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1775. Part first

Cork. 17th Sepr. 1780

Huttons experiments on the force of fired Gun powder, initial velocities of cannon balls, and the relation of the initial velocities to weight of the shot and quantity of Powder

The velocity of a cannon ball
is very great being from 1 to
2 thousand feet in a second
— To estimate this velocity it is
necessary to reduce it in some
known proportion, to a small
one. It may be effected thus:
suppose the ball strikes a heavy
body at rest from which it
does not rebound, but pene-
trates it and is carried along
with it, such as a large block
of wood. By this means the ori-
ginal velocity of the ~~bullet~~ ball
may be reduced to any slow
velocity which may be conveni-
ently measured. For it is well
known that the common velocity with

which the block and ball would
move forward after the stroke,
bears to the original velocity of
the ball only, the same ratio
which the weight of the ball bears
to that of the ball and block to-
gether. Thus their velocities of
a thousand feet in a second are
easily reduced to those of two
or three feet only. This small
velocity Mr Robins first ventured
the following curious simple me-
thod of measuring - The block of
wood was suspended like a pen-
dulum moveable upon a ho-
rizontal axis by a long iron
stem. This pendulum when
struck by the ball will be pene-
trated by it it will then swing
on its axis, and describe an arch

which will be quicker or less in proportion to the stroke: and from the size of the arch described the velocity of any point of the pendulum can be clearly ascertained; for a body acquires the same velocity by falling from the same height whether it descends perpendicularly or otherwise; therefore the length of the arch described, and of its radius, being given, the versed sine becomes known, which is the height perpendicularly descended by the corresponding point of the pendulum. The height descended being thus known, the ~~correspondin~~ velocity acquired in falling through that height, can easily be found from the common rules for the descent of bodies by the force of gravity; and this is the velocity of that point of the pendulum. This velocity of any point must be reduced to the velocity of the center of oscillation, by the proportion of their radii or distances from the axis of motion; and the velocity of this center, thus obtained is to be esteemed the velocity of the whole pendulum itself. which being now given that of the ball ~~itself~~ before the stroke becomes known from the given weights of the ball and pendulum. Thus then the mensuration of the very great velocity of the ball is reduced to the observation of the magnitude of the arch described by the pendulum in consequence of the blow struck

This arch in the following experiments was measured by its chord ascertained by a piece of tape or small ribbon one end of which was fixed to the bottom of the pendulum, and the rest of it made to slide through a small machine to be described hereafter. — The ribbon drawn out was always equal to the chord of the arch of vibration. — Besides the center of oscillation, and the weights of the ball and pendulum, the effect of the blow depends also on the place of the center of gr. and the point of impact.

First Pendulum

A Cube 20 Inches of sound dry elm fastened on the back part to a strong iron stem, with a thick iron axis at the top whose ends were turned truly cylindrical to move ~~in~~ easily in the sockets

Length of the pendulum from the middle of the axis to the end of the Ribband was 102 ½ Inch

To find the centre of oscillation the pendulum was hung up, and made to vibrate in small arcs, and the time of making two or three hundred vibrations was observed by a half second pendulum. — Having thus obtained the time answering to a certain number of vibrations the finding

of the center of ~~gravity~~ Oscillation is easy
Let v denote the number of
vibrations made in s seconds
then it is well known that

as $vv : ss :: 39.2 : \frac{39.2\,ss}{vv}$ the
distance in inches from the axis
of motion to the center of oscillation
and by this rule the place of that
center was found for each Day.

— To find the center of gravity
of the Pendulum

A rectangular iron fulcrum
was laid horizontally ~~on the~~ supported
and the Pendulum balanced
on this, while it lay in this
position the distance of the ~~fu~~
fulcrum from the center of the
axis was measured, this was
the distance of the center of gravity

Another method

The axis was [lay] horizon[tal] on two up-
rights, a cord fastened to the lower
end of the pendulum was past over
a pulley, weights were suspended
untill the pendulum was brought
to a horizontal position, then
taking the whole weight of the
pendulum and its length from
the axis to the bottom where
the cord was fixed. The place of the
center of gravity is found by this
proportion as P. the w. of the
pendulum is to W. the appended
weight so is d. the whole length
of the pendulum to $\frac{dW}{P}$ = the
distance from the axis to the center
of ~~motion~~ gravity – The coincidence
of these two methods was extremely
satisfactory.

Rule for computing the velocity of the Ball

b the weight of the ball

p the whole weight of the pend^m. ~~with its axis~~

g the Distance of the Cent: of Gy^y below the axis

h the Distance of the C^r. of Oscill^n:

k Distance to the point struck by the ball

Z Vel^y. of this point after the blow

v. Original Velocity of the ball

c the Chord of the arch meas^d. by the tape

r its radius or the Distance from the axis to the ~~axis~~ bottom of the pen^m.

Then the effect of the blow struck by the ball is as $\frac{gh}{kk}$ or as $kk : gh :: p : \frac{ghp}{kk}$ = the weight of a body which being placed at the point struck would acquire the same velocity from the blow as the pendulum does at the same point. These then are

two

bodies b and $\frac{ghr}{pk}$, the former of which with the velocity v strikes the latter at rest, so that after the blow they both proceed ~~with~~ forward together uniformly with the same velocity z; in which case it is well known that b is to $b + \frac{ghr}{pk} :: z : v$; and therefore the velocity z is $= \frac{bkkv}{bkk+ghr}$. But because of the accession of the ball to the pendulum, the place of the center of oscillation will be changed; and from the known property of that point, we find $\frac{bkk+ghr}{bk+gp}$ = its distance from the axis. Call this distance of the center of osc. of the mass compounded of the ball and pendulum H.

Then since z is the ~~distance~~ velocity of of the point whose distance is k, we have this proportion

as $k : H :: Z : \frac{ZH}{k} = \frac{6kv}{6k+9p} =$

the velocity of this compound ~~pendulum~~ center of oscillation.

