香港考試及評核局
Hong Kong
Examinations and
Assessment Authority

Hong Kong Diploma of Secondary Education Examination

Physics and Combined Science (Physics)

School-based Assessment Sample Tasks

(Practical Related Tasks)

Teachers may use the sample tasks for non-profit making educational and research purposes with proper acknowledgement.

TABLE OF CONTENT

Practical Skills (%)	
Reporting (%)	
Total	

E1 Relationship between Pressure and Volume of Gas

Name :__________
Class :__________ No.:______
Date :__________

Objectives: To investigate the relationship between pressure and volume of air in a syringe.

Apparatus:
60 cm^3 plastic syringe
Bourdon gauge
rubber tubing
vaseline

Theory:

Boyle's law states that pressure is inversely proportional to the volume of a gas, provided that the mass and temperature of the gas remain constant. This relationship can be demonstrated by a syringe of air. The syringe is connected to a Bourdon gauge to measure the pressure. The volume of the gas can be estimated by reading the scale on the syringe.

Procedures:

1. Take out the piston of the syringe. Put a little vaseline evenly on top of piston. Fit the piston back to the syringe.
2. Set the volume of air inside the syringe to roughly 25 cm^3.
3. Connect the syringe to the Bourdon gauge with rubber tubing. Put a little vaseline on the surface of connectors before fitting in the rubber tubing.

4. The Bourdon gauge should read roughly 1.0×10^5 Pa (approximately equal to atmospheric pressure). As the pointer of the Bourdon gauge may get stuck due to the friction of the mechanical parts inside, tap the Bourdon gauge slightly every time before you take a reading.

5. Adjust the piston until the Bourdon gauge reading is 1.0×10^5 Pa. Record the volume of the gas inside the syringe.
6. Pull out the piston slowly until the pressure is reduced to 0.9×10^5 Pa. Keep this pressure and hold the piston for 15 seconds. Take the reading of the volume of the gas inside the syringe.
7. Repeat step 6 by further pulling out the piston and reducing the pressure by 0.1×10^5 Pa each time. Remember to keep the pressure and hold the piston by 15 seconds before the volume is read.
8. When the pressure is reduced to 0.7×10^5 Pa, repeat the experiment by returning the piston to 1.0×10^5 Pa in steps of 0.1×10^5 Pa.
9. The volume after the pressure is returned to 1.0×10^5 Pa should be roughly the same as the initial volume. If there is a large difference, check the apparatus and repeat the experiment.
10. Repeat the experiment by pushing in the piston and increasing the pressure to 1.1×10^5 Pa, 1.2×10^5 Pa, 1.3×10^5 Pa and 1.4×10^5 Pa. Then repeat the experiment by returning to 1.0×10^5 Pa. Remember to hold the piston for 15 seconds before taking each reading.

Results:

Pulling out the piston:

Pressure (p) / 10^5 Pa	1.0	0.9	0.8	0.7	0.8	0.9	1.0
Volume (V) / cm^3							

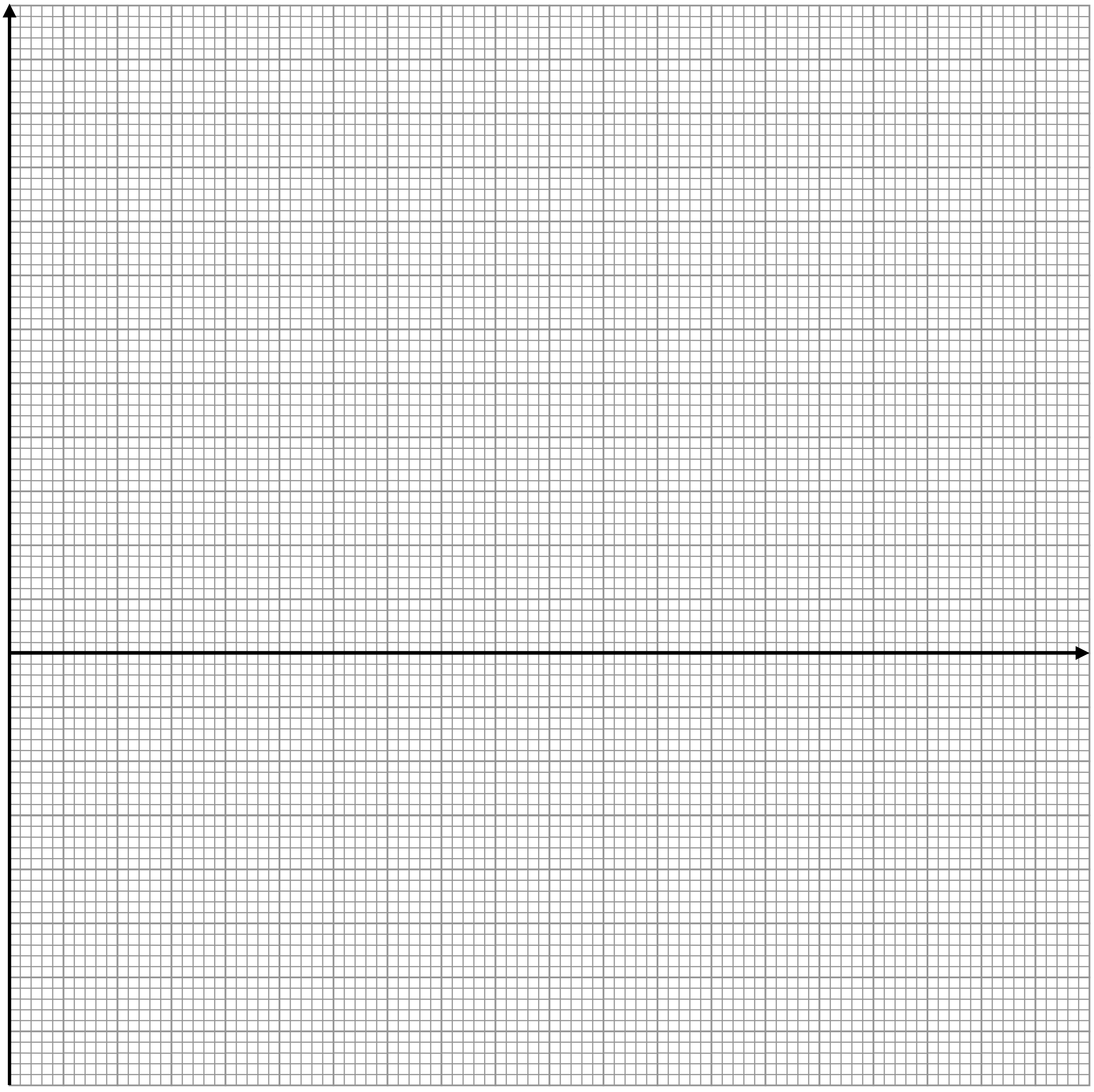
Pressing in the piston:

Pressure (p) / 10^5 Pa	1.0	1.1	1.2	1.3	1.4	1.3	1.2	1.1	1.0
Volume (V) / cm^3									

For a particular pressure, take the mean of volumes when the pressure is increased and decreased. Complete the table below.

