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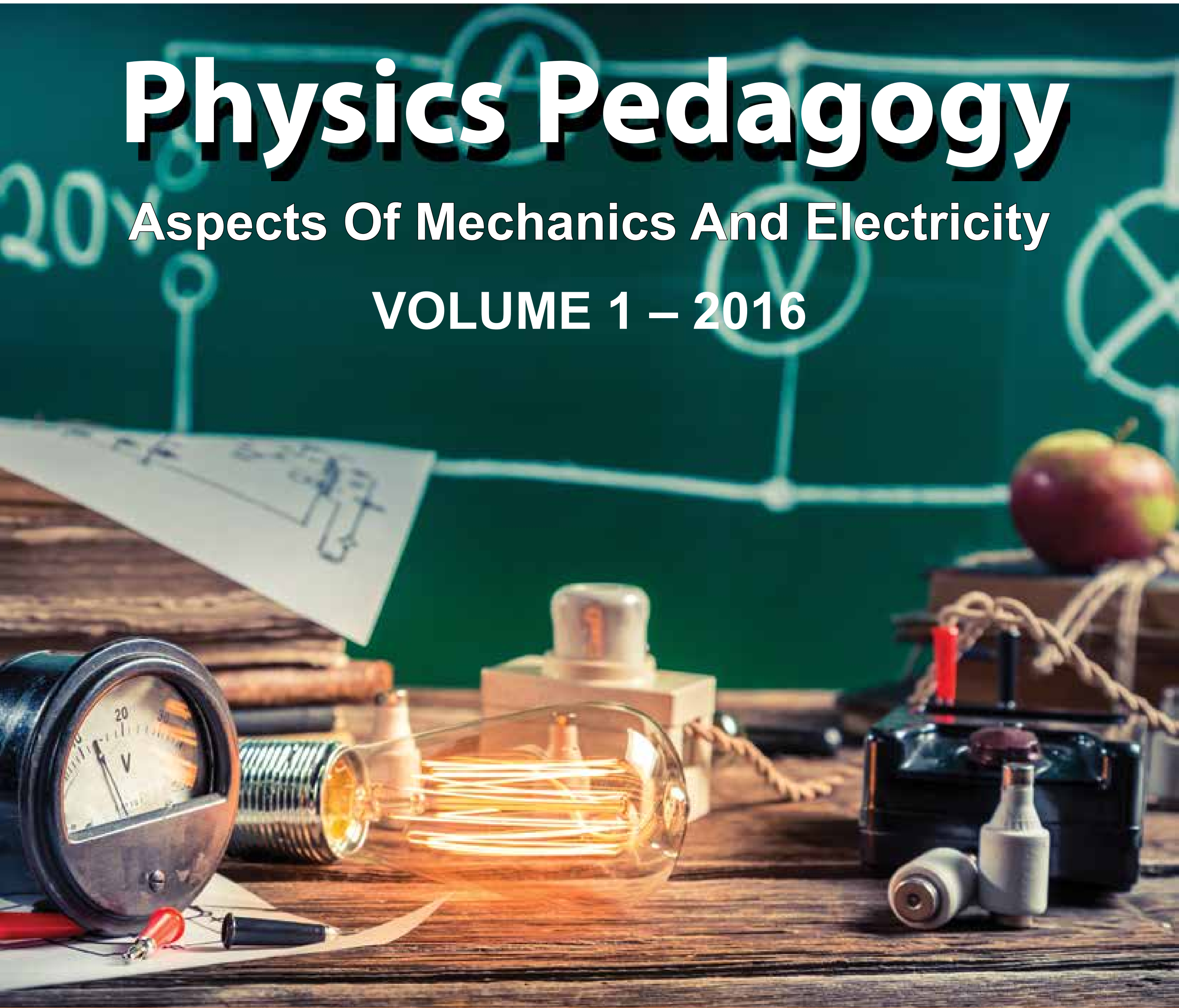
Physics Pedagogy

Aspects Of Mechanics And Electricity

VOLUME 1 – 2016



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BACKGROUND

The SA Institute of Physics (SAIP) is a non-profit, voluntary and professional physics society that was established in 1955.

The SAIP has a membership of over 600 made up of professionals, academics and students.

Over 10% of the membership are in other African countries and further abroad.

SAIP is dedicated to increasing the understanding and application of physics in South Africa.

OUR OBJECTIVES

To promote study and research in physics and the encourage applications thereof

To further the exchange of knowledge among physicists by means of publications and conferences. To uphold the status and ensure a high standard of professionals conduct among physicists

To do all such other lawful things as many be necessary to attain the above objectives including the co-operation with other institutes, companies, organisations or societies, to the benefit of both

To offer a wide range of services addressing many levels of involvement with the Physics community and related stakeholders

CONTACT DETAILS

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Physics Pedagogy

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With thanks to unknown artist

This is not the way we want to do it!

Physics Pedagogy

1 Background

The primary aim with this booklet is to introduce an approach to teaching students to learn the concepts needed to understand Physics and solve Physics problems. The conceptual knowledge required includes Physics concepts they have difficulty with in constructing solutions to problems, ie a constructivist approach is adopted. The approach is not a set of rules for manipulation, but a set of concepts that are implemented by the teachers at an appropriate time or place.

Another hurdle faced by students is that of misconceptions, of which there are many, but can be classified as follows:

- Preconceived notions
- Non-scientific beliefs
- Conceptual misunderstandings
- Vernacular misconceptions
- Factual misconceptions

These need to be broken down, which means that the following steps have to be taken:

- Identifying students' misconceptions
- Providing a forum for students to confront their misconceptions
- Helping students reconstruct and internalize their knowledge, based on scientific models

1.1 Some examples of misconceptions

1.1.1 Motion/velocity implies force. One of the most deeply held misconceptions (or naive theories) about force is known as the pre-Newtonian "impetus theory" or the "acquired force" theory and it is typical among elementary, middle and high school students and among adults. It is erroneously believed that objects are kept moving by internal forces (as opposed to external forces). Based on this reasoning, force is an acquired property of objects that move. This reasoning is central to explaining the motion of inanimate objects. They think that force is an acquired property of inanimate objects that move, since rest is considered to be the natural state of objects. Hence, the motion of objects requires explanation, usually in terms of a causal agent, which is the force of another object. Hence force is the agent that causes an inanimate object to move. The object stops when this acquired force dissipates in the environment. Hence force can be possessed, transformed or dissipated.

1.1.2 Static objects cannot exert forces (no motion – no force). Many high school students hold a classic misconception in the area of physics, in particular, mechanics. They erroneously believe that "static objects are rigid barriers that cannot exert force." The classic target problem explains the "at rest" condition of an object. Students are asked whether a table exerts an up-ward force on a book that is placed on the table. Students with this misconception will claim that the table does not push up on a book lying at rest on it. But, gravity and the table exert equal, but oppositely, directed forces on the book thus keeping the book in equilibrium and "at rest." The table's force comes from the microscopic compression or bending of the table.

1.1.3 Only active agents exert force. Students are less likely to recognize passive forces. They may think that forces are needed more to start a motion than to stop one. Hence, they may have difficulty recognizing friction as a force.

1.1.4 Gravity. On the correct understanding of gravity, falling objects, regardless of weight, fall at the same speed – which leads to the following misconception:
Heavier objects fall faster than lighter objects. Many students learning about Newtonian motion often persist in their belief that heavier objects fall faster than light objects

1.1.5 Ontological misconceptions. There is one class of alternative theories (or misconceptions) that is very deeply entrenched. These relate to ontological beliefs, i.e., beliefs about the fundamental categories and properties of the world. Some common mistaken ontological beliefs that have been found to resist change include:

- that objects like electrons and photons move along a single discrete path
- belief that time flows at a constant rate regardless of relative motion
- belief that concepts like heat, light, force, and current are a material substance
- belief that the seasons are caused by the Earth's closer approach to the Sun during summer due to the exaggerated ellipse drawn for the Earth's orbit
- belief that force is something internal to a moving object

There are of course many others, including those about Newton's Third Law! It would be worthwhile to have students identify others and discuss how best to correct these. Is solving related problems a possible route to helping students resolve/reconstruct these misconceptions?

1.2 Developing a Problem Solving Strategy

Students need to develop a strategy to tackle problems and solve them, and it is difficult to do so without knowing more than one way to solve the problem. Most students have developed a habit of looking at a problem, decide what formula to apply, use the data given and produce an answer. What a Physics teacher called "Cookery Book Physics": find the recipe, mix the ingredients, put it in the oven and out comes the cake!

Students generally don't use concepts to tackle a problem, primarily because they are unable to identify which ones to use or are relevant. They have a minimal grasp of concepts and are thus unable to use them to resolve the problem: they don't really understand the concepts or **how** to use them.

Below are some of the various types of knowledge that students need to know:

Conceptual knowledge, like the concept of momentum or energy, or that the velocity of an object changes when it accelerates, or that the gravitational potential energy of an object decreases as it falls

Factual Knowledge, like the value of the gravitational constant g, the radius of the Moon, or the mass or velocity of an object.

Representational knowledge, like how to draw and use graphs.

Operational knowledge, like how to manipulate equations, resolve vectors and so on.

Procedural knowledge, for instance, if all forces are not involved with friction to then use the conservation of energy, or when finding potential energy, always specify a positive/negative, or when to apply Newton's Laws and draw a free-body diagram.

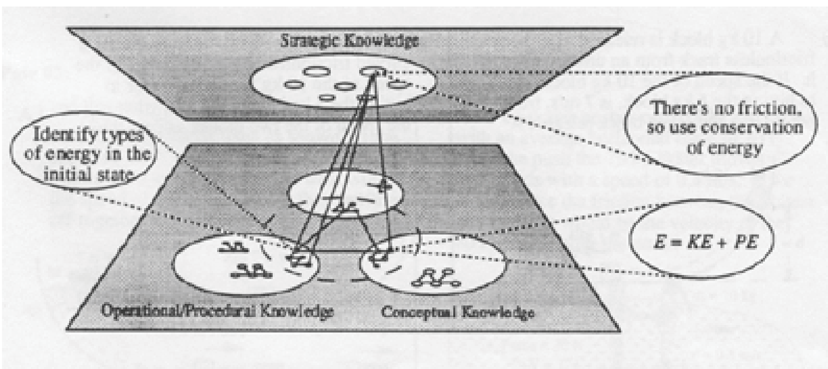


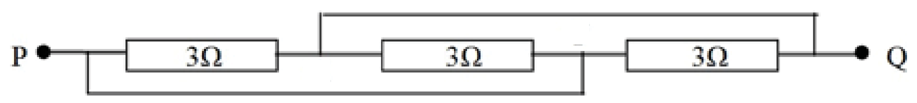
Fig. 1 The formation of a strategic knowledge element. *(DLG)*

2 Introductory Examples

Below are a few simple examples, using some typical multiple choice questions, MCQs, of how to interpret the words of the question: what is the question asking. Then decide on an approach to develop a strategy, using known concepts and knowledge, to solve the problem. Once students have worked their way through these they can adopt a similar approach to many of the remaining MCQs.

What is important to remember here is that problems can be discussed between students to try and get them to find different ways to solve the same problem – try working in groups – most often there is more than one way to do this, and it is of great value to try both – even if it is only to see if the answers are the same – which of course they should be!

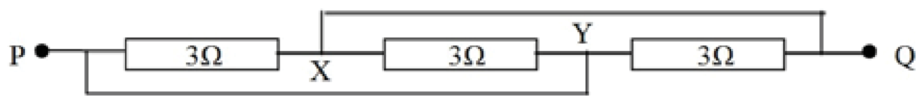
2.1 In the circuit shown below the resistance, in ohms (Ω), between the points P and Q is:



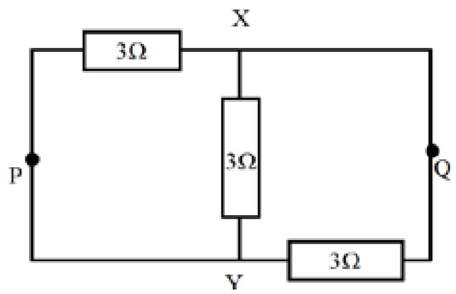
A 3/2 B 9 C 2/3 D 1

This has the answer D or 1Ω. But why?

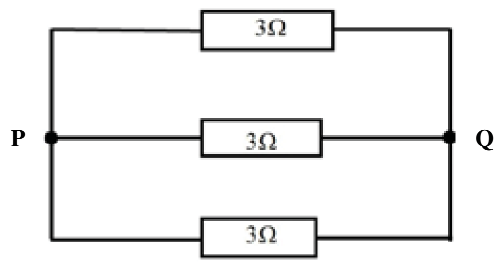
Many have a problem with interpreting this type of diagram correctly. Let's look at the same problem with a few extra labels:



Looking at the upper wire, the RHS has X connected to Q, which means that Q and X are the same point! The same applies to the lower wire, Y and P are the same point. So we could redraw the diagram as follows:

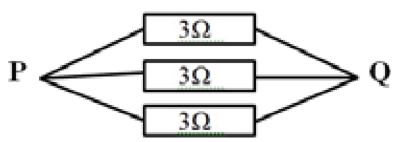


Which is another way of asking the same question, but it becomes easier to see the obvious. By simply sliding Y to P and X to Q you get:

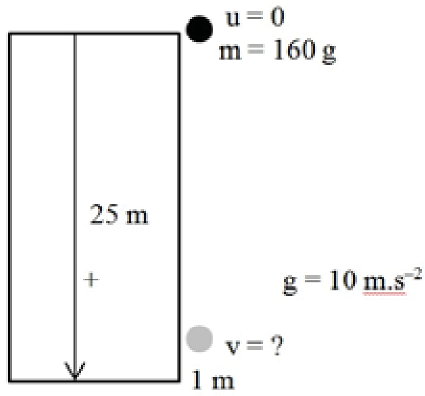


So the equivalent circuit is simply three, 3Ω resistors in parallel, so the equivalent resistance is 1Ω.