Again since $\frac{cc}{2r}$ = the versed sine of the described arc c, its radius being r, therefore as

$r : H :: \frac{cc}{2r} : \frac{cc}{2rr} \times \frac{6hk+9hp}{6k+9p}$

= the versed sine ~~of~~ to the radius H, or the versed sine of the arc described by the center of oscillation which call V; then is V the perpendicular height descended by this center, and the velocity it acquires by the descent through this space is thus easily found

as $\sqrt{16\frac{1}{12}} : \sqrt{V} :: 32\frac{1}{6} : \frac{5.02c}{r\sqrt{2}} \times$

$$\times \sqrt{\frac{6kk + 9hp}{6k + 9p}} = \text{the}$$

velocity of the center of oscillation deduced from the chord of the arc which is actually described

Having thus obtained two different expressions for the velocity of this center independent of each other, let an equation be made of them, and it will express the relation of the several quantities in the question thus we have

$$\frac{6kv}{6k+9p} = \frac{5.02c}{r\sqrt{2}} \sqrt{\frac{6kk+9hp}{6k+9p}}$$ from

which we obtain

$$v = \frac{5.02c}{6kr\sqrt{2}} \sqrt{6k+9p \times 6kk+9hp}$$

the true expression for the original velocity of the Ball the moment before it struck the pendulum -

Corollary. But this theorem, may be reduced to a form much more simple and fit for use, and yet be sufficiently near the truth. Thus let the root of the compound factor $\sqrt{6k+9h \times 6hk+9hh}$ be extracted and it will be $= \sqrt{h} \times \overline{hg+6k \times \frac{h+k}{2h}}$ within the 100000th part of the truth in such cases as generally happen. But since $6k \times \frac{h+k}{2h}$ is usually but about the 300th or 400th part of hg, and that $6k$ differs from $6k \times \frac{h+k}{2h}$ but about the 50 or 100th part of it self, therefore $hg+6k$ is within about the 20,000 or 30,000th part of

$pq + bk \times \frac{h+k}{2h}$. Consequently
v is $= 8.02c\sqrt{\frac{1}{2}h} \times \frac{pq+bk}{bkr}$ very
nearly. Or farther if g be written
for k in the last term bk, then
finally $v = 8.02cg\sqrt{\frac{1}{2}h} \times \frac{p+b}{bkr}$ or
$v = 5.672cg\sqrt{h} \times \frac{p+b}{bkr}$, which
is an easy theorem to be used
on all occasions; and being
within the 3000th parts of the
truth, is sufficiently exact for
all practical purposes what-
ever. Where it must be observed
that, c, g, k, r, may be taken
in any measures, provided
they be all of the same kind;
but h must be in feet,
because the theorem is adapt-
ed to feet

Scholium. As the balls remain in the pendulum during the time of making one whole set of experiments, by the addition of their weight to it, both its weight and centre of gravity and oscillation will be changed after ~~after~~ every shot, and therefore p, g and h must be corrected after every experiment in the theorem for determining the velocity v. Now the succeeding value of p is always $p+b$; or ~~the~~ p must be corrected by the continual addition of b: and g is corrd. by taking always $g+\frac{h-g}{p+b}b$ or $g+\frac{h-g}{p}b$ nearly for each

successive values of q; or q is
corrected by adding always
$\frac{h-q}{p} b$ to ~~it~~ the next preceding
value of q: and lastly h is
corrected, by taking for its new
values successively $\frac{pqh + bkk}{pq + bk}$ or
by always adding $\frac{k-h}{pq+bk} bk$ or $\frac{k-h}{p} b$
nearly, to the preceding value
of h; so that the three corrections
are made by adding always

q to the value of p

$\frac{h-q}{p} \times b$ to the value of q

$\frac{k-h}{p} \times b$ to the value of h. —

There are three seeming causes
of error which have not been
taken into account in the fore-
going theorem. 1st the penetration
of the ball into the wood of the pend.m
2. The resistance of the air to
the back of it acted 3d. the friction
of the axis –
The former rule supposes the
momentum of the ball to be
communicated to the pend.m
instantaneously; but this is
not accurately true, because
that this force is com: during
the small time in which
the ball reaches the pend.m;
but as this is generally effected
before the pendulum has
moved one tenth of an inch
out of its vertical position,
and usually scarce amounts to

scarcely
more than the 200th part of a
second, its effect will be quite im-
perceptible, and may therefore be
safely neglected in these Exper:
force
As to the 2d retarding cause
or the resistance of the air, it
is manifest it will be quite in-
sensible when it is considered
that its velocity is not more
than 5 feet in a second, that
its surface is but about 20 Inch
square, and that its weight is
4 or 5 hundred pounds. Neith
ever
can the friction of the axis amount
to a quantity considerable enough
to be brought into account in
these experiments, for besides
the care taken to remove it in
the construction of the machine,
the effect of the little friction that
does remain is nearly both. by

the effect it has on the distance
of the center of oscillation; for as
this center was determined from
the actual vibrations of the
pend.m; the friction on the axis
would a little retard its motion
and cause its vibrations to be
slower, and the consequent
distance of this center to be greater;
so that the other parts of our
theorem being multiplied by
the $\sqrt{h}$, or the root of this distance
which is as the time of a vib.n;
it is evident that the friction
in the one case of producing and
that in the other; and that
the difference of the two is the
real efficacious cause of resistance
and which therefore is either e-
qual to nothing or very nearly so
-These three causes therefore will

not sensibly retard the motion of the pendulum: —

The Gun with which these experiments were made was of brass; the diameter of the bore or cylinder of the muzzle was 2.16 Inches; but its diameter ~~of~~ near the breech was only 2.05; so that the greatest cast iron ball it would admit was just 19½ Oz Avoirdupoise 1¼ lb — ½ Oz: — but sometimes leaden balls were used which weighed 1¾ lb, and sometimes long or cylindrical shot which weighed near three pounds; the length of the bore was 42.6 Inches, so that it was nearly 20½ Calibres long.

