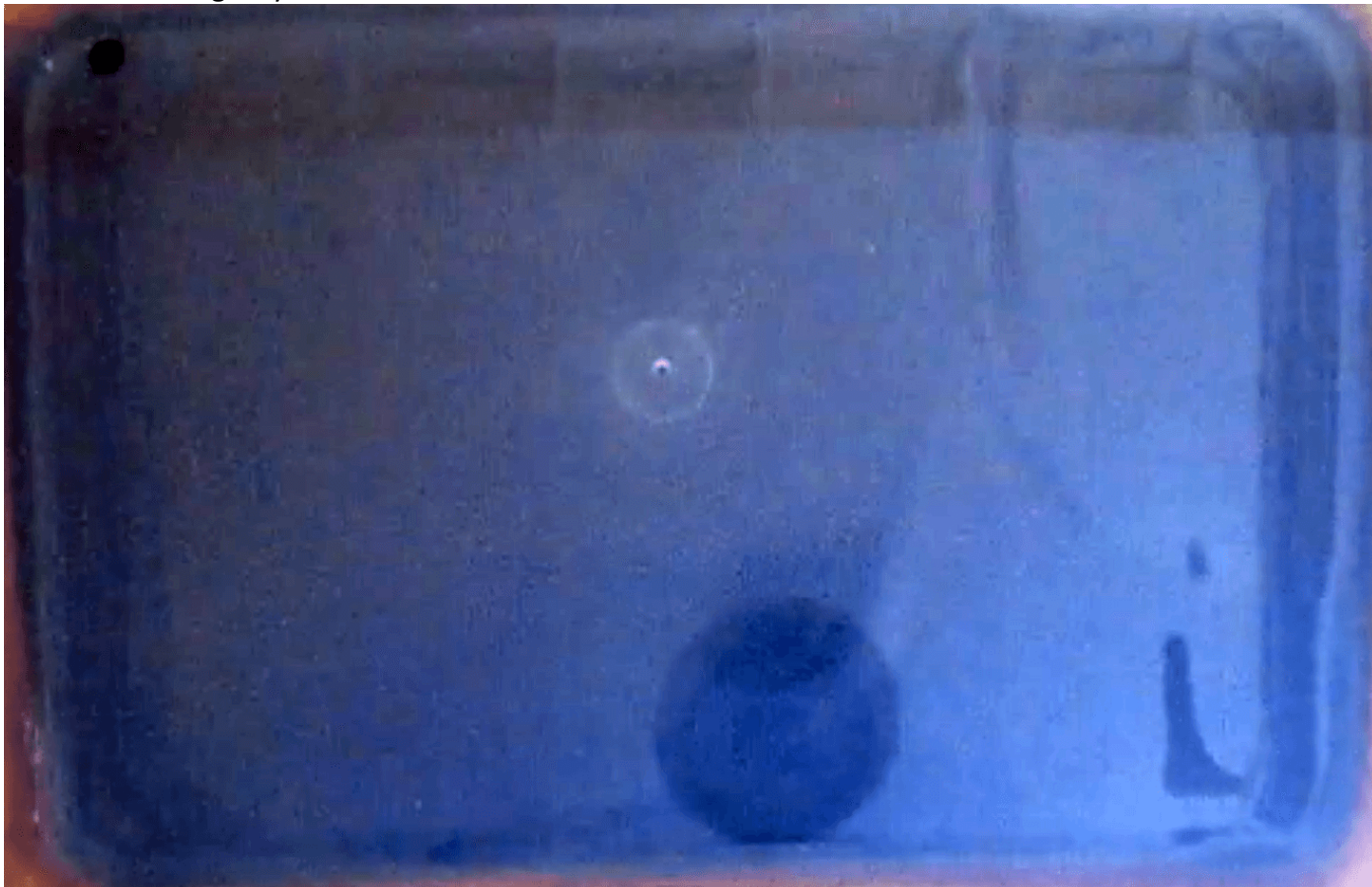
B2.
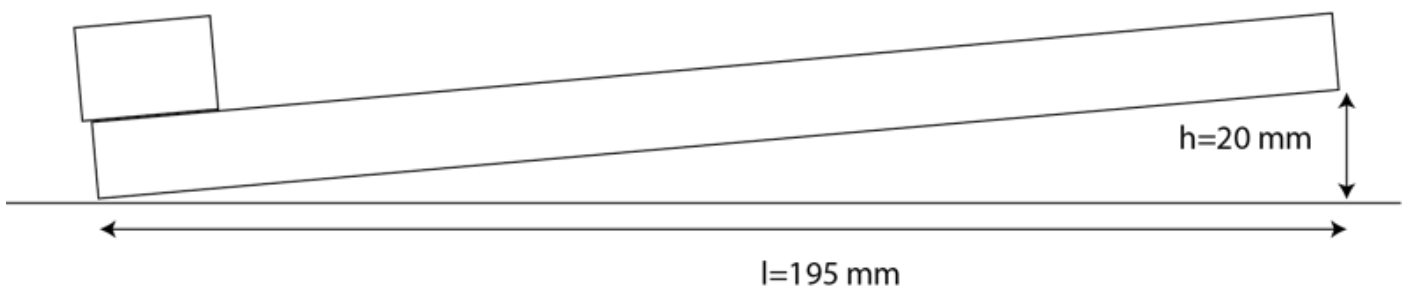
$h = 20 \pm 1\ mm$, $l = 195 \pm 2\ mm$. The latter uncertainty is larger due to difficulty lining up ruler with projection of end of the board.