Students have got used to drawing circuits, as shown above, with straight lines at right angles to each other. But are many other ways of doing this, especially if a student is drawing a free hand sketch! Discuss the difference between these diagrams, especially the concept of a "line" being equivalent to a "point". Try drawing a few freehand sketches of different, but equivalent circuits.



2.2 A cricket ball of mass 160 g is dropped from the top of a building 25 m high and caught 1 m above the ground. What is the speed of the ball as the catcher catches it? You can ignore air resistance.



Solution 1 – using the equations of motion and assuming that the mass of the cricket ball has no effect – not proven – but generally accepted – should it be?

Note a diagram has been drawn and all the information needed has been added, including that down is +ve!

Since u = 0, v = v, a = g and s = 25 – 1 = 24 m. Then using:

$v^2 = u^2 + 2gx$ gives $v^2 = 0 + 2 \times 10 \times 24 = 480$.

So $v = \sqrt{480} = 21.9\ m.s^{-1}$

Solution 2 using the conservation of energy. This can be used as there are no energy losses due to friction (air resistance).

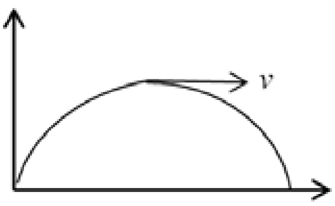
Now E_P = mgh and this will equal the kinetic energy as the ball is caught. Note that the ball only travels 24 m. Then taking down as +ve

$E_P = E_K$. So $mgh = ½ mv^2$ or $v^2 = 2gh$ so $v = \sqrt{(2 \times 10 \times 24)} = 21.9\ m.s^{-1}$

Note: The speed of the ball does not depend on its mass – which as legend has it is what Galileo demonstrated when he allegedly dropped two different size cannon balls from the Leaning Tower of Pisa.

One could have assumed that fact and then simply used the equations of motion to find the speed of the ball without using the Conservation of Energy, but as will be seen later, there are many occasions that show that using the Conservation of Energy, leads to a faster and often easier solution, as the following two problems show.

2.3 A ball whose kinetic energy is E is thrown at an angle of 45° with the horizontal. What is its kinetic energy at the highest point of its flight? Ignore the effects of air resistance.



Solution 1 Using the conservation of energy as there is no air resistance. Note that again a simple diagram is drawn. See below for comments.

Initial kinetic energy = $\frac{1}{2}mu^2$

The horizontal speed/velocity is always $v = u\cos 45 = \frac{u}{\sqrt{2}}$, which will be the velocity at its highest point as well.

So the Kinetic Energy at the top is $\frac{1}{2}mv^2 = \frac{1}{2}m\left[\frac{u^2}{2}\right] = \frac{1}{2}\left[\frac{1}{2}mu^2\right] = \frac{E}{2}$

Solution 2 The initial velocity can be resolved into two components: vertical and horizontal. In this case some additional arrows indicating the directions of the vertical and horizontal components could be added at the origin.

Initial vertical component = u sin 45 $= \frac{u}{\sqrt{2}}$

Initial horizontal component is $v = ucos45 = \frac{u}{\sqrt{2}}$, and it should be remembered that this component has no acceleration, and as there is no air resistance, is therefore constant.

At its highest point the vertical component = 0, so only the speed at this point that needs to be considered to calculate E_K is the horizontal component!

So the energy at its highest point is $\frac{1}{2}mv^2 = \frac{1}{2}m\left[\frac{1}{\sqrt{2}}u\right]^2 = \frac{1}{2}\left[\frac{1}{2}mu^2\right] = \frac{E}{2}$ as before.

2.4 A stone, with a mass of *m*, is thrown from the top of a cliff, *H* metres above a lake, at a speed of *u* $m.s^{-1}$. At what angle must it be thrown so that it hits the water at the maximum speed? Again, ignore air resistance.

Solution 1 – using the conservation of energy again, as there is no air resistance.

Total energy of stone $E_T = E_K + E_P = ½mu^2 + mgH$.
On reaching the water the potential energy is converted to kinetic energy: $mgH = ½mv^2$

So $E_T = ½\, m(u^2 + v^2) = ½\, mV^2$ where *V* is the speed of the stone as it strikes the water.

Therefore $V = \sqrt{(u^2 + v^2)}$. Here *u* is fixed (given) and *v* is the speed gained by falling H metres, so V is not dependent on the angle thrown.

Note: remember that $v^2 = 2gH$ – so the speed *v* due to its loss of E_P is independent of the angle at which it is thrown – depends just on the height – ie E_P

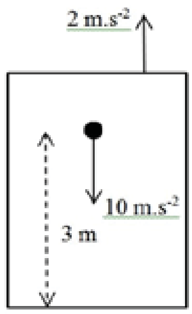
Solution 2 this poses a challenge as the question has two unknown quantities: the angle at which it is thrown and the speed that the stones strikes the water.

The only alternative here is to go by trial and error! Try for example throwing the ball straight up, straight down and horizontally. Firstly straight up and straight down are the same. (***Why? Discuss!***) Then use the vertical and horizontal components for the horizontal throw. The horizontal component is constant, and the equations of motion can be used to find the final vertical velocity and thus the final speed can be found and shows that it's independent of the angle.

However here again it is assumed that the speed independent of the mass.

2.5 A lift is accelerating upwards at 2 $m.s^{-2}$. A ball is held 3 m above the floor of the lift and then released. How long before it hits the floor?

Solution – always draw a diagram of the situation!



Assume acceleration due to gravity g = 10 $m.s^{-2}$
Initial velocity **u** = 0
Displacement **s** = 3 m
Time t = ?

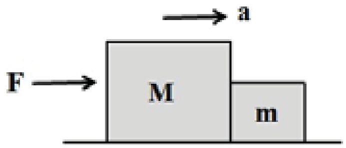
Acceleration: since g is +ve one can consider the ball as stationary the floor of the lift is accelerating towards the ball at 10 – (–2) – so **a** = 12 $m.s^{-2}$

Then using $s = ut + \frac{1}{2}at^2$, gives $t = \sqrt{\frac{2s}{a}} = \sqrt{\frac{6}{12}} = 0.7s$

2.6 Two blocks of masses M and m are in contact, with M > m and a force F acts on M. What is the acceleration of the blocks?

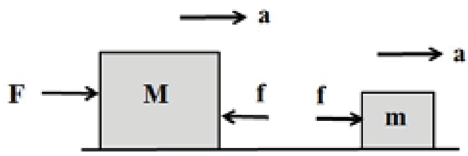
Solution 1 – the total mass approach – commonly used because it "works", but as will be shown, there is a serious Physics problem in doing this.

As usual, start with a diagram.



It is clear that **F**= (M + m)**a** so $\mathbf{a} = \left(\frac{\mathbf{F}}{M+m}\right)$

Solution 2 Free body approach – this might appear a bit long winded and more complex, but as will be seen it is ultimately the only way to solve this type of problem – often referred to as **connected particles.**



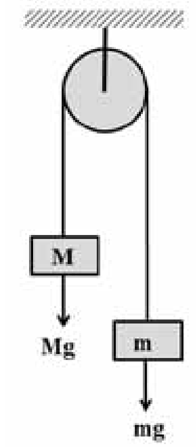
Here we look at the forces acting on each body, (particle). So for M and m:

$$\mathbf{F} - \mathbf{f} = M\mathbf{a}$$
$$\mathbf{f} = m\mathbf{a}$$

Adding these two equations we get, as before **F**= (M + m)**a** so $\mathbf{a} = \left(\frac{\mathbf{F}}{M+m}\right)$

Many ask "What's the difference"? The difference lies in the conceptual approach. As will be seen, as problems become more complex different solutions need to be constructed using the free body approach.

2.7 A pulley is supported from a beam and two masses M and m (M > m) are connected by a thin rope passing over the pulley. Find the acceleration of the masses. Assume the pulley has no mass.

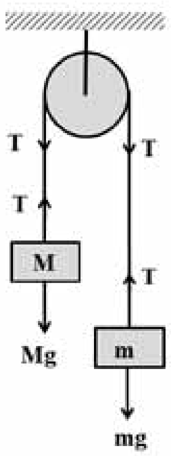


Solution 1 – total mass approach. As usual, draw a diagram.

Difference in downward force **F** = M**g** – m**g** = (M + m)**a**

So $\mathbf{a} = \left(\frac{\mathbf{g}\,(M - m)}{M+m}\right)$

Solution 2 – the free body approach. As usual draw a diagram, putting in all the forces acting on particle (or body) as shown. The tension **T** is the same throughout the string,



So M**g** – **T** = M**a**

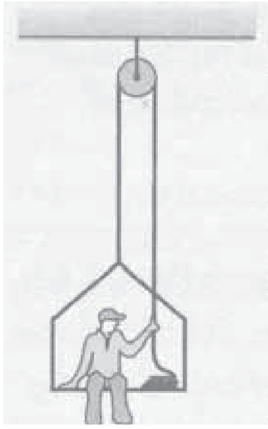
and **T** – m**g** = m**a**

Adding these equations gives us $\mathbf{a} = \left(\frac{\mathbf{g}\,(M - m)}{M+m}\right)$

Again, what's the difference? Well the pulley had no mass which meant that the tension T in the rope was the same throughout. But if the pulley had mass, the tension would be different on each side of the pulley because there would be a torque making the pulley turn, rendering the problem unsolvable with the total mass approach. There are other situations where the total mass approach fails. See below.

2.7 Richard Feynman's problem. A painter of mass 85 kg is working in a Bosun's Chair, of mass 30 kg, hanging down the side of a tall building, and desires to move up. He pulls down on the rope with such a force that he presses against the chair with a force of 400 N:

a) what is the acceleration of the painter and chair?
b) what is the total force on the pulley?



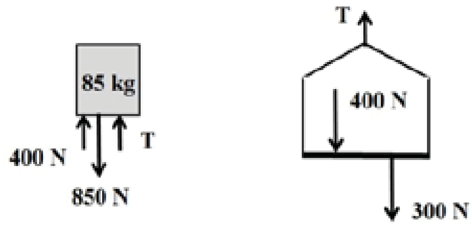
Solution – free body approach – total mass approach doesn't work!

As usual – draw the free body diagrams.

a) Force on painter: $\mathbf{T} + 400 - 850 = 85\mathbf{a}$
Force on chair: $\mathbf{T} - 300 - 400 = 30\mathbf{a}$

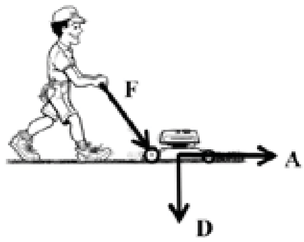
ie $250 = 55a$ so $\mathbf{a} = 4.55$ m.s^{-2}

b) Using $\mathbf{T} - 300 - 400 = 30\mathbf{a}$, we get:
$\mathbf{T} = 700 + 30 \times 4.55 = 836.5$ N
So total force on pulley = $2\mathbf{T}$ = 1 673 N

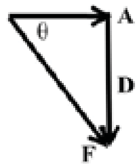


2.8 Drawing diagrams

This is an important part of problem solving and often involves drawing more than one diagram. One thing to avoid at all costs is to try and use a single diagram for both the space or situation diagram and the force diagram. **Always** separate them as shown on the right. An example is shown below.



Situation Diagram

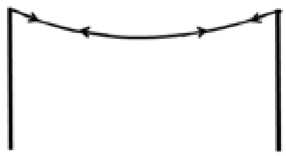


Force diagram

2.9 A heavy cable is stretched between two pillars. Find the tension in the cable if it has a weight W. Why is it, that no matter how tightly the cable is strung, it always hangs with a slight curve down, like power lines?

We can solve this by constructing a situation, or space diagram, and a separate force diagram.

The diagram right shows the cable hanging as it is usually seen. It should also become clear that the heavier the cable, the greater the curve will be. In addition if the tension in the cable is increased, the curve will become flatter.



To solve the this problem is difficult, but we can get some idea of the answer by assuming that the cable is light (has no mass) and that the mass is concentrated in the middle, as shown in Fig. 1 below. This is called the situation or space diagram, which schematically shows what forces are acting where. The force diagram, Fig. 2 shows the forces acting on the mass.

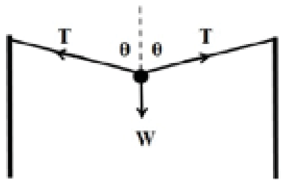


Fig. 1

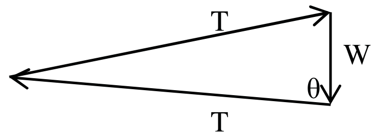
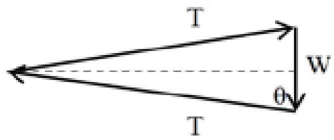


Fig. 2

Solution 1 – Scale drawing. Here one would draw something like Fig. 2 as large as possible to scale, say 1 cm = 100N (depending on the value of W) and then measure the length of T to find its value.

Solution 2 – Trigometry.

Redraw the diagram slightly and it becomes clear that:



$$T \cos \theta = W/2 \text{ ie } W = 2T \cos \theta, \text{ or}$$

$$T \cos \theta + T \cos \theta = 2T \cos \theta = W$$

Solution 3 – components

Referring to Fig. 1, there is no nett horizontal force as T sin θ – T sin θ = 0.

Resolving vertically   T cosθ + T cosθ = 2T cos θ = W

Discussion – For all the answers $T = \dfrac{W}{2 \cos \theta}$, so as θ gets larger, T will increase, and no matter how high the tension in the rope/cable/chain becomes, there will always be the weight of the cable acting down! The isosceles triangle of Fig. 2 can become very elongated and the angle θ can approach 90^{o}, but never get there, because if θ = 90, cos θ = 0 and T = ∞ which is not possible.