Pressure (p) / 10^5 Pa	0.7	0.8	0.9	1.0	1.1	1.2	1.3	1.4
Mean Volume (V) / cm^3								
$1/p$ /10^{-5} Pa^{-1}								

Plot a graph of volume (*V*) of the gas against 1/pressure (1/*p*) at room temperature.



Discussion:

1. Do the points in the graph lie on a straight line ? Does the line/curve pass through the origin ? Give a reason for the discrepancy of the result from the Boyle's law.

2. What is the purpose of adding vaseline on the piston of the syringe ?

3. Why is it necessary to hold the piston for 15 seconds before each reading is taken ?

4. Why do we repeat the experiment by returning the piston back to the initial position, so that two volumes are taken for each pressure ?

Further Investigation:

From the graph, find the volume of air inside the rubber tubing and the Bourdon gauge. Derive the formula you used.

(The y-intercept of the graph should be equal to $-V_d$, where V_d is the dead volume of the air in the rubber tubing and the Bourdon gauge, since $p(V + V_d)$ = constant.)

Remark for teachers:

1. In textbook Boyle's law experiment usually takes volume as the independent variable. As Bourdon gauges usually do not have fine scale, it will not be easy to read gas pressure to an acceptable precision. Here the volume on the syringe is read while pressure is the independent variable. Moreover if the dead-volume of the tube and Bourdon gauge is wanted, it is essential to plot V against $1/p$.
2. It is not recommended to use glass syringe for safety reason.
3. As the diameter of the plastic syringe outlet does not fit the inlet of Bourdon gauge, two layers of rubber tubing are required.
4. If the dead-volume is too large, the initial volume (25 cm^3) should be reduced.
5. The main error of this experiment is the leakage of air, which depends very much on the age and condition of the syringe.

Hong Kong Diploma of Secondary Education
School-Based Assessment for Physics
Mark Sheet for Assessment of Performance in Practical Work (Practical skills)

Assessment Criteria / Teacher's Remarks \ Group No. / Experiment No.	Gp. 1 Exp.E1	Gp. 2 Exp.E1	Gp. 3 Exp.E1	Gp. 4 Exp.E1	Gp. 5 Exp.E1
Student No.					
(1) The procedure for practical work is carried out safely. **Alert of the safety concern in an experiment which requires applying considerable amount of force, particularly potential hazard on eyes.** **Excess force is not used.** **(10%)**					
(2) Work is done in an organized and efficient way. **Setup is tidy and easy to follow.** **Appropriate flow of procedures.** **Graph is plotted during the experiment to check for unexpected result.** **(20%)**					
(3) Apparatus are handled competently. **Set up the apparatus according to instructions.** **Achieve air tight with vaseline.** **Can hold a steady pressure during the volume is read.** **(30%)**					
(4) Instruments are used in appropriate ways to make accurate readings and measurements. **Can take accurate reading with the syringe and Bourdon gauge.** **Follow the requirement to hold for 15 s.** **Tap the Bourdon gauge before reading is taken.** **(30%)**					
(5) Positive attitude towards scientific investigation. **Good cooperation among the students.** **Double check and evaluate the result after the experiment.** **Making certain investigation after / during experiment.** **(10%)**					
Remarks : (e.g. students' strength/weaknesses) **E1 Relationship between pressure and volume of a gas**					
Group Total					
Student Total					

Note : The marks for individual students within a group may not be the same as teacher's observation on individual students and questioning during experiment are taken into account.

E1 Relationship between Pressure and Volume of Gas
Marking Scheme (Reporting)

Results:

Table of data on pulling out the piston.

- Reasonable readings of volume.
- Consistent reading between increasing and decreasing sessions. (2)

Table of data on pushing in the piston.

- Reasonable readings of volume.
- Consistent reading between increasing and decreasing sessions. (2)

Table of Mean Volume and $1/p$.

- Correct mean from the first two tables.
- Correct $1/p$. (2)

A graph of V against $1/p$ is plotted with

- correctly labeled axes with units,
- correct data points,
- a best fit line. (4)

Total: 10

Discussion:

1. The points lie roughly on a straight line,
   but the line does not pass through the origin.
   It is because there is some air in the rubber tube and Bourdon gauge not included in V. (3)

2. To keep the syringe air tight. (1)

3. As the temperature should be kept constant, the gas is allowed to return to the room temperature after the air is expanded or compressed. (2)

4. To check whether there is significant air leakage during the action of piston. (May consider other answers, e.g., if the two readings of the volume are not consistent, the experiment should be repeated.) (2)

Total: 8

Overall:

Presentation and communication (2)

Total: 2

Full marks: 20

Practical Skills (%)	
Reporting (%)	
Total	

E2 Newton's second law of motion

Name :__________________________

Class :________________No.:_______

Date :__________________________

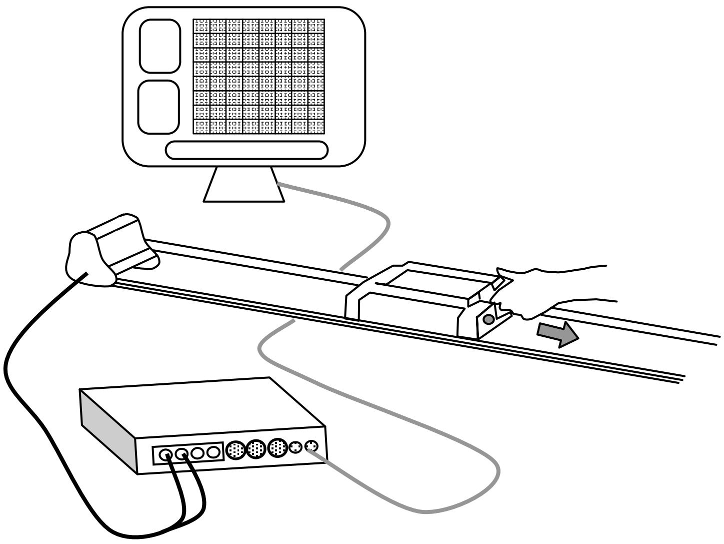
Objective: To investigate the relation of the mass, acceleration and net force acting on an object.