Government powder was used

and all the first practition in and most of the moderns — first part or straight line —

Galileo —

1.st In vacuo all bodies descend with the same vel.

2. The reason why small bodies meet with more resistance than large bodies —

3. Descent of bodies —

4. Curve in vacuo —

16
96
16
256

sufficient number of well attested facts and of well performed Exp:

There is perhaps no branch of Nat: knowledge where Exp: are more necessary and at the same time have been more neglected than that which is the subject of our present enquiry —

Hitherto almost every writer on Gunnery set out with calcul: the path of a projectile, and if you take his own for it makes it a very easy affair —

One tells us a projectile moves for some time in a straight line then in a curve —

Another that it describes a Gothic arch —

The quantity was 2 4 or 8 oz
to a charge, which was always
put into a tight flannel bag, and
rammed more or less as was usual
in each days experiments, but
without ever using any wad
before it. ——
The distance of the gun from
the pendulum was 29 or
30 feet, which distance was
found by firing the piece
with eight ounces of powder
without a ball, at different
distances till the force of the
elastic vapour was found
not to move the pendulum
— The penetration of the balls
into the wood uncertain
on account of the balls striking
often in or near the same point
the depth of the pen.n ascends

be about three inches in solid wood with two ounces of pow:

First course of experiments was on the 13 May 1775 it being a clear Day. the weights and measures then taken were these

p = 325 pounds wt. of the pend:m

g = 72 Inches Dist: Cent: of Gr:ty

h = 88 Inches = 7⅓ feet Cent: Osc:n

r = 102½ Inches Dist: to tape

The value of h = 88 was deter:m: from the number of 40 vib:ns being made in a minute, for

as $40^2 : 60^2 :: 4 : 9 :: 39.2 : 88$.

The number of shot was eight and the circumstances and results as exhibited in the following table.

The velocities in the first table computed from the preceding theorems come out all pretty regular except the first which is about one-fourth part less than the first — this irregularity caused by some unperceived accident — The values of p and g were each corrected by their respective theorems, but the value of h was kept the same $7\frac{1}{3}$ feet throughout, because that the correction was so small as not to make a difference of above a foot or two at most in the velocity: and for the same reason this correction is neglected as quite unnecessary in the rest of the experiments

The mean velo.y with 20 ounces of powder neglecting the first Exp.t is 626, and with 40 oz 915, and these two numbers are in the ratio of 1 to 1.46. But the mean weight of the balls in the former case was 17 1/3 ounces and in the latter 17 1/8, and the ratio of the quantities of powder was that of 1 to 2. but the direct subduplicate ratio of the powder compounded with the inverse sub duplicate ratio of the weights of the shot forms the ratio of that of the ratio of 1 to 1.42 which is nearly equal to 1 to 1.46 of the velocities; that is in this instance the velocities are very nearly as the square roots of the quantities of powder directly and the square roots of the weights of the balls inversely—

The powder was forced up with
only one stroke of the rammer

The 2.d course was perform'd
on the 3.d of June 1775 which
was a clear dry day but windy
-some of the Effect of that day on
each shot as is evident from this
irregularity — The powder
was taken from the bottom
of a barrel and the charges
rammed a little closer than
on the former day, and so
tight did the shots fit towards
the breech that many strokes
of the rammer was necessary
to drive them home. The
fourth and fifth shot were
spherico-cylindrical  the length
near double the diameter

The weight length, and centers of gravity and oscillation were the same as ~~in the~~ when tryed the former day the balls having been exhaled and the holes filled up with wood—

Here the first shot is again so much less than the two following ones, that some irregularity must have attended it.

It is very remarkable that in the experiments of third day the mean velocity with 2 oun of powder is 973 whereas it was no more than 626 in the former day with the same quantity of powder notwithstanding the balls were heavier with the greater velocity than with the less in the proportion of

19 to 17 nearly. This remarkable
difference should be chiefly owing
to the windage in the first course
Hence the great advantage of
the balls fitting nearly the bore of
the piece — probably some part of
this difference was owing to the
greater degree of ramming —
and probably to a difference
in the powder in different
parts of the barrel

3. The third course was made
on the 12 June 1775 it being
a clear dry and calm day
The powder was rammed
with same degree as in
the last one. It was also
nearly the same in the sea-

ceeding days as appears from
the fourth Col.: of each where
which denoting the height of the
charge, shews the degree of compact-
ness with which the Powder was
lodged in the piece. The Dimensions
as taken this day were

p = 324 Lib Wt. of the pendulum
g = 71.4 Inches Dist.: C. of Gravity
h = 55 Inches = $7\frac{1}{2}$ ft Dist. C. of Osc.
r = $102\frac{1}{2}$ Inches Length to the tape

Here the common mean Wt. of
the ball is $15\frac{2}{7}$ ounces, the mean
Velocity with two ounces of powder
is 735 and that with 4 ounces
is 1043 feet pr. Second. The Ratio
of these two velocities is that of
1 to 1.414 that is accurately as the
square roots of the quantities of powder

Experiments with the
second pendulum

No. 2 Pend: consisted of
a cubical block of sound elm of near
2 feet fixed to the iron stem
in a different manner from that
of the other, for in this the stem
was placed vertically over the middle
of the upper end where it was
divided into two branches going
down the sides and meeting at
the middle of the bottom and
fastened to the wood in different
places by iron pins. A thick
sheet of lead was fastened over
each of the two upright faces
into which the ~~ball~~ the shot was
to be fired, to guard them from
splintering very much and to in-
crease

crease the weight of the pendulum
The whole was then firmly secured
with two iron bands near the
upper and lower ends of the wood
so as strongly to resist the endeavour
of the shot to split the wood