Notes

1 Students using this booklet are encouraged to work in groups and discuss problems and their answers. Often there is more than one way to get to the answer, using a totally different conceptual approach. In going through the many examples below the ones that might generate a stimulating discussion have the following phrase inserted below the problem:

Discuss the answer of the above question within your group

2 Sometimes questions do not pose "real" problems – but rather assess the ability of students to recognize what the question is asking, see for example # 4.1, often making something simple look really tough!

3 The MCQs and general questions are not ordered in anyway so they can be answered in any order. The additional problems in # 5 and #6 are a little more challenging and students are advised to start with those one they are comfortable with those in # 3, and section # 4: Mechanics and Electricity respectively.

3 MCQs and General Questions – Mechanics

Below are many MCQs, and a few more general longer questions that would be suitable for discussion. There will also be the occasional "worked example" to show you how new or different concepts can be incorporated into the problem solving exercise. As was stated at the beginning, the approach is not a set of rules for manipulation, but a set of concepts that can be implemented when the occasion arises. Read the question carefully and transform the words into a diagram and then construct a strategy to solve the problem. It is always a good idea to discuss an issue with a colleague or tutor – often the problem can be resolved by getting rid of a misconception or a misinterpretation.

The questions are not graded for degree of difficulty or type – just a random selection of questions from a range of sources and individuals. So read through the questions and tackle the ones that interest you – but eventually you will have done the bulk of them. Or they can be answered in numerical order!

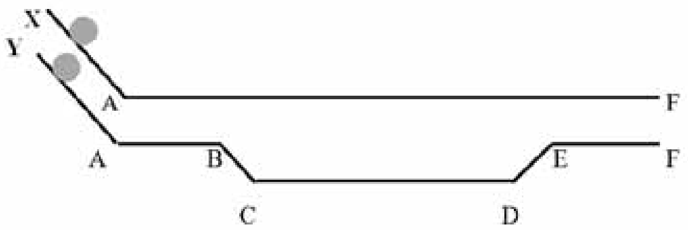
3.1 A force of 40 N pulls a mass of 20 kg at constant speed through a distance of 10 m along a horizontal surface. The work done on the mass is:

A 40 J B 100 J C 400 J
D 2 000 J E 4 000 J

3.2 A 1 000 kg car collides head-on with a 2500 kg bus. They stop instantly on collision. If before the impact the car was travelling at 20 ms^{-1}, the speed of the bus was

A 5.7 ms^{-1} B 8.0 ms^{-1} C 20 ms^{-1} D 25 ms^{-1}.

3.3 The balls roll down the two slopes below. They start at A at the same time and end at F. Which ball gets to F first, the one on slope X, (AF) or the one on slope Y (ABCDEF) ? Also draw the V-T graphs for both.



Discuss the answer of the above question within your group

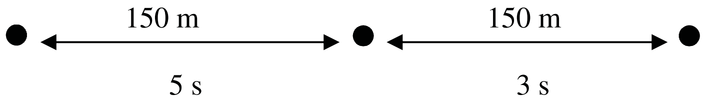
3.4 Two forces are acting at the same point. If their resultant lies between a maximum of 100 N and a minimum of 20 N, then the magnitude of

A each is 50 N.
B the smaller one is 20 N and the larger one is 100 N.
C one is 40 N and the other is 60 N.
D each lies between 30 N and 50 N

3.5 Thandi drops an orange from a tall block of flats. How far does the orange fall in the 4th second? (Assume g = 10 $m.s^{-2}$ and neglect air resistance).

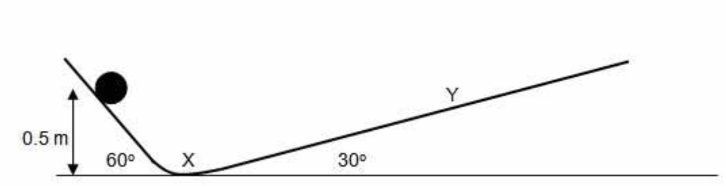
A 25 m
B 30 m
C 35 m
D 45 m

3.6 A car accelerates along a straight road at a uniform rate. Next to the road are telephone poles 150 m apart as shown below. If the car covers the consecutive distances between three poles in 5 and 3 seconds respectively, then the acceleration of the car is, (in $m.s^{-2}$):



A 10.67 B 8 C 5.33 D 5

3.7



A ball of mass 2 kg is held on a slope of 60°, half a metre above a horizontal surface. How far along the slope (distance XY) does the ball roll after being released? (You may assume there is no friction and take g = 10 $m.s^{-2}$ and that the ball loses no energy when it rolls.)

A 1.73 m
B 1.58 m
C 1.15 m
D 1.00 m

3.8 Two masses of 5 kg and 10 kg are connected by an elastic cord and are rest on a frictionless horizontal surface. The masses are pulled apart stretching the elastic cord, and then released simultaneously. As a result they move towards each other and:

A the 5 kg mass and the 10 kg mass accelerate at the same rate,
B they collide at a point midway between the points from which they were released,
C the 5 kg mass has a greater acceleration than the 10 kg mass,
D the 10 kg mass takes longer to reach the collision point than the 5 kg mass.

3.9 Which one of the following statements about a pendulum bob swinging to and fro from the end of a string is true? (Ignore friction)

A Its kinetic energy is always greater than its potential energy.
B Its potential energy is always greater than its kinetic energy.
C The sum of its potential and kinetic energy remains constant.
D The speed with which it swings remains constant.

3.10 **Worked Example**
A Formula 1 racing car has momentum ***P*** and kinetic energy ***T*** when it crashes into a tyre wall. It comes to rest after travelling a distance of ***d*** metres in ***t*** seconds. Which one of the following gives the force exerted on the car during the crash?

A (*P* x *d*)/*T* B *T/d* C *P* x *d* D *P/t*

Solution 1 – using Newton's 2nd Law.

F = rate of change of momentum, ie. $\mathbf{F} = \frac{\Delta \mathbf{P}}{t} = \frac{\mathbf{P}}{t}$ since all the mtm is lost during the collision.

Solution 2 – Equations of motion and then Newton 2!

Using $v = u + at$ or $0 = \mathbf{v} - \mathbf{a}t$ means $\mathbf{a} = \frac{\mathbf{v}}{t}$ ie. $\mathbf{F} = m\mathbf{a} = \frac{m\mathbf{v}}{t} = \frac{\mathbf{P}}{t}$ as before

Solution 3 – equations of motion 2! Using $\mathbf{s} = \mathbf{v}t - \frac{1}{2}at^2$ and $\mathbf{s} = \left(\frac{\mathbf{v} + \mathbf{u}}{2}\right)t$

Here $s = \left(\frac{v + u}{2}\right) t = \frac{\mathbf{v}}{2} t$ then using $s = vt - \frac{1}{2}at^2$: $\frac{2\mathbf{s}}{t} = \mathbf{v} + \mathbf{a}t$ so $2\mathbf{v} - \mathbf{v} = \mathbf{a}t$ $\therefore$ $\mathbf{a} = \frac{\mathbf{v}}{t}$

Then as before $\mathbf{a} = \frac{\mathbf{v}}{t}$ ie. $\mathbf{F} = m\mathbf{a} = \frac{m\mathbf{v}}{t} = \frac{\mathbf{P}}{t}$

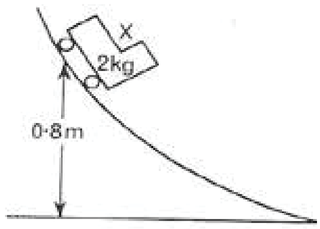
It should be clear from this that solving problems depends to a large extent to concepts that are used and that it is therefore important to understand these fully and when to apply them.

Had the question only given P and t, then answer would have been simple recall! Quite often more information than is necessary is given so that several alternative answers can be generated!

3.11 Which one of the following statements about a pendulum bob swinging to and fro from the end of a string is true? (Ignore friction)

A Its kinetic energy is always greater than its potential energy
B Its potential energy is always greater than its kinetic energy
C The sum of its potential and kinetic energy remains constant
D The kinetic energy is always the same as the potential energy.

3.12 A trolley X of mass 2.0 kg rolls down a frictionless track from a vertical height of 0.8 m, as shown. What is the velocity of X in ms^{-1} when it reaches the bottom?



A 16.0 B 8.0 C 4.0 D 1.6

3.13 If a runner doubles her speed, the ratio of her new kinetic energy to her original kinetic energy will be

A $\frac{1}{4}$ B $\frac{1}{2}$ C 2 D 4

3.14 The net work done on a car to increase its speed from 0 to *v*, is *W*. Which one of the following answers shows the net work needed to increase its speed from *v* to 3*v*?

A 2*W* B 3*W* C 8*W* D 9*W*

3.15 The net work done on an object, moving on a horizontal rough surface in a straight line, is found to be zero. Which one of the following is true for this object?

A There is no frictional force acting on the object.
B The object has zero kinetic energy.
C The object moves at constant speed.
D The object moves at constant acceleration

3.16 Two objects, P and Q, have equal momentum. Object P has a mass of 1 kg and object Q has a mass of 4 kg. Which one of the following represents the ratio of their kinetic energies?

A 2:1   B 4:1   C 8:1   D 16:1

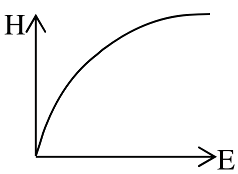
3.17 A machinegun fires bullets into a wall at a rate of 100 bullets per minute. Each bullet has a mass of 4 g and is fired at a speed of 450 $m \cdot s^{-1}$. Assume that all the momentum of the bullets is transferred to the wall. The average force, in newtons, exerted by the bullets on the wall, is:

A 1.8   B 3   C 30   D 1 800

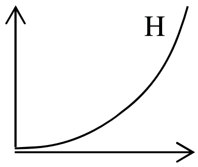
Use the following to answer questions 3.18 and 3.19. A ball of mass M is dropped from a height H.

3.18 Which one of the following graphs correctly shows the change of **kinetic energy** E with the ball's **height**, ignoring air resistance?

A

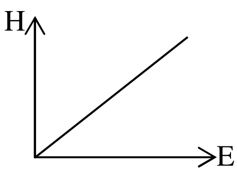


B

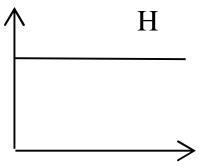


E

C



D



H

3.19 Which one of the above graphs correctly shows the change of **kinetic energy** E with the ball's **height**, if there is air resistance?

3.20 Two bodies of mass M and 4M are moving in a straight line, each with kinetic energy E. The ratio of their momenta is:

A 4:1   B 1:4   C 1:3   D 1:2

3.22 When a spring is stretched by 2 cm, its potential energy is U. If the spring is stretched by 10 cm, its potential energy will be

A U/25   B U/5   C 5U   D 25U

3.23 A, B, C and D are four points on the same vertical line such that AB = BC = CD. If a particle falls freely from rest at A, the time taken by it to describe AB, BC and CD are in the ratio of:

A 1:3:5   B 1:4:6   C 1:4:9   D $1:(\sqrt{2} - 1):(\sqrt{3} - \sqrt{2})$

3.24 A train 100 m long travelling at 40 $m \cdot s^{-1}$ overtakes another train 200 m long travelling at 30 $m \cdot s^{-1}$. The time taken by the first train to pass the second is:

A 30s   B 40s   C 50s   D 60s

3.25 An object of mass 5 kg, falls from rest, a vertical distance of 20 m in air and reaches a velocity of 10 m·s^{-1}. How much work is done by the air on the object? (Take g = 10 m·s^{-2})

A –250 J B –750 J C 500 J D 750 J

3.26 A car covers half distance between two points at 20 km/h and the remaining next half at 30 km/h. The average speed of the car is:

A 30 km/h B 25 km/h C 26 km/h D 24 km/h

3.27 A truck of mass 10 000 kg travelling due east at 15 m·s^{-1} collides with a car of mass 1 500 kg travelling north at 25 m·s^{-1}. The wrecked vehicles tangle together after collision. The velocity of the wreckage after collision is:

A 13.4 m·s^{-1}
B 13.4 m·s^{-1} 14° north of east
C 29.2 m·s^{-1} 76° east of north
D 37 m·s^{-1}

3.28 A light body and a heavy body have the same momentum. Which one has more kinetic energy?

A The light body,
B The heavy body,
C Neither. They also have the same kinetic energy,
D It cannot be decided as there is not enough information.

3.29 Two vehicles X and Y are on the same road. X is moving at a constant velocity of 30 m.s–1 and Y is at rest and starts with an acceleration of 5 m.s–2 as X passes it. Y passes X after

A 7200 m B 800 m C 360 m D 180 m

3.30 A constant horizontal force of 10 N is required to drag an object across a rough surface at a constant speed of 5 m.s^{-1}. What power is being expended ?

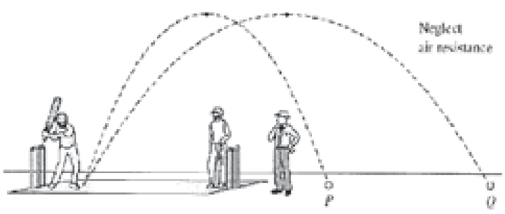
A 500 W B 50 W C 5 W D 0.5 W

3.31 Dale Steyn bowls a standard cricket ball of mass 160g at Joe Root at a speed of 144 kph. Root smashes it straight back past Steyn at 108 kph. If the ball is in contact with the bat for 10 ms, what force does Root's bat exert on the ball?

A 25 200 N B 3 600 N C 1 120 N D 160 N

3.32 The picture below shows two consecutive shots by AB de Villiers. Both balls reach the same maximum height above the ground but ball Q travels further than ball. Which one of the following is **different** for balls P and Q?