B3.

B – fastest at largest y.

A – slowest at y=0.

B4. i. Diffuse light is more appropriate as the pulses are curved, so it is not possible to get direct reflections from the available source from enough of the pulse. See the start for a diagram of light position.

ii.

x (gr sq)	y (gr sq)	x^2 (gr sq^2)	(x-x_0)^2			
5	0.2	25	0.25			
6	0.3	36	2.25	t=	0.28	s
7	0.6	49	6.25	x_0=	4.5	gr sq
7.8	1.4	60.84	10.89			
8.5	2.2	72.25	16			
8.7	2.8	75.69	17.64			
9	4	81	20.25			
9.3	5	86.49	23.04			
9.8	6	96.04	28.09			
10	8	100	30.25			
9.9	7	98.01	29.16			

Here x_0 is the x coordinate of the position where the pulse front is at y=0. This is treated as the new origin.

B5

y vs x^2, y>2, at t=8/25 s

y = 0.3665x - 3.6081

y (gr sq)

(x-x_0)^2 (gr sq)^2
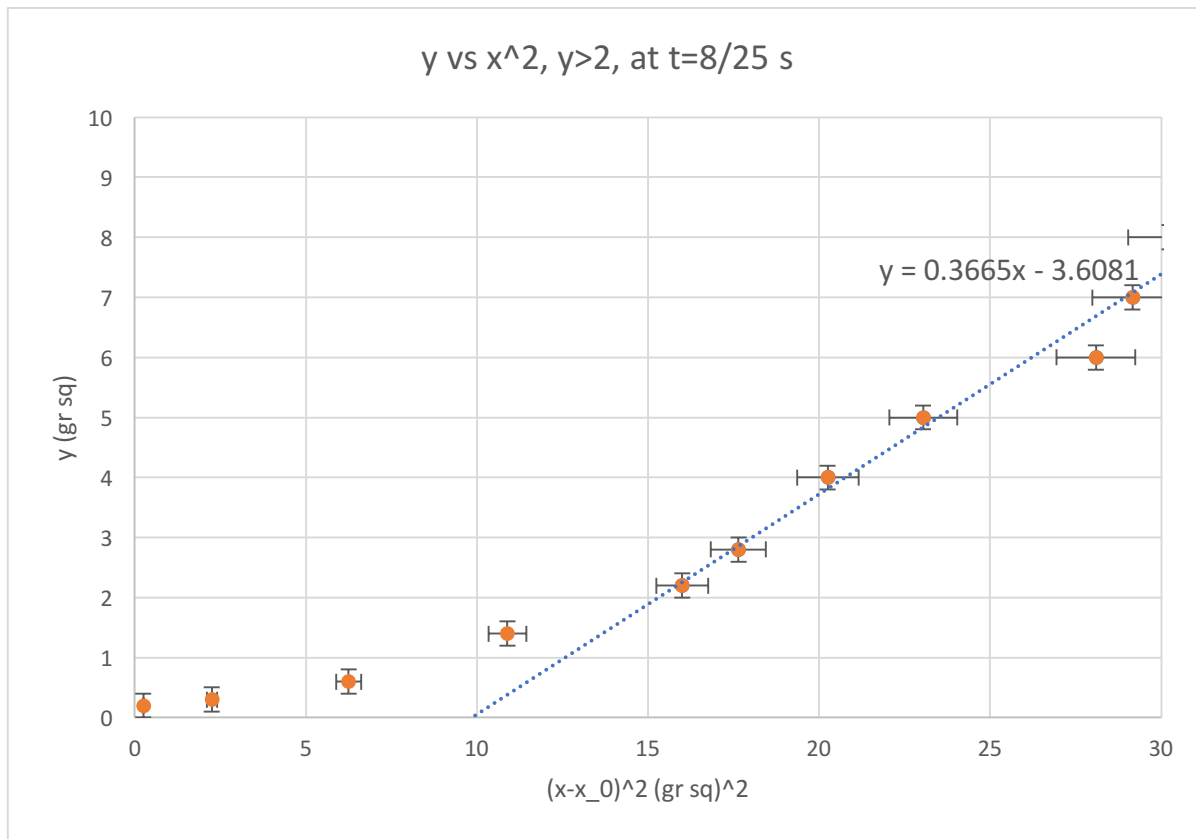
Converting to SI units, the slope m = 0.280 /m.
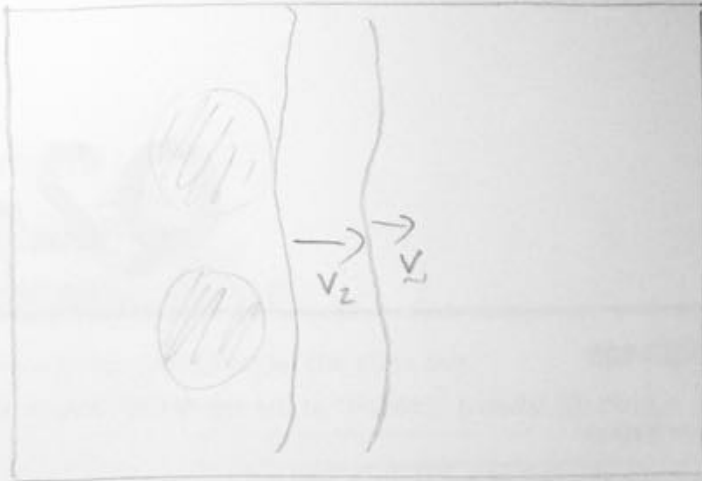
$$m = \alpha^2 \tan\theta \, t^2$$

Hence $\alpha = 5.9 \pm 0.5 \; m^{1/2}s^{-1}$, and $v(d) = 5.9 \times \sqrt{d}$.

Uncertainty was calculated from the slope of the line of worst fit m = 0.331/m.