The whole weight of the pend:
thus fitted up was 552 pounds
Length from the middle of the
axis to the lower ... bottom was
101 Inches. The Distance to the
Center of gravity was 75 Inches;
and to the center of oscillation
was 88 Inches the same as the
Inst, their vib.ns being performed
in the same time. The axis
instead of turning in hollow
grooves rested on flat pieces
of wood with a small cavity ...
...

thrown off by the shot. —
By this contrivance the friction was considerably lessened. —
A new and better machine for the tape was adapted to this foundation. — This machine consisted of about 6 or 8 inches of the list of wollen cloth, fastened upon the arch of a small piece of wood shaped into the form of the segment of a circle, the tape being made to pass through between the curved side and the list which was moderately stretched and fastened by its two ends to those of the latter arch.
When the whole the machinery was so perfect, and every circumstance attending the experiments of the two ensuing days so carefully observed that

that the conclusions resulting from them may be safely relied on —

And in those of the one day e[illegible] made with leaden balls, and of the other with iron ones, which differ greatly in weight every other circum being the same, they afford very good means for discovering the laws of the different weights of shot while the variations in the powder from two to four and eight ounces furnish us with the rule for the different quantities of it. —

4th — The fourth course was on the 20 July 1775, a fine clear day the powder was a mixture of the powder was a mixture of several of the sorts made by government, and the balls were of lead, the powder was 2, 4 and 8 ounces alternately

The dimensions of pend. in

p = 552 pounds = Wt. pendm.
r = 101 inches
g = 78 inches — C. of G.
h = 88 inches .. C. of Osc.

The uniformity of these velocities is very striking and the means with 2, 4 and 8 ounces of powder are 613, 873 and 1162 which are in the ratio of 1, 1.424 and 1.9, these numbers are nearly in the ratio of the square roots of the quantities, 2. 4 and 8, of powder, the numbers in their latter ratio being 1, 1.414 and 2, where the small difference lies chiefly ~~[illegible]~~ in the last number. A small part of this defect in the greatest velocity is to be attributed to the mean weight of the bullets used

with it being greater than in the
other, for the mean vel. of the balls
used with 8 ounces of pd. was to $28\frac{2}{3}$
ounces, while that with the 2 and 4
ounces is only $28\frac{1}{3}$; the reciprocal
subduplicate ratio of these is that
of 1 to 1.006 in which proportion
increasing 1.9 the number for the
greater velocity it becomes 1.91
which still falls short of 2 by
.09 which is about the $\frac{1}{22}$ part
too small for the subduplicate
ratio of the powder. This defect
of a 22d part is owing to 3
evident causes. 1st. The less
length of cylinder through which
the shot was impelled; for by
observing the height of the charge
in the 4th. Col. it appears that
the

be at least three or four miles
nearer to the muzzle of the piece
with the eight ounce charge
than with the others — 2
The greater quant: of Elastic
fluid which is evolved in this
case than in the others by the
and more windage, on account of ~~the~~ the g:
velocity — 3 Greater quantity
of powder blown out unfired, in
this case than in the lesser
velocities, for the ball continues
a shorter space of time in the piece
and also in this case had a
less length of barrel to move
through — besides the quantity of
is greater, on this account the
powder will take longer time to
be inflamed — The effect however
will arise chiefly from the first
and

each of these causes, as that of the
second will amount to very little,
because that the effect arising from
the greater velocity with which
the fluid escapes at the vent
and windage, is partly counterbalanc-
ed by the shorter time in which
it acts. From the above reflec-
tions
we may also perceive how
small the quantity of powder
is which is blown out unfired
in any of these cases, and the
can any way ~~velocity~~ quickness
with which it fires is occasion-
for although 8 ounces of powder
impelled the ball nearly in half
the time that 2 ounces did it,
it is evident that in half the time the
there was nearly four times as

quantity of powder fired

5th. The fifth or last was

was on the 20 Apr. 1775

fine clear weather but a little

windy — the machinery and

the balls were of iron — powder

the same as in the last war

Dimensions

p = 553 pounds

i = 101 Inches

g = 75½ Inches C. of G.n

h = 84.775 Inches C. of Osc.n

= 7.066, the pendulum making

65 vibrations in 100 seconds

The mean Vel.

by — 4 — 8

2

701 — 993 — 1397 — ÷

= 1 : 1.416 : 1.993 but subdupl.

ratio of the weights as

1 : 1.414 : 2 sufficiently near

the former

Thus as in the last ounce, the greatest difference lies in the last number which answers to the greatest velocity, and which is again in defect. It will still be a little more in defect if we make the allowance for the weight of the balls; for the mean weight of the balls with the 2 ounce weights is $18\frac{3}{4}$ ounces, but of the 8 ounces $18\frac{7}{5}$; diminishing therefore the number 1.997 in the reciprocal & subduplicate ratio of $18\frac{2}{3}$ to $18\frac{7}{4}$, it becomes 1.985, which falls short of the number 2 by .015 or the 133 part of it self; which defect is to be attributed to the same causes as in the last ounce

Let us now compare the corresponding velocities in this course and the last.

	2	4	8
In this course they are	701,	993,	1397
In the last they were	613,	573,	1162

Now the ratio of the first two numbers or the velocities with 2 ounces of powder is that of 1 to 1.1436; the ratio of the next two is that of 1. to 1.1375 and that of the third is that of 1 to 1.2022. But the mean weight of the shot was for 2 and 4 ounces of powder 25 $\frac{1}{2}$ ounces in the last course and 12 $\frac{3}{4}$ in this: taking now the reciprocal subduplicate ratio of these weights of shot, we obtain

the

ratio of 1 to 1.224, for that of
the balls fired with 2 and 4 ounces
of powder, and the ratio of 1 to
1.224 for the balls fired with
8 ounces of powder. But the real
ratios above found are not much
greatly different from these, and
the variations of the actual ratios
from this law of the weights of
shot incline the same way,
in this course, as they appear
to do in the second course of
these experiments.