A Acceleration due to gravity
B Vertical component of the initial velocity
C Time of flight
D Initial velocity



Discuss the answer of the above question within your group

3.33 A man weighs 1 000 N on the surface of the Earth. What would his weight be on a planet that has half the radius and half the mass as the Earth?

A 500 N B 1 000 N C 2 000 N D 4 000 N

3.34 A body of weight W rests on a plane inclined at an angle of 30º to the horizontal. The magnitude of the frictional force which prevents the body from moving down the incline is

A W cos30º B W sin30º C W tan30º D W

3.35 Which one of the following statements is true for a freely falling body?

A The average speed during the first second is 5 $m.s^{-1}$
B The acceleration increases by 10 $m.s^{-2}$ each second
C displacement of the body increases by 10 m each second
D During each second the body falls 10 m

3.36 The acceleration due to gravity, g, on Earth is 9.81 $m.s^{-2}$. What would you expect the value of g to be inside the ISS, the International Space Station, when in orbit around the Earth, about 400 km above Earth's surface?

A 0 B 0.0002 $m.s^{-2}$ C 8.69 $m.s^{-2}$ D 9.81 $m.s^{-2}$

3.37 The barrel of a gun is pointing directly at a target. If the target is dropped the instant the bullet leaves the barrel of the gun, then neglecting air resistance and assuming that the bullet can reach the target, it will:

A pass above the target
B pass below the target
C only hit the target if the barrel is level
D always hit the target

Use the following information to answer questions 3.38 and 3.39. A car is travelling at a steady speed of 100 km/h when it passes a stationary motorcyclist. The instant the car passes the motorcyclist, he sets off in pursuit of the car, accelerating uniformly, and overtakes the car after t seconds.

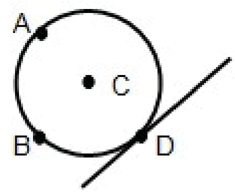
3.38 Which of the following must be the same for the car and the motorcyclist the instant the motorcyclist passes the car:

A their speed and t
B their speed and the distance travelled
C t and the distance they travelled
D only t

3.39 What is the speed of the motorcyclist as it passes the car?

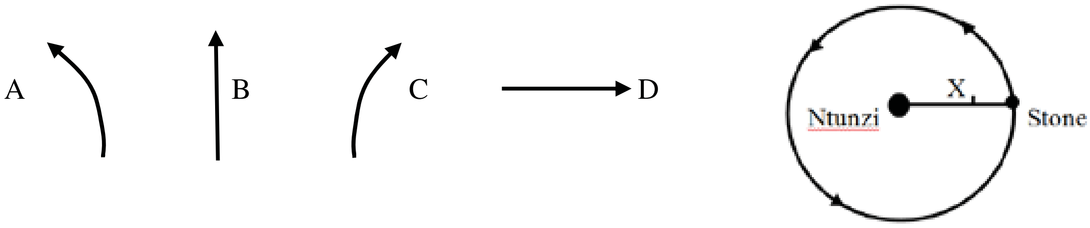
A 100 km/h
B just more than 100 km/h
C 200 km/h
D more than 200 km/h

3.40 A hoop is **rolling** down a slope as shown. The points A and B are marks on the hoop, C is the axle and D is where the hoop touches the ground. Which one of the points does not change speed as the hoop rolls down the slope?



Discuss the answer of the above question within your group

3.41 Ntunzi ties a stone to a piece of string and swings it around her head in a horizontal circle as shown. In which direction does the stone start to travel after the string breaks at X.



Discuss the answer of the above question within your group especially the difference between centripetal and centrifugal force.

3.42 A car of mass 1 200 kg is freewheeling down a road sloping at 30° to the horizontal and reaches a steady speed of 54 km/h. What is the power of the car's engine if it is travelling along a horizontal road at the same speed and all other conditions are unchanged?

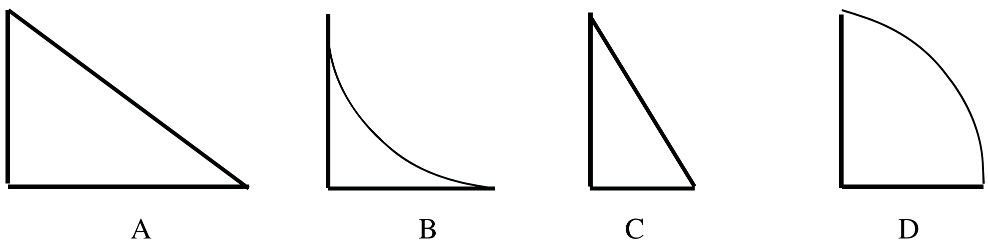
A 18 kW B 65 kW C 78 kW D 90 kW

Discuss the answer of the above question within your group

3.43 Two bodies A and B attract each other with a gravitational force of F newtons when they are a distance R apart. If the mass of A is doubled, the mass of B is tripled and distance between them is doubled, then the force between A and B will be:

A $3F$ B $3F/2$ C $3F/4$ D $3F$

3.44 On which of the following hills does the ball roll down with increasing speed and decreasing acceleration?



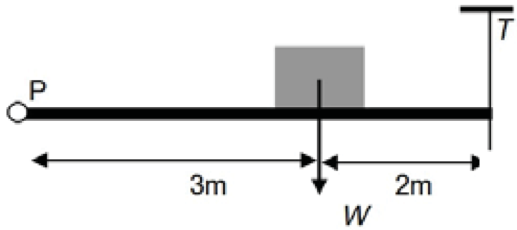
3.45 A body that is in equilibrium could have

A uniform velocity
B motion in a circular path at uniform speed
C a uniform acceleration
D a constant net force applied to it

3.46 The amount of work you have to do against gravity to push your car on a level road

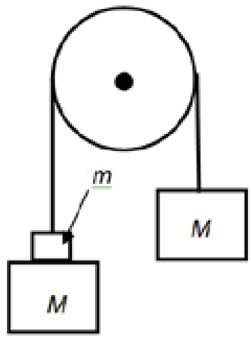
A depends on the local value of the acceleration due to gravity
B is zero
C depends on the mass of the car
D depends on the force you apply

3.47 The diagram on the right shows a uniform beam of weight W, pivoted at point P and held horizontally by a string, and supports a block of weight W as shown. The tension T in the string is:



A 5W/2
B 11W/6
C 10W/11
D 11W/10

3.48 The pulley system shown below is frictionless and the pulley has negligible mass. When released the masses have an acceleration *a*. The value of *m* is:

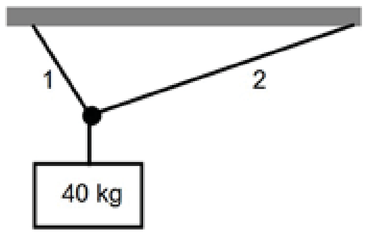


A $\dfrac{2M}{\frac{g}{a} - 1}$ B $\dfrac{2Ma}{g}$

C $\dfrac{Ma}{2g}$ D $\dfrac{2Ma}{a - g}$

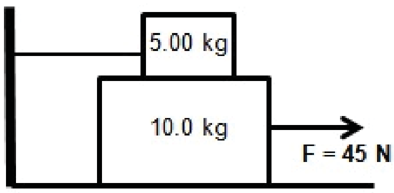
E $\dfrac{2Mg}{g - a}$

3.49 A 40 kg mass is suspended from a knot joining three strings. The resultant of the forces in strings 1 and 2 is:



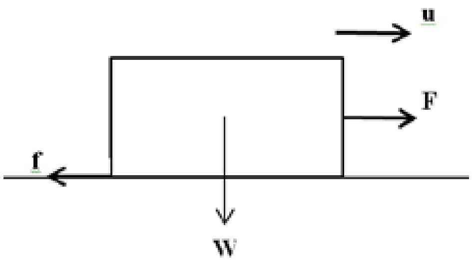
A impossible to calculate since the directions of 1 and 2 are not given
B impossible to calculate since 1 and 2 are not the only forces acting on the knot
C zero
D 400 N upwards,
E 400 N downwards.

3.50 A 5.00 kg block is placed on a 10.0 kg block in the figure right. A horizontal force of 45.0 N is applied to the 10.0 kg block, and the 5.00 kg block is tied to the wall. The coefficient of kinetic friction between all moving surfaces is 0.200. Determine the tension in the string.



A 5.00 N
B 50.0 N
C 10.0 N
D 7.20 N
E 6.45 N

3.51 The diagram shows a box of weight **W** sliding over a rough surface at a constant speed **u** by a force **F** against a frictional force of **f N**. Which one of the the following statements is true?



A f ∝ area
B f ∝ mass
C f ∝ speed
D f ∝ weight and area
E f < F otherwise **u** would decrease.

3.52 Which one of the following statements about the Earth's gravitational field is/are correct?

(i) It exerts a force on an object which is falling freely on the Earth.
(ii) It exerts a force on an object on the Moon's surface.
(iii) It arises because the Earth is in orbit.

A (i), (ii) and (iii) B (i) and (ii) only
C (i) and (iii) only D (iii) only
E (i) only

Us the information to answer questions 3.53 and 3.54. A car of mass 1 000 kg is travelling along a straight road when the driver suddenly brakes, causing the car to skid. The car's speed when it begins to skid is 30 $m.s^{-1}$ and the average frictional force exerted is 10 000 N.

3.53 From the moment the driver applies the brakes to the moment the car comes to rest, the distance travelled is:

A 15 m B 30 m C 45 m
D 60 m E 90 m

3.54 How long does it take for the car to come to rest from the moment the driver applies the brakes?

A 3s B 6s C 9s
D 10s E 30s

3.55 A soccerball is kicked and acquires a speed of 25 $m.s^{-1}$. The mass of the ball is 0.4 kg and the toe of the boot is in contact with the ball for 0.05s. The best estimate of the average force with which the ball is kicked is:

A 0.5 N B 5 N C 50 N
D 200 N E 2 000 N

3.56 A toy bear is hung from the rear view mirror of a car by a piece of string. When the car accelerates at ***a*** the string is at an angle α with the vertical. Which one of the following is true?

A $\tan \alpha = 1/g$ B $\tan \alpha = 1/a$ C $\tan \alpha = a$
D $\tan \alpha = a/g$ B $\tan \alpha = g/a$

3.57 A ball is kicked on level ground at an angle θ. It lands after travelling D m and reaches a height h. The ratio h/D is:

A tan θ B ½ tan θ C ¼ tan θ D 4 sin 2θ E ¼ sin θ

Use the following to answer questions 3.58, 3.59 and 3.60. The diagram below shows two trolleys, X and Y of mass 1 kg and 2 kg respectively. They are moving towards each other, X at +4 m.s^{-1} and Y at – 3 m.s^{-1}, ie left to right is positive.

3.58 The total momentum of X and Y after the collision is, kg.m.s^{-1} :

A	+10	B	+2	C	0
D	–2	E	–10		

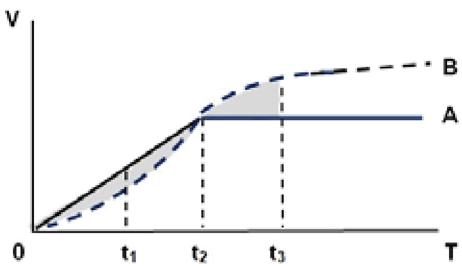
3.59 The total kinetic energy of X and Y before the collision is:

A	– 17 J	B	– 1 J	C	0
D	+1 J	E	+ 17 J		

3.60 If the collision is perfectly inelastic, the total kinetic energy after the collision is:

A	17 J	B	12.5 J	C	7 J
B	6 J	E	0 J		

Use the V - T graph and information below to answer questions 3.61 and 3.62. Car A (solid line) and Car B (broken line) are having a race. They start at the same place when $T = 0$. The velocity versus time graph for the two cars is illustrated by the solid and broken lines in the diagram. The two lines have the same slope at t_1 and t_3 is the time where the shaded areas have exactly the same area.



3.61 At what time, other than when they started, do the two cars have the same speed**?**

A At t_1
B At a time between t_1 and t_2
C At t_2
D At a time between t_2 and t_3
E At t_3

3.62 At what time do the two cars pass each other?

A At a time between t_1 and t_2
B At t_2
C At a time between t_2 and t_3
D At t_3
E Sometime after t_3

3.63 A heavy particle of mass M collides elastically with a light particle of mass m. The initial velocity of the heavy particle is u and the final velocity is v. The light particle is initially at rest. After the collision the light particle goes off in the forward direction with velocity V, what fraction of the energy of the heavy particle is lost in the collision?

A $1-\left(\frac{v}{u}\right)^2$

B $1-\left(\frac{u}{v}\right)^2$

C $1-\left(\frac{v}{u}\right)^{\frac{1}{2}}$

D $1-\left(\frac{u}{v}\right)^{\frac{1}{2}}$

3.64 A rocket engine is mounted on a wagon which is free to move horizontally. When the engine is first ignited, the wagon acquires some acceleration. This acceleration is independent of:

A Mass of exhaust gases emitted per unit time.
B Mass of wagon.
C Acceleration due to gravity.
D Velocity of exhaust gases

3.65 Which of the following requires the greatest power? To lift a bag of oranges through

A ½ metre in 1 second
B 1 metre in 1 second
C 1 metre in ½ second
D 1 metre in 2 seconds

3.66 Which one of the following has the same SI unit as acceleration?

A $\frac{\text{energy}}{\text{mass}}$ B $\frac{\text{velocity}}{\text{area}}$ C $\frac{\text{weight}}{\text{mass}}$ D $\frac{\text{force}}{\text{length}}$

3.67 The world record for a high dive into deep water is 54 m. A diver of mass 65 kg dives into the water below him. If air resistance is insignificant, his velocity on entering the water is independent of his:

A Height above the water B Weight
C Gravitational acceleration D All of the above

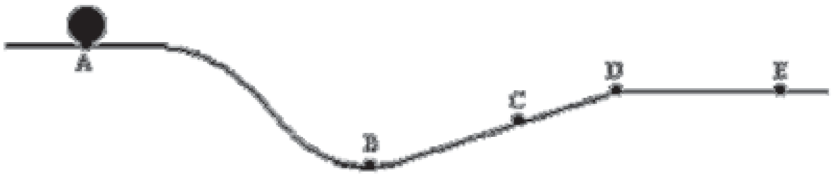
3.68 It takes a man 10 s to ride down an escalator. The same man takes 15 s to walk back up the escalator against its motion. How long will the man take to walk down the escalator at the same rate he was walking before?