Part C

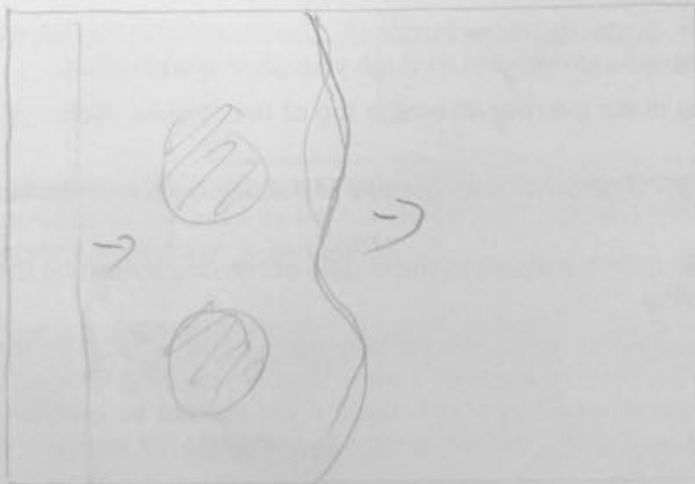mechanically driven by pushing glass

v_2 v_1

Refraction observed by perturbation of front over magnets,
Interference when the fronts meet,
Reflections from end.
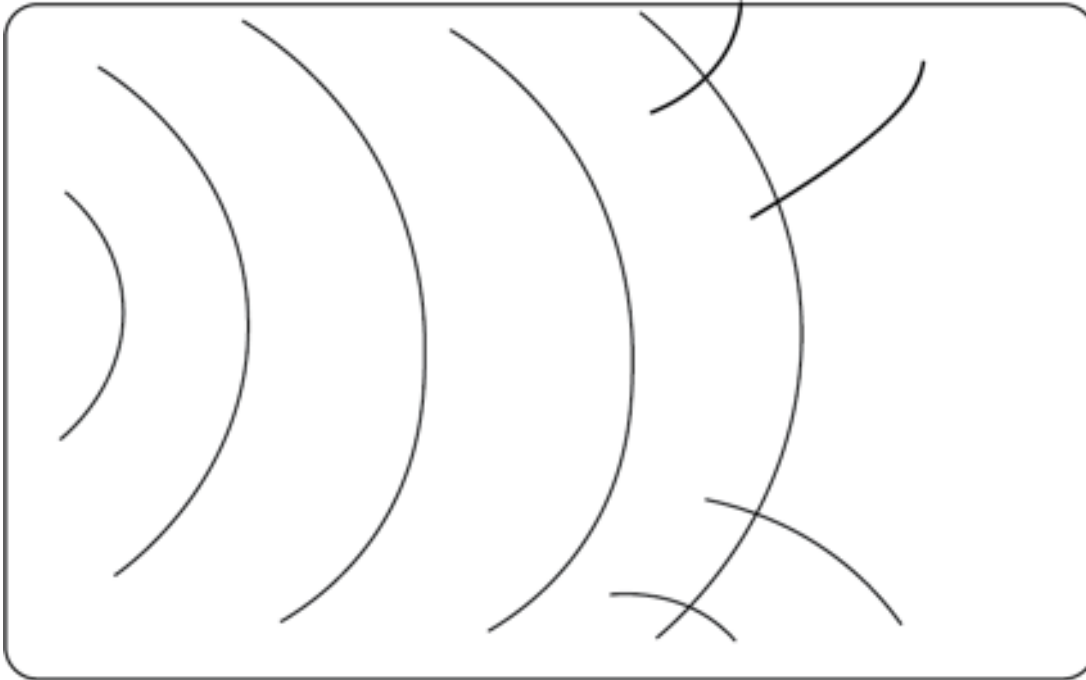
mechanically driven by pushing base

Refraction as wave is perturbed over the fronts,
Reflections from ends,
Maybe some diffraction after passing between the lumps over the magnets.

magnetically driven

Reflections from side walls and ends
Diffraction after passing between the lumps.
Interference from many waves crossing.

D1

Note the multiple lines demonstrate times rather than wave fronts.