We may now collect what
are the principal infer-
ences from these experiments

1st It is evident that powder fires
almost instantaneously, seeing
that almost the whole of the
charge fires through the time

be much diminished —

2. The velocities commun.d to balls or shot of the same wt. with different quantities of powder are nearly in the subduplicate ratio of those quantities; a very small variation in defect taking place when the quantities of powder become great.

3. And when shot of different weights are fired with the same quantity of powder, the velocities commun.d to y. are nearly in the reciprocal subduplicate ratio of their weights. —

4. So that universally if the powder and shot are both diff: the velocities directly as the square roots of the quantities of powder, and inversely as

the square roots of the weights of the shot.

5. It would therefore be a g^t. improvement in Artillery to make use of shot of a long form or of heavier matter; for thus the momentum of a shot when fired with the same weight of powder would be increased ~~with same~~ in the ratio of the ~~weight~~ square roots of the weights of y^e shot. —

6. It would also be an improvement to diminish the windage; for by ~~that~~ so doing one third or more of the quantity of powder might be saved —

7. When the improvements

mentioned in the last two
which are considered as both
Lightning Balls, it is evidently.
about half the quantity of
powder might be saved, which
is a very considerable object.
But important as this saving
is it is still exceeded by the [illegible]
of the Guns; for thus a small
Gun may be made to have
the effect of one two or three
times ~~as large~~ its size in the present mode by discharging
a ~~ball~~ Shot two or three times
the weight of its natural
ball. And thus a small
ship might discharge
shot as heavy as those of
the greatest now made use
of

Finally as the above expts.
exhibit the regulations ~~and~~ wt.
regard to the weights of powder
and ball when fired from
the same piece of ordnance, so
so by making similar expts.
with a Gun varied in its
length, by cutting off from its
a certain part before each
course of Experiments, the
effects and general rules for
the different lengths of guns
may be certainly determined
by them. In short the princi-
ples on which these expts.
were made, are so perfect &
unexceptionable, that, in every condition
with the effects resulting from the
resistance of the medium, they seem
to be sufficient for answering all the purposes
~~[illegible]~~ enquiries of the speculative Philo-
sophers, or indeed the pract: Artillerists.

4th Day's Experiments

No.	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	
	Oz.	Inches	Inches	Inches	Oz. Dr.	pounds	pounds	Inches	Inches	feet	
1	2	2.021	2.88	90.–	28.4	1.766	552.0	78.0	14.8	612	
2	4	2.021	4.4	87.	28.4	1.766	553.8	78.0	20.5	879	
3	8	2.032	7.1	87.	28.12	1.797	555.5	78.1	27.5	1164	
4	2	2.026	2.88	90.	28.8	1.781	557.3	78.1	15.0	622	
5	4	2.026	4.4	88.	28.8	1.781	559.1	78.1	20.6	871	
6	8	2.032	7.1	92.	28.12	1.797	560.9	78.2	28.5	1154	
7	2	2.021	2.88	89.8	28.4	1.766	562.7	78.2	14.3	605	
8	4	2.026	4.4	91.3	28.8	1.781	564.5	78.2	21.0	870	
9	8	2.026	7.1	87.–	28.8	1.781	566.2	78.3	26.8	1169	
1	2	2.062	3.	88.3	19.–	1.188	553.0	78.1	11.4	702	
2	4	2.062	4.3	88.3	19.–	1.188	554.2	78.1	17.3	1068	
3	8	2.062	6.7	91.0	19.–	1.188	555.5	78.2	23.6	1419	
4	2	2.070	3.	90.7	19.3½	1.201	556.8	78.2	11.4	652	
5	4	2.050	4.3	90.7	19.8½	1.221	558.1	78.2	17.3	1020	
6	8	2.064	6.7	90.7	19.0¾	1.190	559.4	78.2	22.3	1352	
7	2	2.060	3.	91.0	18.15	1.184	560.6	78.3	11.4	696	
8	4	2.058	4.3	90.	18.14	1.180	561.9	78.3	15.3	948	280
9	8	2.049	6.7	90.–	18.9¾	1.163	563.1	78.3	22.9	1443	
10	2	2.047	3.	88.3	18.9	1.160	564.3	78.3	10.9	703	
11	4	2.037	4.3	88.3	18.4½	1.142½	565.5	78.4	14.8	973	
12	8	2.036	6.7	88.3	18.3¾	1.140	566.6	78.4	20.6	1360	
13	2	2.034	3.	92.–	18.3	1.137	567.8	78.4	11.4	725	
14	4	2.034	4.3	92.	18.3	1.137	569.0	78.4	15.0	957	987
15	8	2.031	6.7	94.3	18½	1.141×	570.1	78.5	22.5	1412	1431