A 2.5 s B 5 s C 7.5 s D 10 s

3.69 Under the action of a force, a 2 kg body moves from rest on a smooth horizontal surface such that it reaches a velocity of 1 $m \cdot s^{-1}$ at the end of the first second. It then doubles its velocity each second after that. The work done by the force in the first two seconds is:

A 1J B 4 J C 8 J D 16 J

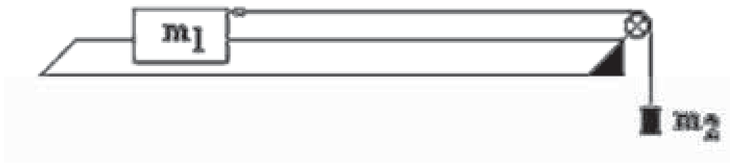
3.70 Consider the following diagram with a ball passing point A at a constant speed. It then rolls down the slope past B, and then up to C, D and E. Neglect the effect of resistant forces.



The ball's kinetic energy at point C is less than its kinetic energy:

A At point A only
B At points A, D & E
C At point B only
D At points D & E

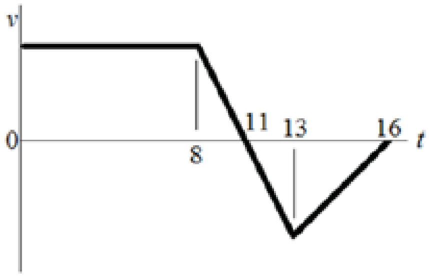
3.71 Consider the two-body situation depicted below. A 20-g hanging mass (m_2) is attached to a 250-g air track glider (m_1). Take $g = 9.8\ m{\cdot}s^{-2}$



The acceleration of the system is:

A $0.18\ m{\cdot}s^{-2}$ B $0.27\ m{\cdot}s^{-2}$ C $0.73\ m{\cdot}s^{-2}$ D $0.78\ m{\cdot}s^{-2}$

3.72 In which of the following intervals is the object **speeding** up in the graph below?

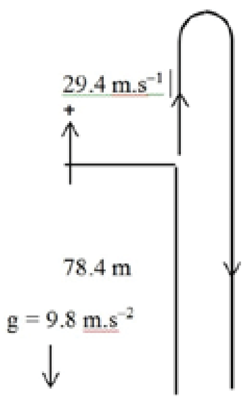


A 8s – 11s B 8s – 13s C 11s – 13s D 13s – 16s

Worked Example

3.73 A stone is throne vertically upwards with a velocity of 29.4 $m.s^{-1}$ from the edge of a cliff 78.4 m high. The stone falls so that it just misses the edge of the cliff and so falls to the ground at the foot of the cliff. The time taken by the stone to reach the ground is: (assume the acceleration due to gravity, $g = 9.8\ m.s^{-2}$)

A 2 s B 8 s C 14.7 s D 88.2 s



First draw a diagram!! Clearly mark positive direction. Then using the eqn:
$x = ut + ½ gt^2$, substitute in the given values, to get: $– 78.4 = 29.4t – ½\ 9.8t^2$

which gives $– 78.4 = 29.4t – 4.9t^2$ a horrible quadratic to solve.

Try dividing by 4.9, to get: $t^2 – 6t – 16 = 0$ – which is easy!!
Answer is 8 or – 2 seconds. Discuss this question and explain the – 2 s!!

3.74 A vehicle of mass 1 000 kg increases its velocity from 5 $m.s^{-1}$ to 10 $m.s^{-1}$ in 15 seconds. Determine the increase in kinetic energy.

A 75 000 J B 37 500 J C 5 000 J D 2 500 J

3.75 A vehicle of mass 800kg is moving at 8 $m.s^{-1}$ is brought to rest in a distance of 40m. The force exerted on the vehicle to do this is:

A 6 400 N opposite to the direction of motion.
B 640 N opposite to the direction of motion
C 640 N in the direction of motion
D 1 288 N opposite to the direction of motion

3.76 A soccer ball of mass 0.42 kg is moving horizontally at 10 $m.s^{-1}$ towards a footballer's boot, who kicks it and it returns along the **same** path as before. If the impulse on the ball is 11 Ns, what is its speed, in $m.s^{-1}$, afterwards?

A 2.62 B 6.8 C 15.2 D 16.2

3.77 If a body of mass *m* has momentum ***P*** then its kinetic energy *E* is:

A $\frac{P^2}{2m}$ B $\frac{2P^2}{m}$ C $\frac{mP^2}{2}$ D $2mP^2$

3.78 The amount of work you have to do against gravity to push your car on a level road

A depends on the local value of the acceleration due to gravity
B is zero
C depends on the mass of the car
D depends on the force you apply

3.79 Two projectiles are launched simultaneously with the same initial speed and position and in the same vertical plane. One is launched at 70^o to the horizontal, and the other at 20^o to the horizontal. If the air resistance is neglected then which of the following statements are true?

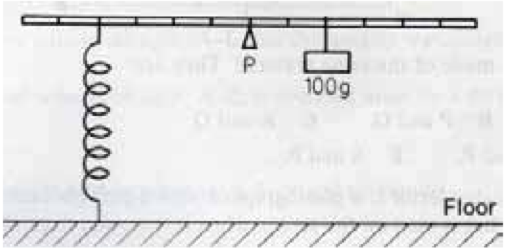
(i) The projectiles will land at the same point.
(ii) The projectile launched at 20^o to the horizontal will land first.
(iii) The projectiles will land at the same time.

A Only (ii) B (i) and (ii) C (i) and (iii) D Only (i)

3.80 A 0.1 kg ball falls 3.2 m, reaching a speed of 8 $m.s^{-1}$. At this point it strikes a surface, exerts an average force of 10 N, and rebounds with a speed of 6 $m.s^{-1}$ and reaches a height of 1.8 m. To find the time during which the ball was in contact with the surface, which one of the following equations would be the best to use?

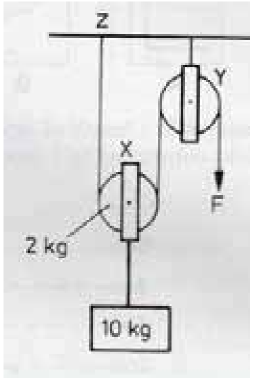
A Potential energy = mgh
B force x time = change of momentum
C kinetic energy = ½ mv^2
D v = u + at
E s = ut + ½ at^2

3.81 A lever is balanced on a pivot P by a spring pulling down on one side and a mass positioned as shown on the other. The tension in the spring is:



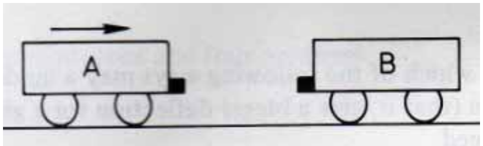
A 0.1 N
B 0.5 N
C 1 N
D 5 N
E 10 N

3.82 X is a pulley of mass 2kg from which hangs a mass of 10 kg. The string has negligible mass and is firmly fixed at Z. Assume there is no friction at the pulleys X and Y. The force F that must be applied to the string to just prevent motion is:



A 10 N
B 12 N
C 50 N
D 60 N
E 120 N

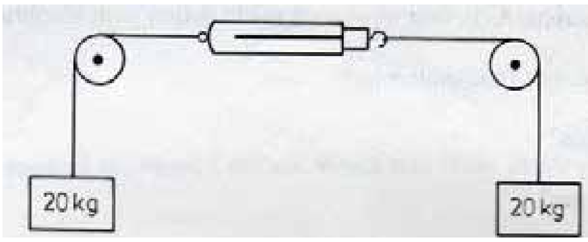
3.83 A trolley of mass M_A moves to the right, as shown, and collides elastically with a stationary trolley M of mass M_B. Which of the following statements is true?



(i) If $M_A > M_B$, both trolleys move to the right.
(ii) If $M_A = M_B$, A comes to rest and B moves to the right.
(iii) If $M_A < M_B$, A move to the left and B to the right.

A (i), (ii) and (iii)
B (i) and (ii) only
C (i) and (iii) only
D (iii) only
E (ii) and (iii) only

3.84 Two masses are connected to a spring balance over two pulleys as shown below. The force registered by the spring balance is:



A 0 N
B 20 N
C 40 N
D 200 N
E 400 N

A cricket ball is thrown vertically upwards and a speed of 20 $m.s^{-1}$. Use this to answer 3.85 and 3.86. Assume g = 10 $m.s^{-2}$

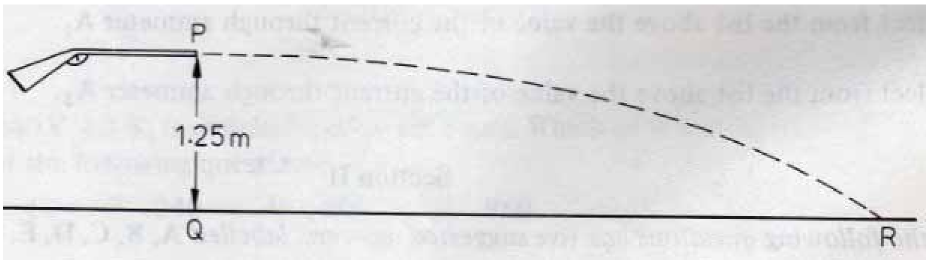
3.85 The time taken for the ball to reach its maximum height is:

A 20 s B 10 s C 5 s D 2 s E 1 s

3.86 The maximum height reached by the ball is:

A 20 m B 10 m C 5 m D 2 m E 1m

3.87 A rifle is held with its barrel horizontal, with the muzzle P 1.25 m vertically above the point Q on level ground. It fires a bullet which hits the ground at R. How long does it take for the bullet to travel from P to R? (ignore air resistance and take g = 10 $m.s^{-2}$)



A	0.25 s	B	0.5 s	C	1.0 s
D	1.25 s	E	2.0 s		

3.88 If the speed of the bullet in 3.87 is 400 $m.s^{-1}$, what would be the distance QR?

A 100 m
B 150 m
C 200 m
D 400 m
E 1 250 m

3.89 The bob of a simple pendulum is passing through its lowest point. At this instant it has:

A maximum velocity and maximum potential energy
B maximum velocity and maximum kinetic energy
C minimum velocity and minimum potential energy
D minimum velocity and minimum kinetic energy
E minimum velocity and maximum potential energy

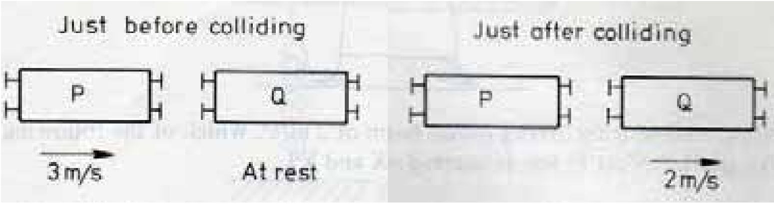
3.90 A car is travelling along a level road when the engine is switched off and the car is allowed to slow down and stop. Which one of the following statements correctly describes the energy changes that take place after the engine is switched off?

A The kinetic energy is of the car is converted into potential energy
B The kinetic energy is of the car is converted into potential energy and heat
C Both the kinetic and potential energy of the car are converted in to heat
D The kinetic energy of the car is converted in to heat
E The kinetic energy is of the car is converted into chemical energy

3.91 A man of mass 60 kg runs up stairs 5 m high in 4 seconds. His average power is:

A 75 W
B 480 W
C 750 W
D 1 200 W
E 12 000 W

Questions 3.93, 3.93 and 3.94 refer to the following data. A railway truck P collides with a stationary truck Q. Just before the collision, P's speed is 3 m.s^{-1}, from left to right, as shown in the diagram. Just after the collision, Q is movingat 2 m.s^{-1} in the same direction. The mass of each truck is 1 500 kg and they Are in contact for 0.5 s.



3.92 Just after the collision the velocity of P is:

A 5 m.s^{-1} from left to right
B 5 m.s^{-1} from right to left
C 1 m.s^{-1} from left to right
D 1 m.s^{-1} from right to left
E 0

3.93 The average force exerted by Q on P is:

A 3 000 N B 4 500 N C 6 000 N
D 9 000 N E 12 000 N

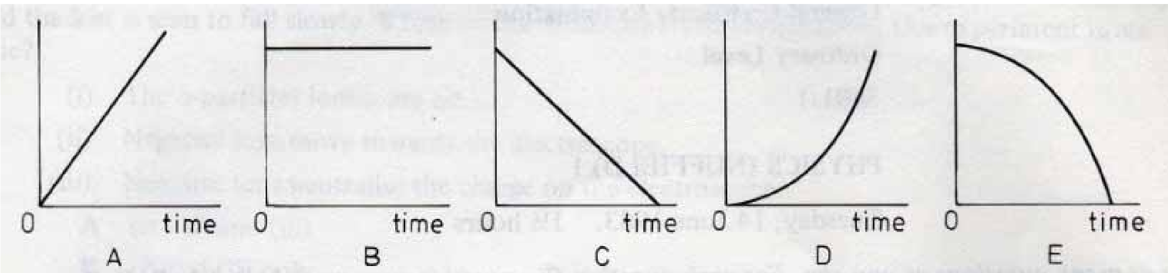
3.94 The loss of kinetic energy during the collision is:

A 3 000 J B 4 500 J C 6 000 J
D 9 000 J E 12 000 J

3.95 A force gives an impulse of 20 Ns to a 5 kg mass. The gain in ***momentum*** is:

A 2 kg. m.s^{-1} B 4 kg. m.s^{-1} C 20 kg. m.s^{-1}
D 50 kg. m.s^{-1} E 100 kg. m.s^{-1}

Use the graphs below to answer questions 3.96, 3.97 and 3.98.