Apparatus:
data-logger interface with a motion sensor
elastic threads (unstretched length about 20 cm) × 4
friction-compensated runway
trolley
0.5 kg weights / additional trolleys × 3
electronic balance (optional if the mass of the trolley is known)

Part A—Net force and acceleration

Procedures:

1. Prepare a set-up to record the motion of a trolley on a runway as shown below. While necessary, adjust the runway for <u>friction compensation</u>.



2. Start data-logging. Use 1 elastic thread to pull the trolley along the track. <u>The thread should be stretched by the same amount throughout</u>.
3. From the slope of the velocity-time graph generated by the data-logging program, find the acceleration of the trolley.
4. Take one more confirmatory trial and obtain the mean value of the acceleration of the trolley.
5. Repeat steps 2–4 with 2, 3 and 4 elastic threads respectively. The threads should be stretched by the same amount as before.
6. Plot a graph of the acceleration *a* of the trolley against the number of elastic threads *N* used.

Results:

Mass of the trolley m = ___________ kg

Number of threads N	Acceleration a / m s^{-2}		
	1st trial	2nd trial	Mean
1			
2			
3			
4			

A graph of a against N:

Discussion:

1. With the aid of a free body diagram, explain the meaning of friction compensation in step 1 of the procedures above. Describe briefly the experimental steps to show that the runway is friction compensated.

----

2. State the control variable(s), dependent variable(s) and independent variable(s) in this experiment.

----

3. What physical quantity does the number of threads N represent ? From the graph plotted above, what can you say about the relation of the mass, acceleration and net force acting on an object ?

----

4. While you pull the trolley, the thread should be stretched by the same amount throughout. Explain briefly why it is important in this experiment.

Part B—Mass and acceleration

Procedures:

1. Prepare the same set-up as Part A to record the motion of a trolley on a runway. While necessary, adjust the runway for friction compensation.
2. Start data-logging. Use 2 elastic threads to pull the trolley along the track. The thread should be stretched by the same amount throughout.
3. From the slope of the velocity-time graph generated by the data-logging program, find the acceleration of the trolley.
4. Take one more confirmatory trial and obtain the mean value of the acceleration of the trolley.
5. Repeat steps 2–4 with additional weights placed on the trolley. The threads should be stretched by the same amount as before.
6. Plot a graph of the acceleration a of the trolley against $\frac{1}{m}$ where m is the total mass of the trolley.

Results:

Number of threads N = __________

Total mass of the trolley m / kg	$(\frac{1}{m})$ / kg^{-1}	Acceleration a / m s^{-2}		
		1st trial	2nd trial	Mean

A graph of a against $\frac{1}{m}$:

Discussion:

1. State the control variable(s), dependent variable(s) and independent variable(s) in this experiment.

2. From the graph plotted above, what can you say about the relation of the mass, acceleration and net force acting on an object ? Hence, together with the results from Part A, suggest a general relation among them.

3. Discuss **TWO** major sources of errors in this experiment and way(s) for improvement.

----

4. Now, if the runway were inclined at an angle greater than that required for friction compensation, how would the graphs obtained in Part A and Part B be affected ? Assume that the friction is unchanged throughout.

Hong Kong Diploma of Secondary Education
School-Based Assessment for Physics
Mark Sheet for Assessment of Performance in Practical Work (Practical skills)

Assessment Criteria / Teacher's Remarks \ Group No. / Experiment No.	Gp. 1 Exp. E2	Gp. 2 Exp. E2	Gp. 3 Exp. E2	Gp. 4 Exp. E2	Gp. 5 Exp. E2
Student No.					
(1) The procedure for practical work is carried out safely. **Apparatus correctly set up** **Trolleys are pulled with care.** **(15%)**					
(2) Work is done in an organized and efficient way. **Friction-compensated runway is set up.** **Friction-compensation is tested.** **Work is done efficiently.** **(25%)**					
(3) Apparatus are handled competently. **Data-logging interface can be connected correctly.** **Data-logging software can be set up correctly.** **(20%)**					
(4) Instruments are used in appropriate ways to make accurate readings and measurements. **Elastic strings are pulled with same extension every time.** **Graphs can be obtained from the software.** **Slope of v-t graph can be obtained from the software accurately.** **(30%)**					
(5) Positive attitude towards scientific investigation. **Good cooperation among the students.** **(10%)**					
Remarks : (e.g. students' strength/weaknesses) **E2 Newton's second law of motion**					
Group Total					
Student Total					

Note : The marks for individual students within a group may not be the same as teacher's observation on individual students and questioning during experiment are taken into account.