D2 Speed measurements of the magnetically driven waves are around the same, to somewhat faster than small amplitude mechanically driven waves. Students should find that pulses are around 0.1-0.4 (gr sq)/m faster than in A2/3.

Data and sketches should look similar to A2/3 otherwise.

The height of the lump can be estimated by observing from the side, or more accurately by using the limiting value from E1 Part C.

D3 The light was placed in the diffuse light set up. See figure near start.
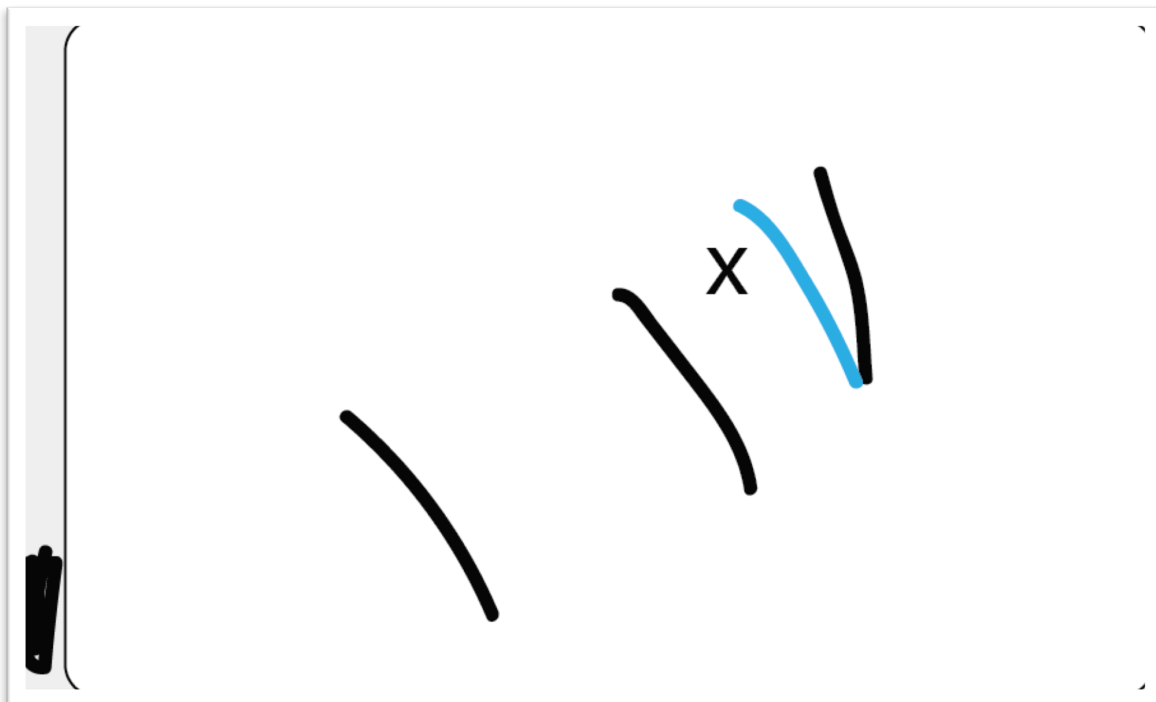
The black represents observed pulses over the magnet x. The blue represents the expected positionsing of the pulseafter travelled that distance.

A wave front was observed to travel as additional 0.8 gr sq over 8 frames. The extent of the lump is assumed to be 3cm in diamete and the additional distance in the time all occurs over the lump. This means that the wave travels at a speed of around 0.35 m/s over the lump.

By looking through the side of the box, with a ruler it is estimated the height of the lump be 5mm. The expected speed of fluid of depth 9mm, compared to fluid of depth 4mm is $\sqrt{\frac{9}{4}} = \frac{3}{2}$ times larger, which is $\frac{3}{2} \times 0.26 \frac{m}{s} = 0.39 \ m/s$. As these are estimates they are close enough that we cannot conlcude that the change in wave speed is due to anything other than the additional depth of the fluid.