A piece of rock is dropped on the Moon's surface. Which one of the above graphs, A – E, most nearly represents

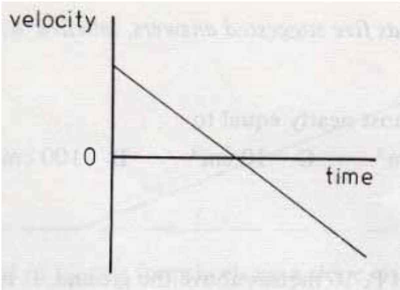
3.96 the acceleration against time?

3.97 the speed of the rock against time?

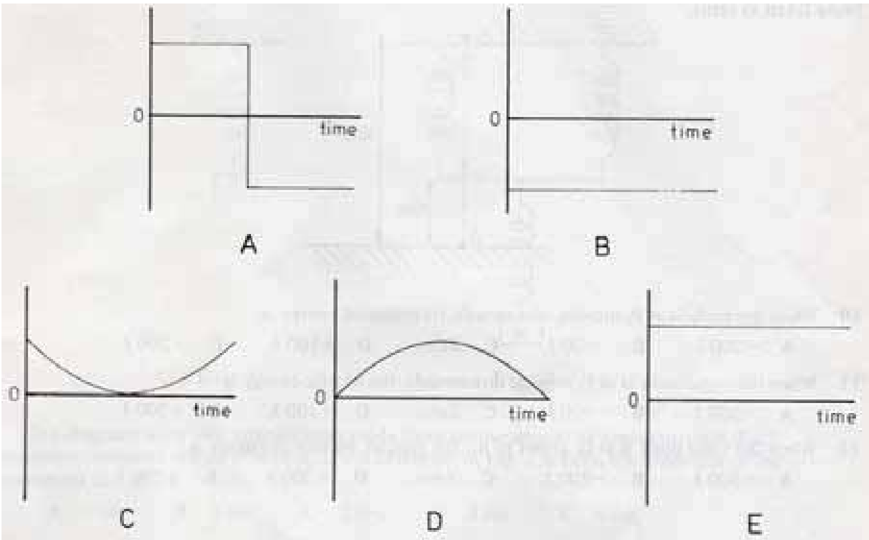
3.98 the distance fallen against time?

3.99 When a cricketer catches a ball, he usually moves his hands in the direction in which the ball is moving rather than holding them rigidly in front of him. This is because

A the impulse of the ball is reduced
B the change of momentum of the ball is reduced
C the velocity of the ball is reduced more rapidly
D the velocity of the ball is reduced more slowly
E the force exerted by the hand on the ball is greater.



The graph above shows how the velocity of a vehicle moving in a straight line changes with time. Use the graphs below to answers questions 3.100, 3.101 and 3.102.



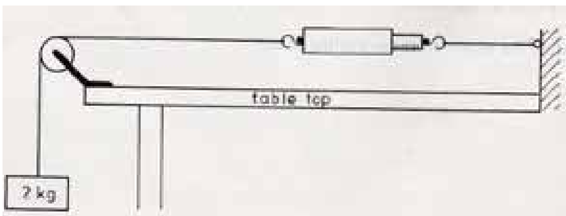
Which one of the graphs A – E most nearly represents the variation with time of

3.100 the acceleration of the vehicle?

3.101 the kinetic energy of the vehicle?

3.102 the distance of the vehicle from its starting point?

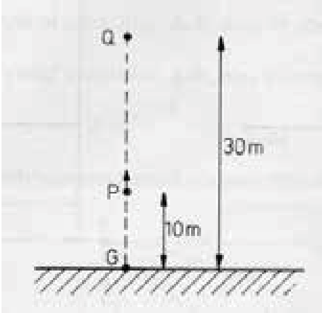
3.103 A 2 kg mass, attached by a nylon thread to a spring balance, is hung over a frictionless pulley as shown on the right.



The reading on the spring balance is most nearly equal to:

A 0 N B 0.2 N C 2 N
D 20 N E 200 N

Use the data given to answers questions 3.104, 3.105 and 3.106. The diagram on the right shows a body at P, 10 m above the ground. It is moving upwards: it reaches Q, 30 m above the ground, and then falls back to ground level at G. Air resistance may be neglected. The gravitational potential energy is +300 J at Q (the gravitational energy at ground level is taken as 0)



3.104 When the body is at P, and moving downwards, its potential energy is:

A – 200 J B – 100 J C 0 D +100J E +200 J

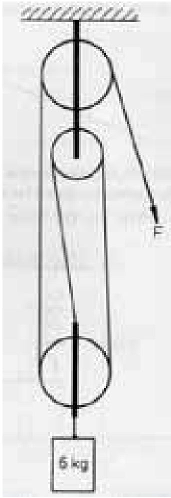
3.105 When the body is at P, and moving downwards, its kinetic energy is:

A – 200 J B – 100 J C 0 D +100J E +200 J

3.106 When the same body is at G, about to hit the ground, its kinetic energy is:

A – 300 J B – 200 J C 0 D +200J E +300 J

3.107 In the pulley system shown on the right, the rope is pulled by a distance of 1.5 m by the force F. The gain in potential energy of the 6 kg load is:



A 20 J

B 30 J

C 40 J

D 60 J

E 90 J

4 MCQs and General Questions – Electricity

4.1 A two bar electric fire is operated from a 240V main supply. Each bar is rated at 1 kW. In order to prevent a fire, a fuse is put in the circuit. What is the lowest rating for this fuse if it is not to "blow" when both bars are in use?

A 3A
B 5A
C 10
D 15A

4.2 Electrons are accelerated from rest through a small potential difference $\boldsymbol{V}$ and reach a speed $\boldsymbol{u}$. The ratio of the charge of the electron to its mass (*e/m*) is:

A $\boldsymbol{u}/\boldsymbol{V}$
B $\boldsymbol{V}/\boldsymbol{u}$
C $\boldsymbol{u}^2/2\boldsymbol{V}$
D $2\boldsymbol{u}^2/\mathbf{V}$

4.3 A cell has an emf E Volts and internal resistance r Ω. It is connected to an external resistance R Ω. What is the power dissipated in the external resistance R, if R = r?

A E/(R + r)
B $E^2/(4r)$
C $E^2/2r$
D E/2R

4.4 At a distance "d" from a point charge Q the electric field strength is $E = kQ/d^2$, where k is constant. What will the field strength at a distance "d/2" from the charge Q be?

A $1/\sqrt{2}$ E
B 2 E
C 4 E
D 8 E

4.5 Two bulbs are marked 100 W, 200 V and 50 W, 200 V respectively. If the bulbs are connected in series, then the ratio of their respective power output is:

A 1:2
B 1:1
C 2:1
D 1:4

4.6 A galvanometer has a resistance of 100Ω. It gives a full scale deflection when a potential difference of 50mV is applied across its terminals. The resistance of the shunt that enables it read up to 5A will be:

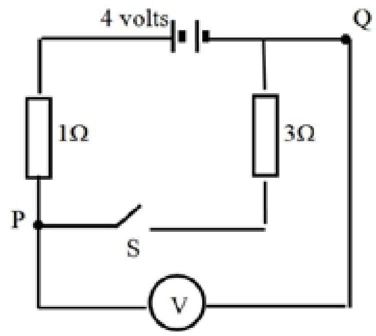
A 0.01 Ω
B 10.0 Ω
C 0.20 Ω
D 0.5 Ω

4.7 A cell has an emf E Volts and internal resistance r Ω. It is connected to an external resistance R Ω. What power is dissipated in the external resistance R, if R = r?

A E/(R + r)
B $E^2/(4r)$
C $E^2/2r$
D E/2R

4. 8. Electrons are accelerated through a small potential difference V and reach a velocity u. The ratio of the charge to the mass of an electron (e/m) is given by:

A u/V
B V/u
C 2u/V2
D $u^2/(2V)$



The following information is to be used for answering questions 4.**9** and 4.**10.** The battery has no internal resistance and resistors have the values shown. S is a switch (shown open) and V is a high resistance voltmeter connected between P and Q as shown.

4.9 With the switch S in the open position, what is the reading on the voltmeter?

A 0 volts
B 1 volt
C 3 volts
D 4 volts

4.10 With the switch S now in the closed position, what is the reading on the voltmeter?

A 4 volts
B 3 volts
C $^4/_3$ volts
D 0 volts

4.11 Electric motors:

A convert electrical energy into mechanical energy,
B convert mechanical energy into electrical energy,
C convert electrical energy into heat,
D all of the above

4.12 The back emf in a DC motor is a maximum when the motor is:

A under maximum load,
B just starting to turn,
C running at it maximum speed,
D slowing down.

4.13 An electron volt (eV) is a unit of:

A electric field strength
B work
C potential difference
D charge on an electron.

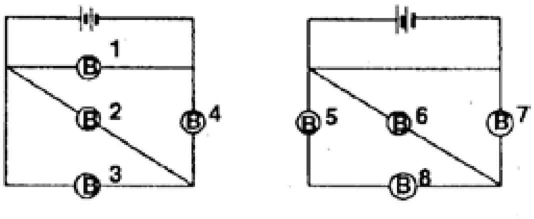
4.14 The core of a transformer is laminated to avoid the loss of energy due to:

A to improve the flux linkage,
B to reduce the flux leakage,
C to reduce the eddy currents in the metal core,
D to reduce the heat conduction.

4.15 The circuits below have identical batteries and bulbs. Which of the bulbs burns equally brightly?

(B) = bulb  = Battery

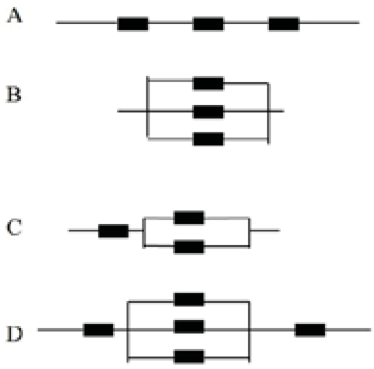
A 2, 3, 6 and 8
B 4 and 7
C 2 and 3
D 4, 5 and 8



4.16 A charged capacitor of 1 μF holds 10μC charge. What is the energy stored by this capacitor?

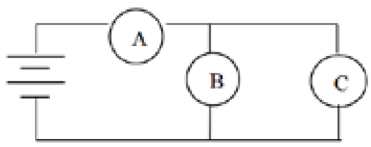
A 50×10^{-12} J
B 50×10^{-9} J
C 50×10^{-6} J
D 50×10^{-3} J

4.17 Which arrangement of 3 ohm resistors will give a total resistance of 7 ohms?



4.18 Which of the following identical light bulbs will glow the brightest?

A Bulb A　　B Bulb B only
C Bulb C only　　D Bulbs B and C



4.19 Three resistors, X, Y and Z are connected in parallel, with the resistance of X < Y < Z. The value of the equivalent resistance *R* of the parallel combination is:

A $R > Z$
B $R < X$
C $R = \frac{1}{X} + \frac{1}{Y} + \frac{1}{Z}$
D $R = \frac{X + Y + Z}{XYZ}$

4.20 If one, two or three identical resistors can connected in series, in parallel or in a combination of these, how many different values of resistance can be created?

A 3
B 5
C 6
D 7

4.21 A transformer has 100 turns in the primary coil and 2 000 turns in the secondary coil. If an alternating potential difference of 12 V is applied across the primary, the potential difference across the secondary will be:

A 0.6 V
B 6 V
C 240 V
D 480 V

4.22 If E is the emf of a cell, n the number of cells, r the internal resistance of each cell and R an external resistance, then the current I in a circuit where these components are connected in series is:

A $\frac{nE}{(R+nr)}$ B $\frac{nE}{(R+r)}$ C $\frac{E}{(R+r)}$ D $\frac{nE}{\left(R+\frac{r}{n}\right)}$

4.23 A flash of lightning discharged 60 C of charge at a potential difference of 10^9 V in 10^{-2} s . The current is:

A 0.6 A B 36 A C 6 000 A D 1.67×10^5 A

4.24 At a distance "d" from a point change Q the electric field strength is $E = kQ/d^2$, where k is constant. What will be the field strength at a distance "d/2" from the change Q?

A 2E B 4E C 6E D 8E

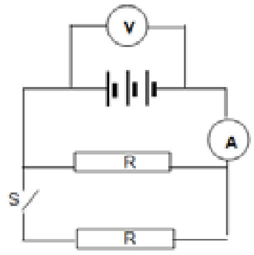
4.25 S and T are two charged spheres placed on insulated stands. The charges on S and T are – 2 μC and + 6 μC respectively. The spheres are allowed to touch each other and then returned to their original positions. Which one of the following statements is true.