E2 Newton's second law of motion
Marking Scheme (Reporting)

Part A—Net force and acceleration

Results:

Mass of the trolley *m* is measured / stated correctly. (1)

Values of acceleration are filled in the table with suitable significant figures. (1)

A graph of *a* against *N* is plotted with

- correctly labeled axes with units
- correct data points
- a best fit line (3)

Total: 5

Discussion:

1. weight component along the runway is equal to the friction acting on the trolley
   a free body diagram is correctly drawn
   experimental set-up description
   constant speed verified in the data-logging system (4)

2. control variable: mass of the trolley
   dependent variable: acceleration of the trolley
   independent variable: no. of threads (3)

3. *N* represents the net force acting on the trolley
   When *m* is kept constant, *a* is proportional to *F* (2)

4. To ensure the force acting on the trolley is constant throughout the experiment. (1)

Total: 10

Overall:

Presentation and communication (2)

Total: 2

Full marks: 17

Part B—Mass and acceleration

Results:

Number of threads N is stated correctly. (1)

Values of acceleration are filled in the table with suitable significant figures. (1)

A graph of a against $\frac{1}{m}$ is plotted with

- correctly labeled axes with units
- correct data points
- a best fit line (3)

Total: 5

Discussion:

1. control variable: no. of threads
   dependent variable: acceleration of the trolley
   independent variable: mass of the trolley (3)

2. When F is kept constant, a is proportional to $\frac{1}{m}$

   Hence, a is proportional to $\frac{F}{m}$ or F is proportional to ma (2)

3. The thread was not stretched by the same amount. (1)
   Friction was not exactly compensated throughout.
   Or friction was not constant throughout. (1)

4. The net force acting on the trolley is increased.
   The acceleration will be larger.
   The graphs will be shifted upwards. (3)

Total: 10

Overall:

Presentation and communication (2)

Total: 2

Full marks: 17

Practical Skills (%)	
Reporting (%)	
Total	

E3 Centripetal force

Name :____________________

Class :____________No.:______

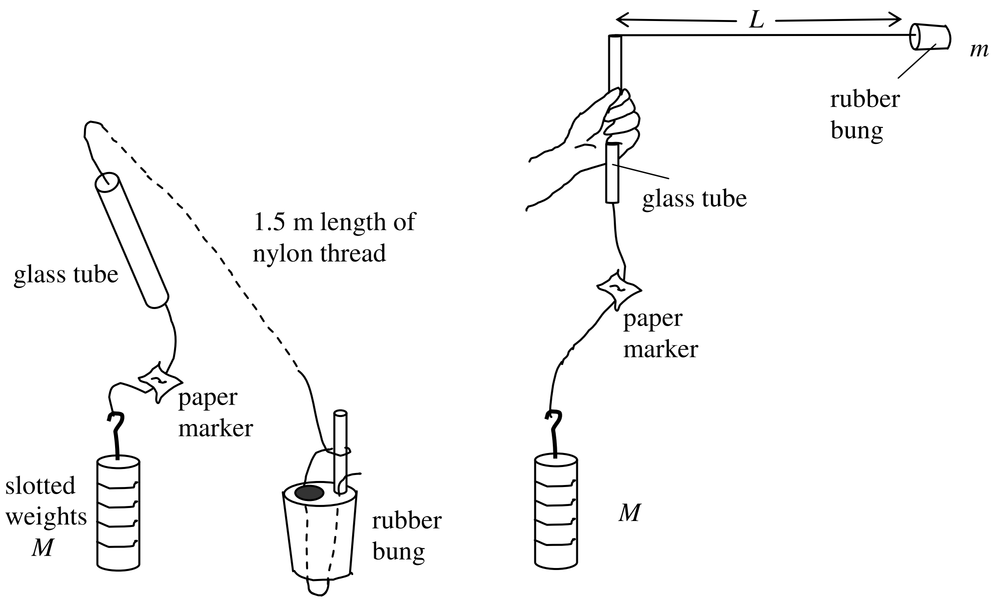
Date :____________________

Objective: To measure the centripetal force of whirling a mass round a horizontal circle and compare it with the theoretical value.

Apparatus:
rubber bung
glass tube about 15 cm long
slotted weights, with hanger 12 × 0.02 kg
nylon thread 1.5 m
paper marker
adhesive tape
metre rule
stop watch

Procedures:

1. Attach one end of a 1.5 m length of nylon thread to a rubber bung and thread the other end through a glass tube, a paper marker and a number of weights as shown.



2. First adjust the position of the paper marker so that it is at one end of the glass tube, and the length of the thread L from the other end of the glass tube to the rubber bung is, say, 0.8 m. Fix the position of the paper marker using adhesive tape if necessary. First start with M = 0.12 kg (i.e. 120 g).
3. Holding the glass tube vertically, whirl the bung around above your head in a horizontal circle. (Note that the nylon thread <u>need not</u> be horizontal.) Increase the speed of the bung gradually and allow it to move out (i.e. let L increases) until the paper marker is <u>just below the glass tube without touching it</u>.

4. Try to keep the angular speed constant so that the paper marker is just below the tube throughout. Ask your partner to time 20 revolutions of the bung using a stop watch. Remember to start the stop watch at 0 and stop it at 20. Take one more confirmatory reading and obtain the mean time for 20 revolutions. Calculate the tension T in the string and the angular velocity ω.
5. Repeat the procedures using different masses M. Remember to check confirmatory reading for each value of M.
6. Measure the mass m of the rubber bung.
7. Plot a suitable graph to find the relation between ω and T.

Results:

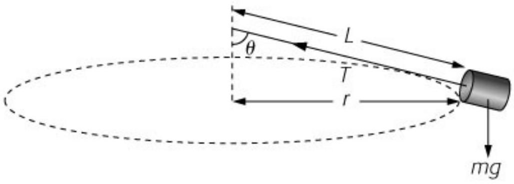
Mass of the rubber bung m = ___________ kg

Length of the thread L = ___________ m

M / kg	$T = Mg$ / N	Time for 20 revolutions $20t$ / s			Angular speed $\omega = \frac{2\pi}{t}$ / rad s^{-1}
		1st trial	2nd trial	Mean	

Discussion:

1. The string may not be horizontal as the rubber bung moves around.



Show that

(i) the tension T in the string is equal to $m\omega^2 L$;

(ii) the angle θ is independent of the angular velocity ω.

2. From the graph plotted above, what can you say about the relation between ω and T ? Calculate the slope of the graph. What is the physical significance of the slope ? Compare the experimental value and the theoretical value of the slope.

3. In step 3 of the procedures above, the marker should be just below the glass tube without touching it. Explain briefly why it is important in this experiment.