	number	weight of powder	Diameter of the ball	length of the charge	Length be-tween the axis × R	weight of the ball	weight of the ball &c	weight of [illegible]	radius of [illegible]	chord of the arc &c	velocity of the ball
		Oz	Inches	Inches	Inches	Oz	pounds	pounds	Inches	Inches	feet
1	1	2	1.98		92.5	17½	1.094	328.0	72.0	13.0	458
	2	2	1.98		92.5	17½	1.094	329.1	72.1	17.8	631
	3	2	1.98	3.15	91.6	17½	1.094	330.2	72.2	15.1	650
	4	2	1.97	3.15	91.	17¼	1.078	331.3	72.3	17.6	646
	5	2	1.97	3.15	90.5	17¼	1.078	332.3	72.3	16.3	604
	6	2	1.96	3.15	92.4	17—	1.063	333.4	72.4	16.2	598
	7	4	1.97	4.5	92.—	17¼	1.078	334.4	72.5	24.0	881
	8	4	1.94	4.5	90.5	17—	1.063	336.5	72.5	25.0	950
2	1	2	2.08	2.55	88½	19½	1.219	328.0	72.0	24.3	800
	2	2	2.08	2.50	89.	19½	1.219	329.2	72.1	30.5	1003
	3	2	2.05	2.55	93½	19½	1.219	330.4	72.1	30.0	943
	4	2	2.08	3.35	92½	46½	2.906	331.6	72.2	57.0	767
	5	2	2.08	3.36	93—	46½	2.906	334.6	72.4	54.0	731
3	1	2	2.050	2.55	94.—	19½	1.219	324.0	71.4	23.0	700
	2	2	2.036	2.55	94.—	18¼	1.141	325.2	71.5	24.5	799
	3	2	2.045	2.55	93½	18½	1.156	326.4	71.6	22.—	715
	4	4	2.062	4.—	92¼	19—	1.188	327.5	71.7	27.3	888
	5	4	2.036	4.—	93½	18¼	1.141	328.7	71.7	35.0	1163
	6	4	2.045	4.—	93½	18½	1.156	329.9	71.8	33.0	1087

A new case in Squinting
by Doctor Darwin —

1 The boy five years old, viewed every object presented to him but with one eye at a time

2. If the object was presented on his right side, he viewed it with his left eye; if on his left, he viewed it with his right eye. —

3. He turned the pupil of that eye next the object, in such a direction ~~so that~~ the image of the object might fall on that part of the bottom of the eye where the optic nerve enters it —

L. When tired with viewing an object with one eye, he turned his head the contrary way and viewed it with equal facility with the other which was equally strong, and had the same limits of distinct vision

From this it appears that there was no defect in either eye, which is the common cause of squinting; but was the effect of L. Dufrasne habit of moving his eyes, which might probably have arisen from the form a particular cap on head dress hiding ~~over~~ the object from one eye whilst the other could view it more easily.

A squint may sometimes be occasioned by wearing a tender eye for some time — By wearing the good eye, the weak one gains, and the good looses something, both which are necessary in the cure of a squint —

Cure of a Muscular contraction in the neck by Electricity — W^m. Newby — Sparks taken from the Muscles most contracted either by sitting her on the electrical stool, or on a chair and using the Glass handled discharging rod, Miss Longford was electrified about three weeks once a day and was perfectly cured and has continued well for some time.

From Mr Marsden's account of
the Island of Sumatra

At Fort Marlboro' near Ben-
coolen in Sumatra the air is
not near so sultry as ~~might~~
from its vicinity to the Equat.
might be expected.

The Thermometer is never
lower in a morning at 6
than 69, or higher than 76.
At noon it varies from 79°
to 88, and at 8 P.M. from 73
to 78 or 80. I have only once
for a year past seen it at
90. and in the Batta country
immediately under the line
I have seen it frequently at 61 at 6 A.M.

A sea breeze always sets in about 9 o'clock A.M. and continues to sunset it is generally pretty fresh and I have never been incommoded by the heat even in the middle of the Day so much as I have frequently been on a Summer's day in England. Rain is very frequent, sometimes very heavy and almost always attended with thunder and lightning we have had a Violent Earthquake since my arrival here. There are several Volcanoes in the Island one in sight of Malbro which continually emits smoke, and at the time of the Earth: quake.

The people in the inland parts of the country are all the same character both in the Melow[?] as the inhabitants of this part of the Island &c. They write on long narrow slips of the bark of a tree with a piece of bamboo; they begin at the bottom and write from the left hand to the right, w.ch I think is contrary to the custom of all other eastern nations — The country is very hilly. In many places it is impossible to ride — The inhab.ts are a few people and live in small villages called Doosans independent of each other, and

governed each by its own
chief, Doopattee. All of them
have laws, some written ones.
They have almost all of them
particularly the women large
swellings in the throat, some
nearly as big as a man's head
but in general as big as an
ostrich's egg, like the Goitres.
It is by them said to be owing
to their drinking a cold white
water. I fancy it must be some
impregnated water they mean.
In the Alps it is supposed to
take its origin from snow-
water, but here there is no
snow. In almost all the
central parts of Sumatra
they find Gold and some iron.
I met here with a ~~s~~ vein of
smallest

of strong sulphurated water so
hot that a quarter of a mile below
the source that I could not walk
across it — The Cassia country
under the line is inhabited by
a people called Battas who
differ from all the other inhabitants
of Sumatra in Language, man-
ners and customs. They have
no religious worship, but have
some confused idea of three super-
ior beings two good and one
bad this last they call Mungiro
to him they use some kind of
incantation to prevent his doing
them any hurt. They think
their Ancestors a kind of superior
beings and always attendant
on them. They have no king
but live in villages, Compongs,

independent of each other, and are perpetually at war with one another. They fortify their villages very strongly with double fences of bamboo planks pointed and placed with their points projecting outwards and between these fences they put pieces of bamboo hardened by fire, and likewise pointed which are concealed by the grass, but will run quite through a mans foot They never stir out of these compounds unarmed. Their arms are match lock guns which as well as the powder, are made in the country and spears with long iron heads