A S has gained 2×10^6 electrons
B T has gained 2×10^6 electrons
C S has lost 2.5×10^{13} electrons
D T has lost 2.5×10^{13} electrons

4.26 Two identical insulated conductors are charged so that one has a charge of $-6\mu C$ and the other a charge of $12\mu C$. They experience a force of **F** N when placed a distance **d** m apart. They are now briefly brought into contact with each other and returned to their original positions. The force they experience now is:

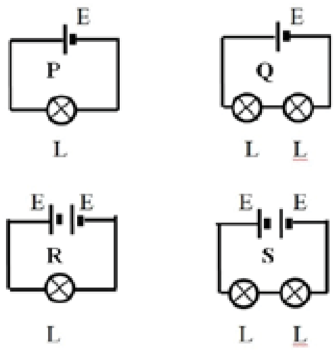
A 9**F**/8
B **F**
C **F**/4
D **F**/8

4.27 The circuit shows two identical resistors connected in parallel to a battery with no internal resistance. How do the readings on the Voltmeter V and the ammeter A change when the switch S is closed?



	Voltmeter	**Ammeter**
A	increases	decreases
B	stays the same	increases
C	decreases	increase
D	stays the same	decreases

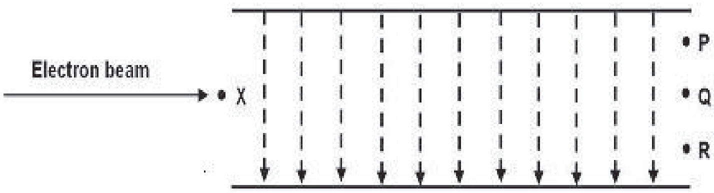
4.28 In the circuits on the right all the cells, E, are identical and so are all the bulbs, L. In which two circuits will the bulbs shine equally brightly?



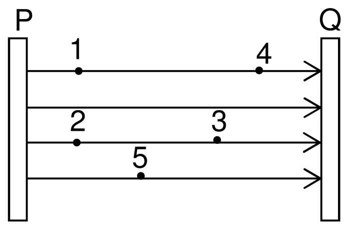
A P and S
B P and Q
C R and S
D P and R

4.29 An electron beam enters in an evacuated tube in which there is a uniform electric field directed as shown in the diagram. Which of the following is a possible path of the beam?

A a curved line from X to P
B a curved line from X to R
C a straight line XQ
D a line curving out of the plane of the diagram

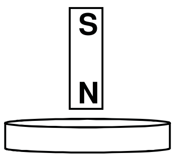


4.30 The diagram on the right shows different points in an electric field between two oppositely charged parallel plates, P and Q. Which one of the following statements is correct



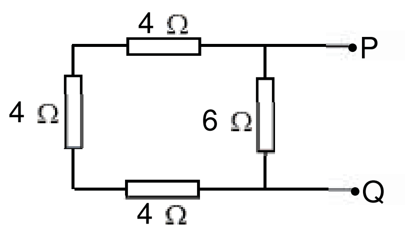
A The charge on plate P is positive and point 2 is at a higher potential than 3.
B The charge on plate P is negative and point 5 is at a higher potential than 4.
C The charge on plate P is negative and point 3 is at a lower potential than 1.
D The charge on plate P is positive and all points are at the same potential

4.31 A bar magnet falls through a copper ring as shown be on the right. Which one of the following correctly describes the magnitude of the acceleration of the magnet while it falls through the ring?



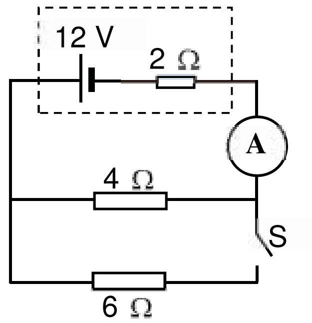
A Equal to $9.8\ m\cdot s^{-2}$
B Greater than $9.8\ m\cdot s^{-2}$
C Less than $9.8\ m\cdot s^{-2}$
D Zero – it falls at a constant speed.

4.32 Four resistors are connected as shown right. The total resistance, in ohms, between points P and Q is:



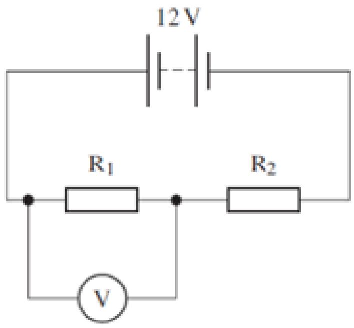
A 4
B 6.4
C 10.4
D 18

4.33 A battery of emf 12 V and internal resistance of 2 Ω is connected in a circuit as shown. When switch S is closed, the ammeter reading changes from:



A 2 A to 1 A
B 2 A to 2.7 A
C 3 A to 1.2 A
D 3 A to 5 A

4.34 In the circuit shown to the right, R_2 is replaced with a thermistor. How will the reading on the voltmeter be effected if the temperature of the thermistor increases.



A Increases
B Decreases
C Stays the same
D The reading drops to 0, as thermistors are not conductors

4.35 A galvanometer has a resistance of 3 663 Ω. A shunt S is connected across it such that (1/34) of the total current passes through the galvanometer. The resistance of the shunt is:

A 3 663 Ω B 111 Ω C 107.7 Ω D. 3 555 Ω

4.36 The armature of a DC motor has 20 Ω resistance. It draws a current of 1.5 amps when run by 220 volt DC supply. The value of back e.m.f induced in it will be

A 150 V B 170 V C 180 V D 190 V

4.37 A Galvanometer of resistance 50Ω is connected ti a battery of 3 volt along with a resistance of 2950Ω in series. A full scale deflection of 30 divisions is obtained in the galvanometer. In order to reduce this deflection to 20 divisions the resistance in series should be

A 4450 Ω B 4050 Ω C 5550 Ω D 6050 Ω

4.38 Seven capacitors each of capacitance $2\mu F$ are to be connected to obtain a capacitance of $\left(\frac{10}{11}\right)\mu F$ Which one of the following combinations is possible?

A 5 in parallel, 2 in series
B 4 in parallel, 3 in series
C 3 in parallel, 4 in series
D 2 in parallel, 5 in series

Below is a list of electrical appliances with appropriate voltages and power ratings.

	Appliance	Volts	Watts
A	Torch bulb	6	7.5
B	CD Player	100	25
C	Portable Floodlight	12	60
D	TV Set	250	200
E	Hotplate	250	1 000

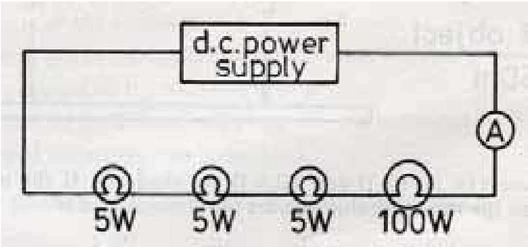
4.39 Which appliance draws the highest current?

4.40 Which appliance has the highest resistance?

4.41 Which appliance transforms electrical energy at the highest rate?

4.42 For which one of these appliances would a transformer with 4 000 turns on the primary and 100 turns on the secondary be suitable when operating from 240-volt mains?

Questions 4.43 – 4.46 refer to the following information. When three 5 W lamos and one 100 W lamp are connected in series, as shown below, the ammeter reads 0.5 A and the lamps are glowing with their normal brightness.



4.43 The energy transformed per second by the 100 W lamp is:

A	0.5 J	B	50 J	C	100 J
D	200 J	E	400 J		

4.44 The energy transformed by ***one coulomb*** passing through one of the 5 W lamps is:

A	0.5 J	B	5 J	C	10 J
D	15 J	E	20 J		

4.45 The resistance of one of the 5 W lamps is:

A	0.5 Ω	B	1 Ω	C	5 Ω
D	10 Ω	E	20 Ω		

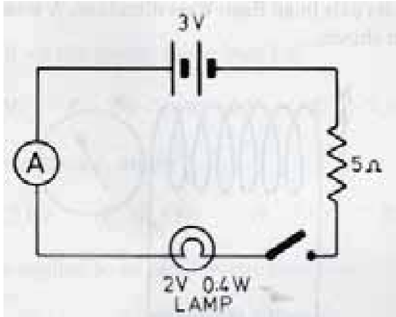
4.46 The PD of the supply causing the current to flow through the circuit is:

A	115 V	B	200 V	C	205 V
D	230 V	E	240 V		

4.47 A step-down transformer, with no energy losses, has a turns ratio of 5:1. An AC supply of 20 V is connected across the primary. The secondary is connected to an 8 Ω loudspeaker. The power developed by the loudspeaker is:

A	1 W	B	2 W	C	10 W
D	625 W	E	1 250 W		

The following information is to be used for questions 4.48 and 4.49. The diagram below shows a 3 V battery with negligible internal resistance, connected in series with a 2 V, 04 W lamp, a 5Ω resistor and an ammeter with negligible internal resistance.



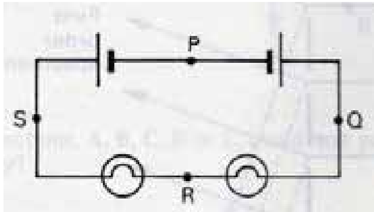
4.48 The resistance of the lamp when burning normally is:

A	0.1 Ω	B	0.2 Ω
C	1Ω	D	2 Ω
E	10 Ω		

4.49 When switch is closed, the lamp will

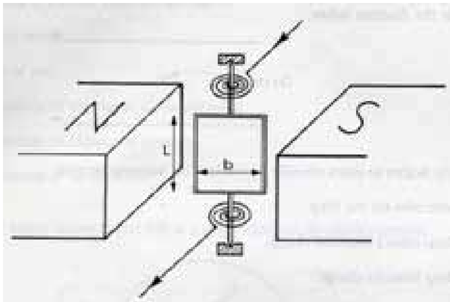
A burn out
B glow more brightly than normal
C glow with normal brightness
D glow less brightly than normal
E not glow at all.

4.50 In the circuit on the right, the two lamps fail to light. In order to make them light, which of the point P, Q, R, S, should be joined with a wire?



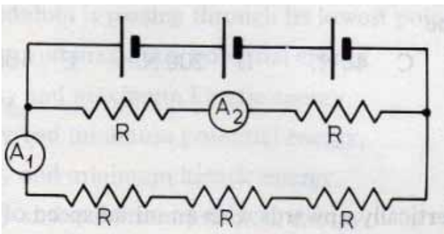
A	R and S	B	Q and R
C	R and P	D	Q and S
E	P and Q and S		

4.51 The figure on the right shows the coil of a simple ammeter, pivoted between the poles of a magnet. Which one of the following changes, on its own, would result in a smaller deflection of the coil for a fixed current?



A increasing the number of turns on the coil
B using a stronger magnet
C increasing the length of the coil, L
D decreasing the strength of the coils
E decreasing the breadth of the coil, b

Use the following to answers questions 4.52 and 4.53. Similar cells, ammeters and resistors are used in the circuit shown above. The cells and ammeters have negligible resistance. When one cell is connected in series with one ammeter and one resistor, the ammeter reads 0.2 A



A 0.2 A B 0.3 A C 0.4 A 0.5 A E 0.6 A

4.52 Select from the answers above the value of the current thought A_1

4.53 Select from the answers above the value of the current thought A_2

5 Additional Problems - Mechanics

5.1 An object of mass m is projected downwards with a velocity u. It then reaches a velocity v after t seconds and a height h above the Earth's surface. The kinetic energy of the body at this point can be expressed as

A $\frac{1}{2} mg^2t^2$
B $\frac{1}{2} m (u^2 + (gt)^2)$
C $2 m (u^2 + vgt + g^2 t^2)$
D $\frac{1}{2} m (u^2 + g^2 t^2) + ugtm$

Discuss the answer of the above question within your group

5.2 A heavy particle of mass M collides elastically with a light particle of mass m. The initial velocity of the heavy particle is u and the final velocity is v. The light particle is initially at rest. After the collision the light particle goes off in the forward direction with velocity V, what fraction of the energy of the heavy particle is lost in the collision?

A $1-\left(\frac{v}{u}\right)^2$ B $1-\left(\frac{u}{v}\right)^2$ C $1-\left(\frac{v}{u}\right)^{\frac{1}{2}}$ D $1-\left(\frac{u}{v}\right)^{\frac{1}{2}}$

5.3 Using the principle of conservation of mechanical energy find the velocity with which a body must be projected, vertically upwards, from the Earth's surface, to reach a height of R above the Earth's surface. Assume the Earth's mass is M and its radius R. Neglect air resistance.

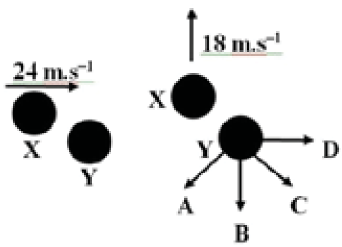
A $v=\sqrt{\frac{GM}{R}}$ C $v = 2GMR$

B $v=\sqrt{\frac{2GM}{R}}$ D $v=\left(\frac{GM}{2R}\right)^2$

5.4 A boy drops a rubber ball from a height of 1 m and lets it bounce. If the ball loses 10% of its energy during the bounce, how many bounces will it take before the ball will only rise 0.5 m above the ground?

A 6 B 7 C 8 D 9

Questions 5.4 and 5.5 refer to the diagram below which shows a ball X of mass 0.5 kg striking a glancing blow to ball Y, also of mass 0.5 kg, but is at rest. After the collision is complete X is moving at right angles to its original direction of motion with a speed of 18 $m.s^{-1}$ (as shown below)



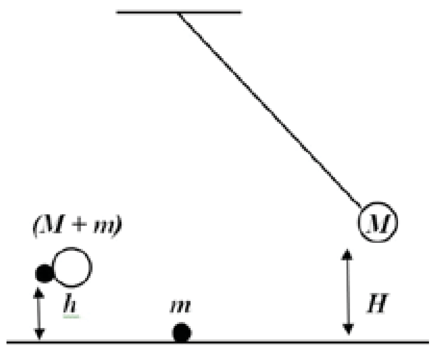
5.4 What is the **magnitude** of the change of momentum of ball X after the collision?