4. Discuss **TWO** major sources of errors in this experiment.

Further Investigation:

1. Design an experiment to find the relation between ω and L.

Hong Kong Diploma of Secondary Education
School-Based Assessment for Physics
Mark Sheet for Assessment of Performance in Practical Work (Practical skills)

Assessment Criteria / Teacher's Remarks — Group No. / Experiment No. / Student No.	Gp. 1 Exp. E3	Gp. 2 Exp. E3	Gp. 3 Exp. E3	Gp. 4 Exp. E3	Gp. 5 Exp. E3
(1) The procedure for practical work is carried out safely. **Rubber bung is far from any object or people.** **(10%)**					
(2) Work is done in an organized and efficient way. **Assembly of screw nuts, glass tube, nylon string and rubber bung.** **Repeat the experiment by using appropriate lengths of string.** **(20%)**					
(3) Apparatus are handled competently. **Can use a stop watch to take the time for 20 revolutions.** **Can use a balance to find the mass of the rubber bung.** **(20%)**					
(4) Instruments are used in appropriate ways to make accurate readings and measurements. **Setting the length L/appropriate position of the marker.** **Whirling the rubber bung uniformly in a horizontal circle.** **Holding the glass tube vertically in an approx. fixed position.** **Start counting when steady situation reached.** **(40%)**					
(5) Positive attitude towards scientific investigation. **Good cooperation among the students.** **Making certain investigation after / during experiment.** **(10%)**					
Remarks : (e.g. students' strength/weaknesses) **E3 Centripetal force**					
Group Total					
Student Total					

Note : The marks for individual students within a group may not be the same as teacher's observation on individual students and questioning during experiment are taken into account.

E3 Centripetal force
Marking Scheme (Reporting)

Results:

Mass of the rubber bung m is measured to within 5% difference from the teacher's value. (1)

Length of the thread L is stated and the value is appropriate. (1)

Values filled in the table (M, T, t and ω) are of suitable significant figures. (1)

A graph of ω^2 against T is plotted with

- correctly labeled axes with units
- correct data points
- a best fit line (4)

Total: 7

Discussion:

1. (i) $T \sin \theta = m\omega^2 L \sin \theta$

   (ii) $T \cos \theta = mg$ (2)

2. ω^2 is directly proportional to T

   slope correctly calculated

   slope = $\dfrac{1}{mL}$

   experimental value and the theoretical value of the slope compared (4)

3. T may not be equal to the weight of the slotted weights

   if the marker is touching the glass tube. (1)

4. Any 2 below: (2)

   - friction between the string and the glass tube
   - the plane of rotation may not be horizontal
   - the glass tube may not be at a fixed position

Total: 9

Overall:

Presentation and communication (2)

Total: 2

Full marks: 18

Practical Skills (%)	
Reporting (%)	
Total	

E4 Focal length of a convex lens

Name :____________________

Class :______________No.:______

Date :____________________

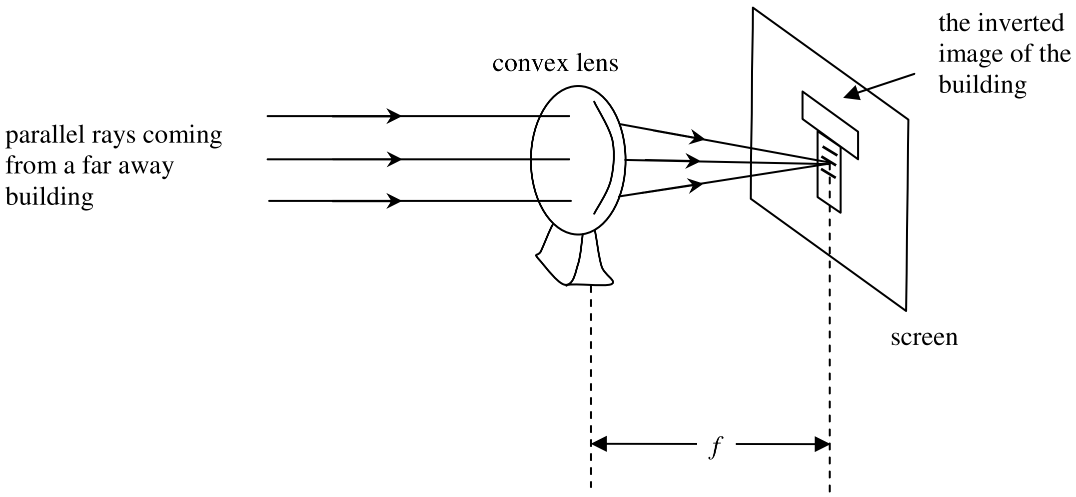
Objective: To measure the focal length of a spherical convex lens.

Apparatus: spherical convex lens with holder
lamp housing
white screen (opague/translucent)
metre rule

Part A—Forming image of a distant object

Procedures:

1. Place a convex lens with a holder near a window. Move the opaque/translucent screen to a position where a sharp image of a distant object is formed as shown below.



2. Measure the distance between the lens and the screen. This is the focal length of the lens.

Results:

The focal length found in Part A, f_1 = __________ cm

Discussion:

1. State the nature of the image formed.

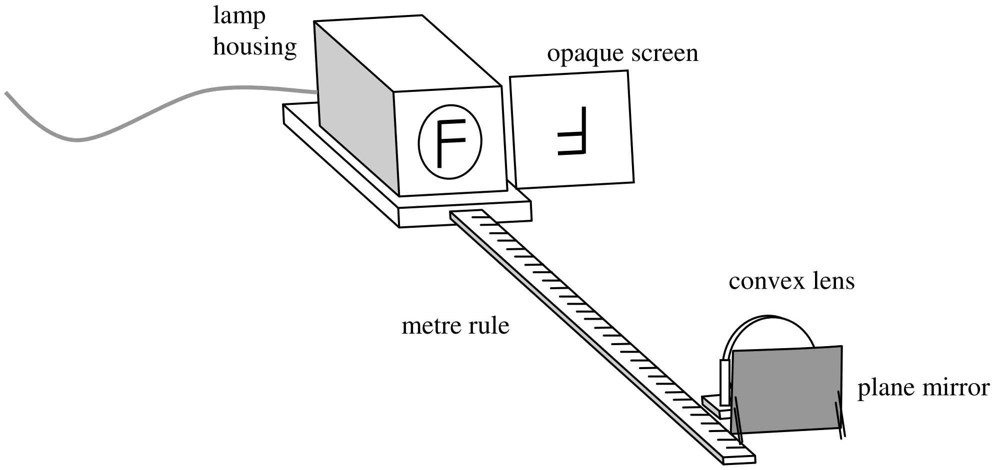
----

2. If the screen is removed, can you see the image of the distant object ?

Part B—Plane mirror method

Procedures:

1. Put an opaque screen side by side with a lamp housing (with a letter F). Attach a plane mirror to a convex lens with holder and place them in front of the lamp housing and the screen as shown below.