They do not fight in open manner but way lay and shoot or take prisoner single people in the woods or fields. These prisoners if they happen to have given the offence, they put to death and eat and hang up their skulls as trophies in the houses where the unmarried men and boys eat and sleep. A man may purchase as many wives as he pleases; but their number seldom exceeds eight. They have no marriage ceremy: but when the purchase is agreed to by the father ~~the~~ the man kills a buffalo or a horse, invites as many people as he can and he and the woman sit and eat together before the whole comp:"

and are afterwards considered
as man and wife.—
A man detected in Adultery is
punished by death and the body
eaten by the offended party and
his friends, the woman becomes
the slave of her husband and
is rendered infamous by cutting
off her hair.— Publick Theft
is also punished by death and
the body eaten. All the wives
live in the same house with
the husband, and the houses
have no partitions; but each
wife has her separate fire-
place. Girls and unmarried
women wear 6 or 8 large rings
of thick brass wire
about their neck, and great
number of tin rings in their
ears; but they lay them all aside

when they marry. They preserve
the Bodies of their Radjas or per-
sons who have property, for several
months before they bury them
They put the body into a coffin
well caulked with Dammar a
kind of resin; they place the
coffin in the upper part of
the house and having made
a hole in the bottom put there-
to a piece of bamboo which
reaches quite through the
house and three or four
feet into the ground, this
carries off the putrid matter
and prevents smell. They
have great ceremonies at the
funerals but would not ad-

mit me be in them. I ~~heard~~
saw several figures dressed
like men ~~[illegible]~~ and heard
a sound of singing and dancing
all night before the body was
interred; they also fired a
great many guns. At these
funerals they kill a great
many Buffalos; Every Radja
for a considerable distance
brings a Buffalo and kills
it at the grave of the deceased;
sometimes even a year after her
interment; we assisted at the
ceremony of killing the 106 Buff
at a Radjas grave –
The Battas eat black cattle
Buffalos, horses dogs, cats and
every other animal & chicken

killed by themselves or found
dead.—Man's flesh may be rather
used to be eaten in terrorem
than to be their common food;
yet they prefer it to all others
and speak with peculiar rap-
tures of the soles of the feet and
palms of the hands.—

Dr. Haygarth's Observations
on the population and Diseases
of Chester —

It is very surprising that
according to this Gentleman's
observation, the inhabitants
of Chester should have near
an equal chance of living to
twice the age of the inhabitants
of Vienna London or Edinb.
and that so large [a] town [its] inhabitants
as far as engineers have more
should approach too nearer pro-
portion of longevity than as
25 to 40. The air of Chester
is uncommonly clear. In the
last four years there were
only six foggy. and thirty

two hazy mornings — In general the atmosphere in the western, is clearer than on the eastern shore of Britain tho' more rain falls on the west than on the east side of the Island.

— The large quantity not rather than the rich quality or exquisite flavour of what we eat and drink is injurious to health.

— The inhabitants of Chester in 1774 were 14713

1060 never had the small pox

that is 1 in 14.

— The proportion of deaths by the small pox to all the deaths this year is 1 : 2.7

under 1 month old not one
died of the small pox by inoc:
under 6 months only 7 out
of 202, and yet above a quarter
of the whole died under one year
old.
Deaths this year 162 males
149 females, a majority of 13
males; 52 husbands and 50
wives, Maj: 2; 25 widowers
and 45 widows, a maj: only
of 20 widows tho' by the
general survey there are 251
widowers and 736 widows
or near three the number.
The total of males is 6697
and of females 5016 hence
there is near a fifth majority
of females. That females live longer
than males has also been proved

by Doctor Price —

The number of married persons
is 4551, unmarried 9532
that is nearly 1/3 is married
which is a common proporti-
Upwards of one half the inhabi-
tants above 15 years old
are or have been married
the proportion being as 4:7
Though Chester is uncommon-
ly healthy yet like most other
great towns it is unfavourable
to population — Upon an
average of ten years one marriage
produces less than three children
This small proportion is part-
ly owing to the want of manufact-
-ures taking the whole town the
number of persons in each fa-

nearly is $4\frac{1}{3}$. The inhabitants under 15 years old are 4456 i.e. more than a third. The proportion of deaths this year, to the no. of inhabitants is nearly as 1:27

The no. who died in Autumn and winter greater than in spring and summer [illegible] by near $\frac{1}{6}$

Saluberrimum ver est: proxime deinde ab hoc hiems periculosior aestas; Autumnus longe periculosissimus

From Doctor White's Experiments
on air &c. at York — Read Feb 5 1775

The Appa. used in these Exp.
consisted of a vessel full of water
of a proper size and figure,
2° a common barometer tube
of a large bore, so that an ounce
phial full of ~~or~~ air ~~would fill~~
being introduced into it, o-
ccupied at a medium 134
decimal parts of an inch: and
upon a further addition of an
half ounce phial of it the whole
air 205: this tube is graduated by
by inches and Decimals 3°
Glass funnels with necks of
such a size as to enter the
tube

The air is conveyed into the
tube by means of the glass
funnel under water, the nitrous
air is then added to it by the
same method: the space occu-
pied by them both immediately
upon mixture is noted down
~~note~~ the time by a watch:
after standing the appointed
time half an hour or two minutes
(the other was mentioned) the
space then occupied is marked
down which being deducted
from the first gives the result
of diminution sought
To compute on some subject
of air from a hundred parts
with the addition of nitrous
air took up the space of 195,
parts of the first being absorbed

by the water in its passage
through it; after half an hour
still 195; so that the diminution
following, it was known to be
mephitic ~~air~~ August 30th the
same quantity of the air of my
garden, with the nitrous air occup:
205, after half an hour it was
diminished to 145 which being
deducted gave 60° the state of the air
that day — The medium state
of the atmosphere in upwards
of 200 ~~ex~~ experiments was
60 or 61 — [illegible] to the worst
state I have ever observed it, on
the 13 Sept., ~~k~~ is 55°, this was
the day on which a slight
shock of an earthquake was
felt

August 9. In the City 59, without the water 62

On the 11th the first was 60 the last 62

Common air agitated with water for half an hour was made worse. In one Exp.

first 59° to 57

2 61 - - 59

3. 62 58

The following Exp. shows the effects of Animal Exhal.s on air

The air of my bed at night I found to be 62, the next morning it was reduced to 58; this diminution will appear very considerable upon observing that it was the effect of the breath &c of a single person

in a large airy room, the bed
curtains always open. candles on
the side facing the window —
large gardens before the room or
None appear the unwholesome-
ness of small rooms close beds
&c., especially in delirium.