A 3 kg. $m.s^{-1}$ B 6 kg. $m.s^{-1}$
C 15 kg. $m.s^{-1}$ D 42 kg. $m.s^{-1}$

5.5 Which **arrow** best indicates the direction in which ball Y moves after the collision?

Discuss the answer of the above question within your group

5.6 A pendulum with a bob of mass M is raised to a height H and released. At the bottom of its swing, it picks up a piece of putty whose mass is m. To what height h will the combination $(M + m)$ rise?



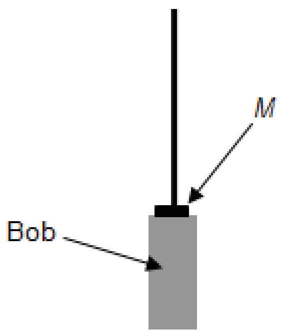
A $\left(\frac{M}{M+m}\right)H$ B $\left(\frac{m}{M+m}\right)H$

C $\left(\frac{M}{M+m}\right)^2 H$ D $\left(\frac{m}{M+m}\right)^2 H$

5.7 A particle is projected vertically upwards at a speed u. It is at a height h after time t and again after time T. The speed u is:

A ½ g t^2 B ½ g $(T + t)$ C ½ g $(T – t)$ D ½ g $(t – T)$

5.8 The diagram shows a pendulum which is used to regulate a clock. The clock is running slow, so a physicist works out that if she were to place a ring with a pre-calculated mass M on the bob as shown, the clock would keep good time again. Which one of the following statements is true?

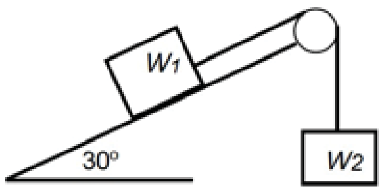


A By placing the ring on the bob, the effective length of the pendulum is shortened, and so decreases the period allowing the clock to keep proper time.
B It wouldn't work as the bob would then be heavier and the clock would slow even more.
C Adding the mass would make no difference since the period of a pendulum is independent of the mass of the bob.
D It wouldn't work as the only way to change the period of the pendulum is to shorten the pendulum shaft.

Discuss the answer of the above question within your group

5.9 A smooth (frictionless) plane, inclined at 30° to the horizontal, supports a block of mass M. It is held in place by a horizontal force, **F** = 100 N. What is the mass of M, in kg? What would be the mass of M if **F** were inclined at 15° above the horizontal?

5.10 The diagram above shows two blocks of weight W_1 and W_2 on an inclined plane. All surfaces are smooth and the strings are light. Which one of the following statements is true?



A If $W_1 = W_2$ then the blocks remain stationary
B The tension in the string is $W_1 – W_2$
C If $W_1 > W_2$ then W_1 will always move up the plane
D The tension in the string is always W_2
E If $W_1/2 = W_2$ motion can be in either direction.

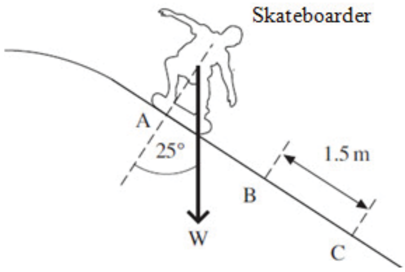
5.11 Two balls of equal masses are thrown upwards along the same vertical direction, at an interval of 2 seconds with the same initial velocity of 39.2 $m.s^{-1}$ If $g = 9.8$ $m.s^{-2}$ they will collide at a height of

A 196.0 m B 117.6 m C 73.5 m D 44.1 m

5.12 Two bodies of mass 2 kg and 4 kg are moving with velocities 2 $m.s^{-1}$ and 10 $m.s^{-1}$ towards each other due to mutual gravitational attraction . What is the velocity of their centre of mass in $m.s^{-1}$?

A 5.3 B 6.4 C Zero D 8.1

5.13 A Skateboarder skates down a slope as shown below.



Between B and C his acceleration is constant and he travels the 1.5 m in 0.43 seconds reaching a speed of 5.0 $m{\cdot}s^{-1}$ at C. What was his speed when he was at B?

A 1.98 $m{\cdot}s^{-1}$ B 3 $m{\cdot}s^{-1}$ C 3.5 $m{\cdot}s^{-1}$ D 3.9 $m{\cdot}s^{-1}$

5.14 The combined frictional force and air resistance on a cyclist has force $F = kv$, where v is the velocity and k is a constant of value 4 $N(m.s)^{-1}$. The maximum power the cyclist can generate is 600 W. What is the cyclist's maximum speed on a level road?

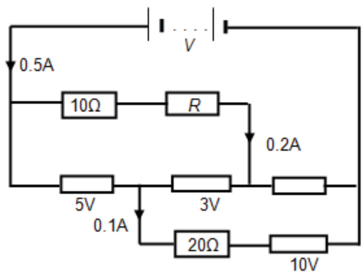
A 12.2 $m.s^{-1}$ B 6.12 $m.s^{-1}$ C 17.3 $m.s^{-1}$
D Unable to calculate unless the air resistance is known.

6 Additional Problems - Electricity

6.1 *N* identical cells of emf $\mathcal{E}$ and internal resistance *r*, are connected in parallel. This combination is then connected to an external resistance *R*. The current in *R* is:

A $\dfrac{\mathcal{E}}{R+r}$ B $\dfrac{\mathcal{E}}{R+Nr}$ C $\dfrac{\mathcal{E}}{R+\dfrac{r}{N}}$ D $\dfrac{\mathcal{E}}{R+\dfrac{N}{r}}$

Questions **6.2** and **6.3** refer to the circuit diagram on the right. The blocks are resistors some values of which are indicated and the PD across some resistors is shown below them. The currents in the various parts are as shown by the arrows.



6.2 The value of *R* is:

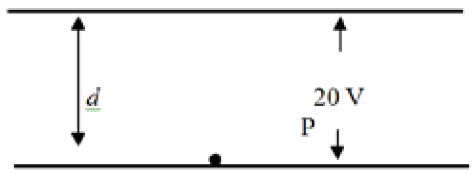
A 40 Ω
B 30 Ω
C 20 Ω
D 16.7 Ω

6.3 The potential difference, *V*, of the battery is:

A 20 V
B 18 V
C 17 V
D 15 V

Questions 6.4 and 6.5 refer to the diagram below. It shows two parallel plates a distance *d* apart a potential difference of 20V between them with A at the higher potential. A small particle P of mass 6×10^{-12} kg carrying a charge of –9 μC is released from plate B. Neglect gravitational effects.

6.4 The speed *u* with which P reaches plate A is:



A 7 746 $m.s^{-1}$
B 1 225 $m.s^{-1}$
C 30 $m.s^{-1}$
D unable to calculate it unless *d* is known,

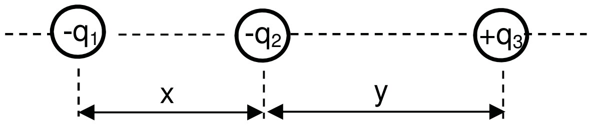
6.5 If the distance between the plates is now increased to 2*d*, the speed with which it reaches plate A is now:

A $2u$ B u C $u/2$ D $\sqrt{2u}$

6.6 Three charges each equal to +2C are placed at three corners of equilateral triangle. If the force between any two charges be F, then the net force on either will be:

A 3F
B 2F
C √2F
D √3F

6.7 The diagram (not drawn to scale) below shows three small metallic balls carrying charges of $-q_1$, $-q_2$ and $+q_3$. They are on an insulated stands in the same straight line. The magnitude of the net electrostatic force experienced by charge q_2 due to the presence of the other two charges can be expressed as:



A $kq_2(\frac{q_1 - q_3}{x^2y^2})$

B $kq_2(\frac{q_1 + q_3}{x^2y^2})$

C $kq_2(\frac{q_1y^2 - q_3x^2}{x^2y^2})$

D $kq_2(\frac{q_1y^2 + q_3x^2}{x^2y^2})$

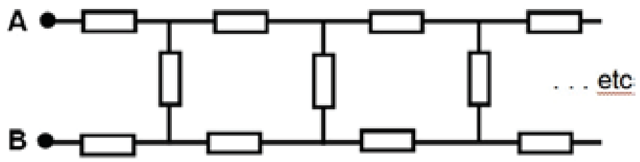
6.8 A beam of electrons was produced from a heated filament and accelerated towards an anode. When the potential difference between the anode and the filament was 4200V, the speed of the electrons in the beam was $3.9 \times 10^7 ms^{-1}$. From this information, the value of the charge/mass $\left(\frac{e}{m}\right)$ ratio for the electron is:

A 1.9×10^{-19} C/kg B 9.3×10^4 C/kg
C 1.8×10^{11} C/kg D 1.8×10^{-11} C/kg

6.9 What voltage is required to balance an oil drop carrying 10 electronic charges when located between the plates of a capacitor which are 6 mm apart?
(mass of the oil drop = $3x10^{-15}$ kg, e = $1.6x10^{-19}$ C)

A 11.25 V,
B 110.25 V,
C 25.11 V,
D 21.15 V

6.10 The diagram below shows an infinite ladder of resistors each of value R Ω. What is the effective resistance between the points **A** and **B**



A (√3 – 1)R
B (√3 + 1)R
C R
D 2/√3 R
E 2R/√3

7 Contributors

7.1 National Science and Technology Forum
7.2 Department of Science and Technology, Rep. of South Africa
7.3 Institute of Physics, IOP for Africa Project, United Kingdom
7.4 British High Commission to South Africa

8 Acknowledgements

8.1 Where the letters DLG appear it is stating that this piece has been adapted from ***An Approach to Promoting Conceptual Understanding of Physics Through Problem-Solving Activities*** by Robert Dufresne, William Leonard and William Gerace, Universality of Massachusetts, Amherst, USA.
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8.4 Mr Brian Masara, Executive Officer, South African Institute of Physics for making it possible.

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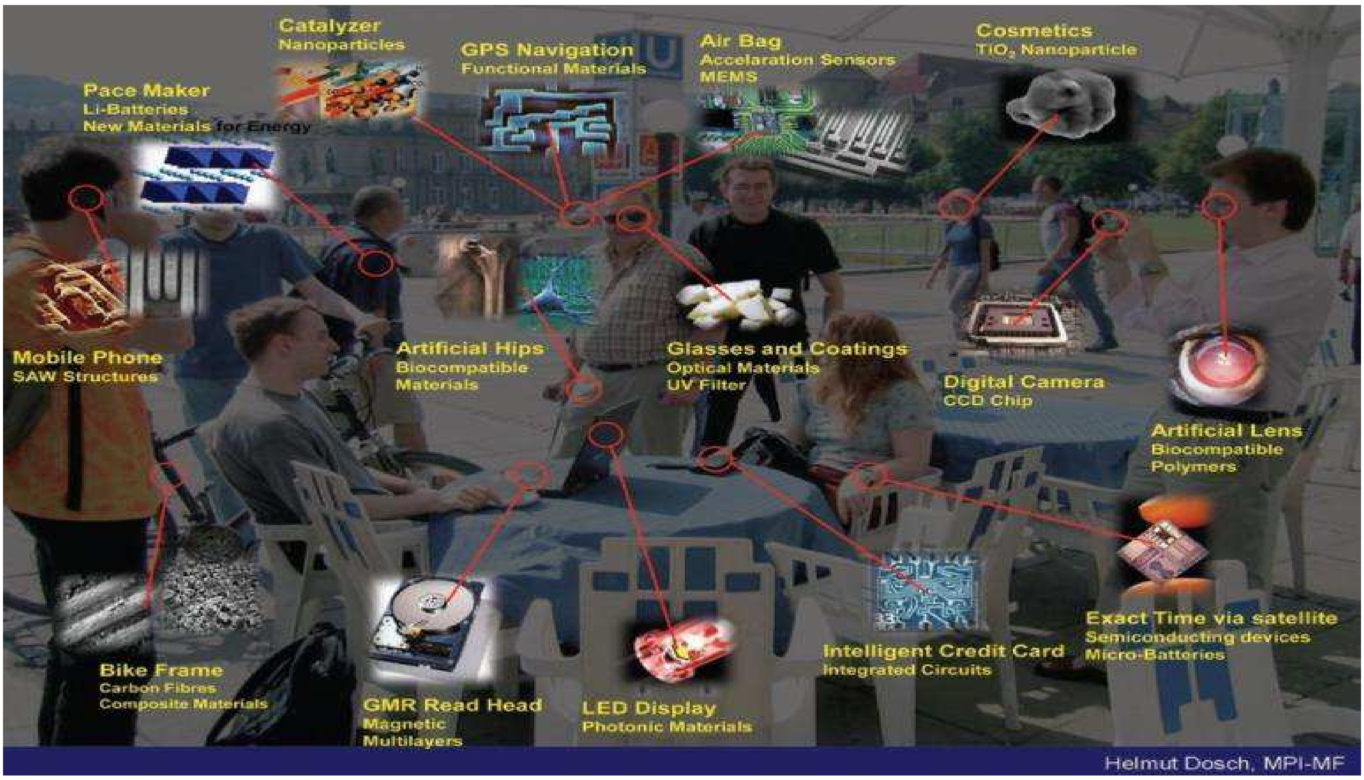

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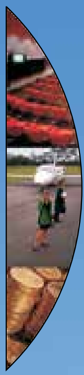

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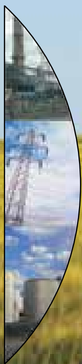

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archaeologist
architect
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cartographer
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climatologist
conservation officer
draughts person
environmental scientist
geologist
geophysicist
health and safety officer
marine scientist
meteorologist
noise engineer
oceanographer
soil scientist
surveyor
water manager

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information scientist
laboratory technician
mathematician
physics lecturer
primary / secondary teacher
science administrator
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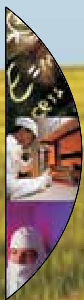

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