2. Move the lens-mirror combination until a sharp image is formed on the opaque screen.
3. Measure the object/image distance, i.e. the distance between the lens and the screen. This is the focal length of the lens.

Results

The focal length found in Part B, f_2 = __________ cm

Discussion

1. State the nature of the image formed.

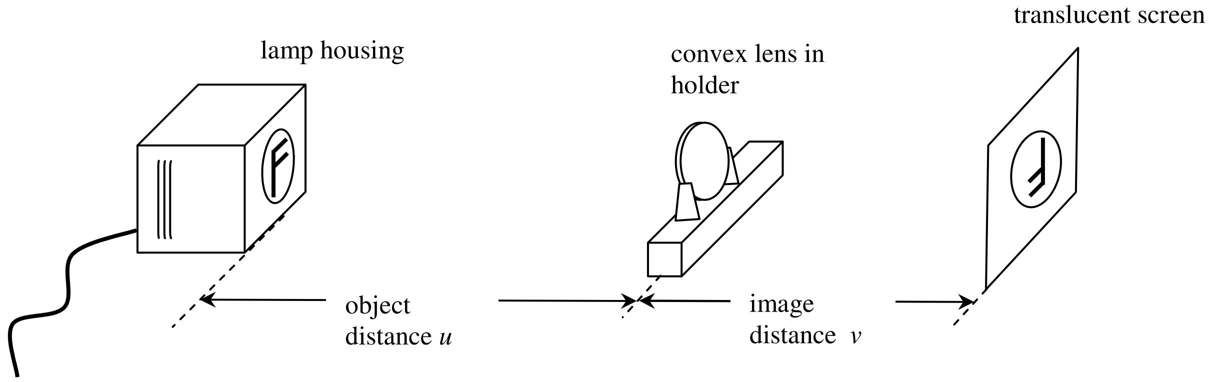
----

2. Will the result be different if the distance between the plane mirror and the lens is changed ?

Part C—Using lens formula

Procedures

1. Prepare the set-up shown below. Set the distance between an illuminated object and the lens, i.e. the object distance u, to a value close to $2f_1$ (or $2f_2$).



2. Adjust the position of the translucent screen until a sharp image is formed on it and measure the distance between the lens and the screen, i.e. the image distance v.
3. Change the object distance u to some values larger than $2f_1$ and repeat the measurement to obtain 3 more pairs of u and v.
4. Change the object distance u to some values smaller than $2f_1$ and repeat the measurement to obtain 3 more pairs of u and v.
5. Plot a graph of $\frac{1}{v}$ against $\frac{1}{u}$. The focal length can be obtained from the y-intercept of the graph.

Results:

	u / cm	v / cm	$\frac{1}{u}$ / cm^{-1}	$\frac{1}{v}$ / cm^{-1}
$u < 2f_1$				
$u \approx 2f_1$				
$u > 2f_1$				

The focal length found in Part C, f_3 = __________ cm

Discussion:

1. State the nature of the images formed in steps 2, 3 and 4.

2. The focal length of a concave lens cannot be found by this method. Why ?

3. By using the lens formula $\frac{1}{f}=\frac{1}{u}+\frac{1}{v}$, show how the focal length of the lens is obtained from the y- intercept of the $\frac{1}{v}$ against $\frac{1}{u}$ graph.

---

4. If half of the lens is covered by a cardboard, describe any changes of the image formed.

Further Investigation:

1. Repeat the experiment with other lenses of different thickness. Find out how the thickness of a lens affects its focal length.
2. In Part C, what is the minimum distance between the object and the image ?

Hong Kong Diploma of Secondary Education
School-Based Assessment for Physics
Mark Sheet for Assessment of Performance in Practical Work (Practical skills)

Group No. / Experiment No. → Student No. ↓ Assessment Criteria / Teacher's Remarks	Gp. 1 Exp. E4					Gp. 2 Exp. E4					Gp. 3 Exp. E4					Gp. 4 Exp. E4					Gp. 5 Exp. E4				
(1) The procedure for practical work is carried out safely. **The lamp house should not be moved after it has been switched on.** **Handling the convex lens with care.** **(20%)**																									
(2) Work is done in an organized and efficient way. **Alignment of the rulers is correct in Part A, B and C.** **Repeat the experiment by using appropriate object distances in Part C.** **(25%)**																									
(3) Apparatus are handled competently. **Can measure the object and image distances correctly.** **(20%)**																									
(4) Instruments are used in appropriate ways to make accurate readings and measurements. **A sharp image can be formed on the screen.** **Measurement is taken only when a sharp image is formed.** **(25%)**																									
(5) Positive attitude towards scientific investigation. **Good cooperation among the students.** **Making certain investigation after / during experiment.** **(10%)**																									
Remarks : (e.g. students' strength/weaknesses) **E4 Focal length of a convex lens**																									
Group Total																									
Student Total																									

Note : The marks for individual students within a group may not be the same as teacher's observation on individual students and questioning during experiment are taken into account.

E4 Focal length of a convex lens
Marking Scheme (Reporting)

Part A—Forming image of a distant object

Results:

f_1 is measured to within 10% difference from teacher's value.	(1)
f_1 is measured to within 5% difference from teacher's value.	(1)
	Total: 2

Discussion:

1. real, inverted, diminished	(1)
2. Yes	(1)
	Total: 2

Part B—Plane mirror method

Results:

f_2 is measured to within 10% difference from teacher's value.	(1)
f_2 is measured to within 5% difference from teacher's value.	(1)
	Total: 2

Discussion:

1. real, inverted, same size	(1)
2. No	(1)
	Total: 2

Part C—Using lens formula

Results:

Values of u and v are filled in the table with suitable significant figures. (1)

Values of $\frac{1}{u}$ and $\frac{1}{v}$ are calculated correctly. (1)

A graph of the $\frac{1}{v}$ against $\frac{1}{u}$ is plotted with

- correctly labeled axes with units
- correct data points
- a best fit line (3)

f_3 is measured to within 10% difference from teacher's value. (1)

f_3 is measured to within 5% difference from teacher's value. (1)

Total: 7

Discussion:

1. Step 2: real, inverted, same size
   Step 3: real, inverted, diminished
   Step 4: real, inverted, magnified (3)

2. The image formed by a concave lens is not real and cannot be formed on a screen. (1)

3. $\frac{1}{v} = -\frac{1}{u} + \frac{1}{f}$ (1)
   Comparing with the equation $y = mx + c$, (1)
   the slope should be -1 while the y intercept should be $\frac{1}{f}$.