— Some air which I had re-
spired as long as could be
without discomfort or incon-
venience was reduced from 62
to 40

— A small piece of fresh meat
was put into a phial cont.g
eight ounces of comm. air. after 24
hours it was reduced from 64°
to 55, the flesh perfectly sweet
24 hours longer, the air was
reduced to 40. nearly mephit

yet the flesh was not putrid
it only smelled a little faint
and musty.
It is evident that something
escaped from the flesh, which
yet void of any putrid smell,
so as to render the air noxious:
I suppose this effluvia to be
pure phlogiston. Hence it seems
that this principle is capable
of escaping as a concomitant
with the saline part of ani-
mal bodies, the union of which
is supposed to give the putrid
smell. It proves also Dr. P.
Priestley's supposition that
phlogiston ~~in~~ when single
is imperceptible to the smell.
It also shews it to be putre-
factive. In our experiments

It was devoid of smell, conseq.^t 4
contained no mixture of volati-
lized ~~alkali~~ acid; yet it had
the common property ~~of contami~~
~~nating with~~ all putrid effluvia
of rendering the air noxious
Air taken from within a
~~common~~ privy was found
in several experiments to be
equally good with common atmosph. [illegible]
air — This shows that the feces
humanae are little or nothing
infectious —

Vegetable effluvia corrupt
the air the same manner as
animal — The flowers most
the leaves next. —

The leaves and flowers of corn.
were put into eight burning

avi

reason a tendency as to spoil
the air and render it not only
useless but fatal to animal
life, and that in so short a time
We have here a striking
example of the necessity of Exp:
by them alone we can add cer-
tainty to science, and develope
nature in her most secret and
obscure operations; and as she
is unchangeable in her self,
every discovery extorted from
her is immutable. It is affirmed
by a late writer "that the effluvia
of rotten vegetable matter have
little effect in contaminating
the air, from some Exp: it appears
"that they possess rather an an-
"tiseptic virtue"

we know however from fatal
Experience that both animal or
vegetable substances ~~have~~ when
in a corrupted state, are the ob-
vious causes of the most dread-
ful and alarming diseases
from the mildest fever even
up to the plague —
A jail fever was occasion-
ed by the infection of a gangrenous
leg — Dreadful fevers were occasion-
ed at Venice by a quantity of cor-
rupted fish, and at Delft by
putrid cabbages and other
vegetables. — Our senses
are by no means capable of
distinguishing infection, for
where there is no smell there
is frequently a ~~high~~ number
exhalations indicating a putrid state

only one small grated window
to the west, the air within could
neither circulate nor be changed.
In less than hour after their being
inclosed, many of the unhappy
people were seized with violent
difficulty of breathing; several were
delirious, the place was filled with
incoherent ravings, and cries of
distress: the cry of water water was
predominant, it was handed to
them by the centinels, but had
no effect in easing their thirst.
Before eleven o'clock many were
suffocated or died violently delirious
by 12 all that survived except
a few at the grate, were to the highest
degree phrenetic and outrageous
They now found no relief from water
but air could not be procured

soon after three all the great num-
so inconceivable that we have no acct
of what happened till they were
released next morning at 6 o'clo
Such were the effects of animal efflu
in a close and unventilated place
~~that~~ in the space of eleven hours
that out of 146 no more than 23
came out alive, and those in a high
putrid fever of which however by
fresh air &c they were soon recovered

Fresh cut fruit have in com-
mon with other vegetables a
power in polluting the air &
rendering it noxious.

From Expts on Mint, Camphor
Assa fetida &c it appears that
the power of corrupting the air of
vegetables is not owing to their
odour. Those odours have no effect
corrupting the air. In these expts

the substances were enclosed 16 h
and yet the air was little affected.
While plants are growing in a
vigorous state they then absorb
from the atmosphere and purify)
but their nature with their life they
then exhale putridity and render
the respiration. How perfect is the
agreement between animal and
vegetable substances —

— Hence the danger of filling rooms
with nosegays and branches of
flowers —

— Volatile alkali is perfectly
innocent —

Consequences of Dr. Whites Expts

1. The atmosph: air is rendered more
by a long continuance of respiration
2. It is purified by warmth and winds
especially westerly winds
3. It is more so in winter than in the country

4. This quality possessed by the air from animal and vegetable substances when not growing though perfectly sweet and free from putridity, nearly in an equal degree, and thus is vegetables not owing to their aroma or odour. 5

5. Phlogiston. air alone

6. Air unperceptible to the smell &c.

7. — is & is perfectly hot

8. The absence of disagreeable smell is by no means a criterion of the healthiest state of Souls &c. or of their freedom from infection

9. The odours does not injure the air nor do volatile alkalies

10. The air is generally from over waters

11. — greatly injured by the effluvia from the black mud of bogs and marshes —

12. But this is much obviated by laying them under water

13. Air is not hurt by earth and when perfectly dry.

14. Air is also infected by the dust of the streets.

15. Pure loamy earth but little affects the air —

16. Air not hurt by some clay soils, nor by those of some sand —

in the living body — we must not
therefore judge of the wholesomeness of ships
hospitals &c by there being well aired
the crowding together a number of people
in camps hospitals &c will be attended
& if the weather is hot generate a
most malignant fever of the low
There a most remarkable in
stance in the affair of Calcutta
Mr Holwell and 145 more people
in health were by order of the Vice-
roy shut up in a place of confinement.
at 7 o'clock in the evening. The
place was 18 feet by 18 containing
324 square feet. so that each person
has a space 26½ inches by 12
which was sufficient to hold them
without pressing violently on each
other. the weather was extremely
sultry, and the place having only