4. The whole image can still be seen
   But it is dimmer. (2)

Total: 8

Overall:

Presentation and communication (2)

Total: 2

Full marks: 25

Practical Skills (%)	
Reporting (%)	
Total	

E5 Internal Resistance of a Battery

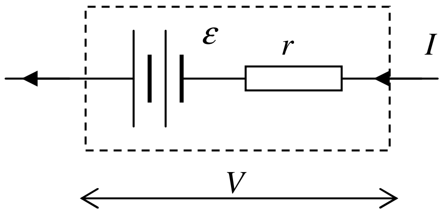
Name :
Class : No.:
Date :

Objective: To determine the internal resistance of a battery.

Apparatus: battery (3 × 1.5 V AA dry cells)
voltmeter (5 V)
ammeter (1 A)
rheostat R
fixed resistor R'
connecting wires
switch

Theory:

A real battery always has internal resistance. Simple theory regards a real battery as an ideal battery of e.m.f. ε in series with the internal resistance r.



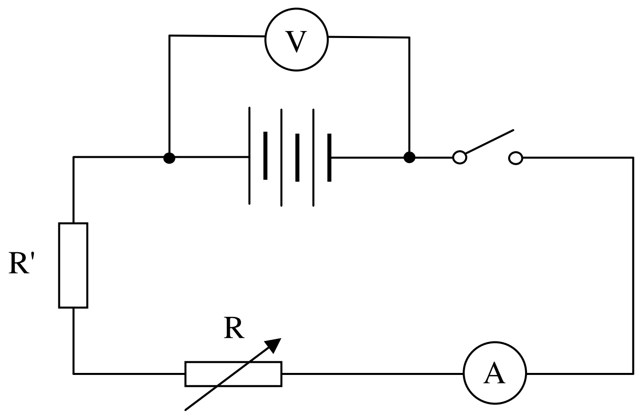
When a current I passes the battery, the potential difference V across the battery is given by

$$V = \varepsilon - Ir$$

If V is plotted against I, the internal resistance and e.m.f. of the battery can be found.

Procedures:

1. Connect the circuit as shown in the diagram below.



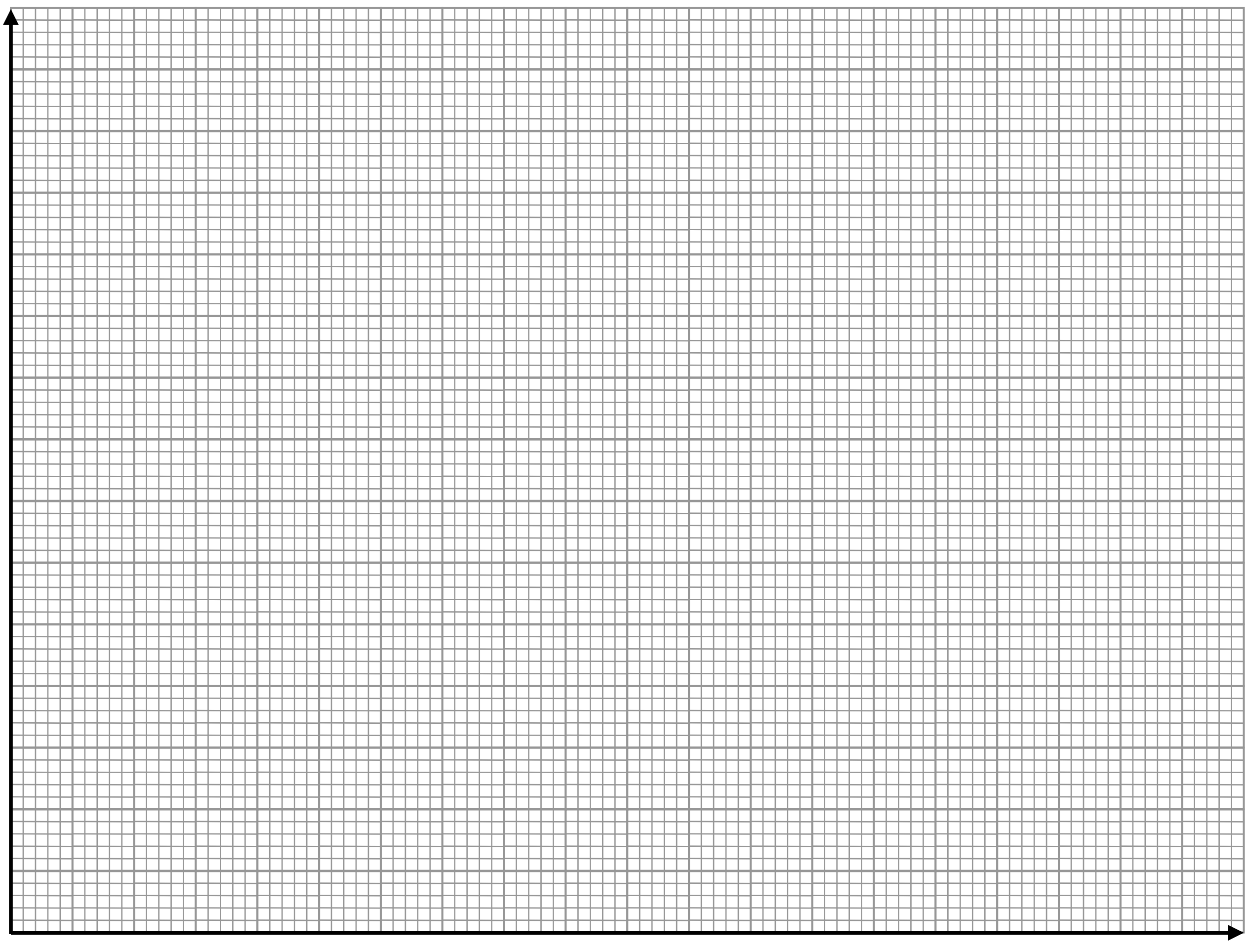
2. Keep the switch turned off. Take the reading of the voltmeter. This is the initial electromotive force (e.m.f.) of the battery.
3. Set the rheostat to zero. Turn on the switch and take the ammeter and voltmeter readings. Turn off the switch once the readings are taken.
4. Increase the resistance of the rheostat. Turn on the switch and adjust the rheostat until the current is roughly 0.1 A below the value in (3). Take the ammeter and voltmeter readings. Remember to turn off the switch once the readings are taken.
5. Repeat step 4 by decreasing the current in steps of 0.1 A. Plot a graph of the voltage V against the current I.

Results:

Initial electromotive force of the battery = ____________________ V

Ammeter reading I/A						
Voltmeter reading V/V						

Plot a graph of V against I.



From the graph above, how can you find the internal resistance and e.m.f. of the battery ? Derive the formulae you used.

____

____

____

____

____

____

Conclusion:

The internal resistance of the battery is ______________________ Ω.

The e.m.f. is ______________________ V.

Discussion:

1. Why is it necessary to turn off the switch after each reading is taken ?

   ____

   ____

   ____

   ____

   ____

2. Do you think that the resistance of the connecting wire is a significant error in this experiment ? Explain briefly.

   ____

   ____

   ____

   ____

   ____

   ____

3. The battery contains three identical dry cells in series. What are the e.m.f. and internal resistance of each dry cell ? Explain briefly.

____

____

____

____

____

____

Further Investigation:

Set the resistance of the rheostat to zero. Turn on the switch for roughly 10 minutes. Repeat steps 3 to 5 and plot another V - I graph. What happen to the internal resistance and e.m.f. after the battery has been discharged for 5 minutes ? Suggest what happens inside the dry cells while they are discharging ?

(Internal resistance increases and e.m.f. decreases. It is because there is chemical reaction inside the dry cells. The concentration of the active ingredients drops and gas bubbles are formed on the electrodes.)

Remark for teachers:

1. The typical internal resistance of the battery (3 × 1.5 V AA dry cells) is 1 Ω. With a 1 A ammeter, the typical voltage drop due to the internal resistance is about 0.1 to 1 V. Therefore the percentage error of this experiment is quite large.
2. The fixed resistor R' is used for protection and control of the maximum current. A 3.3 Ω 5 W ceramic resistor should be suitable for most cases. A 10 Ω rheostat (typical model that can be found in most school) is suitable for R.
3. Alkaline cells or rechargeable cells should not be used in this experiment. Their internal resistances are lower and cannot be measured easily.
4. The e.m.f. and internal resistance of dry cells change significantly when they discharge. To get a more standardized result, fresh dry cells should be used. Before fresh dry cells are used, a brief discharge is preferred so that the initial e.m.f. can be more steady.
5. In order to get good results, the duration of discharging must be kept as short as possible. If this technique is too difficult for some students, a resistor may be added as an artificial internal resistance. However the students should be reminded that the value they measured is not the realistic value of dry cells.

Hong Kong Diploma of Secondary Education
School-Based Assessment for Physics
Mark Sheet for Assessment of Performance in Practical Work (Practical skills)

Group No. / Experiment No. — Student No. — Assessment Criteria / Teacher's Remarks	Gp. 1 Exp. E5	Gp. 2 Exp. E5	Gp. 3 Exp. E5	Gp. 4 Exp. E5	Gp. 5 Exp. E5
Student No.					
(1) The procedure for practical work is carried out safely. **Polarities of the ammeter and voltmeter are checked.** **Ammeter is not overloaded.** **Circuit is opened when left unattended.** **(10%)**					
(2) Work is done in an organized and efficient way. **Circuit is connected in a tidy and easy to follow manner.** **Appropriate flow of procedures.** **Graph is plotted during the experiment to check for unexpected result.** **(20%)**					
(3) Apparatus are handled competently. **Correct connection of the circuit.** **Connect the voltmeter directly across the battery to minimize error.** **Can adjust the rheostat appropriately according to the instructions.** **(30%)**					
(4) Instruments are used in appropriate ways to make accurate readings and measurements. **Can take accurate reading with ammeter and voltmeter.** **Show concern to minimize the time for allowing the current to flow.** **(30%)**					
(5) Positive attitude towards scientific investigation. **Good cooperation among the students.** **Double check and evaluate the result after the experiment.** **Making certain investigation after / during experiment.** **(10%)**					
Remarks : (e.g. students' strength/weaknesses) **E5 Internal resistance of a battery**					
Group Total					
Student Total					

Note : The marks for individual students within a group may not be the same as teacher's observation on individual students and questioning during experiment are taken into account.

E5 Internal Resistance of a Battery
Marking Scheme (Reporting)

Results:

Initial e.m.f. of the battery. (1)

5 to 8 sets of V and I with reasonable values and appropriate significant figures. I is varying in roughly steps of 0.1 A. (2)

A graph of V against I is plotted with

- correctly labeled axes with units,
- correct data points,
- a best fit line. (4)

Derive how e.m.f. and internal resistance are obtained from the graph. (3)

Conclusion:

Values of the e.m.f. and internal resistance. (2)

Total: 12

Discussion:

1. The e.m.f. and internal resistance change as the battery discharges. To get a consistent result, the battery should not be allowed to discharge continuously. (May consider other answers, e.g., safety reason or saving energy.) (2)

2. No. As the voltage is taken directly across the terminals of the battery, the resistance of the wires does not affect the voltmeter reading. As the ammeter is in series with the wires, the resistance of the wires also has no effect on ammeter reading. (May consider other answers, e.g., resistance of connecting wires are far smaller than r.) (2)

3. Let the internal resistance and e.m.f. of each cell be ε' and r'.
   As the cells are in series,
   $\varepsilon = 3\varepsilon'$
   $r = 3r'$
   $\therefore\ \varepsilon' = \ldots,\ r = \ldots$ (2)

Total: 6

Overall:

Presentation and communication (2)

Total: 2

Full marks: 20