Concepts of Physics: Test 2

25 October 2024

Name: SOLUTION **Total:** /60

Instructions

- There are 14 questions on 8 pages.
- Show your reasoning and calculations and always explain your answers.

Physical constants and useful formulae

$$\text{speed} = \frac{\text{distance traveled}}{\text{time elapsed}} \qquad s = \frac{d}{t}$$

$$\text{acceleration} = \frac{\text{change in velocity}}{\text{time elapsed}} \qquad a = \frac{v}{t}$$

$$\text{distance} = \frac{1}{2} \times \text{acceleration} \times \text{time}^2 \qquad d = \frac{1}{2} \times a \times t^2$$

$$\text{final speed} = \text{initial speed} + \text{acceleration} \times \text{time} \qquad v_f = v_i + a \times t$$

$$\text{acceleration} = \frac{\text{net force}}{\text{mass}} \qquad a = \frac{F}{m}$$

$$\text{earth's gravitational force} = \text{mass} \times 9.8 \qquad F_{\text{grav earth}} = m \times 9.8$$

$$\text{KE} = \frac{1}{2} \times \text{mass} \times (\text{speed})^2 \qquad KE = \frac{1}{2} m \times v^2$$

$$\text{speed} = \sqrt{2 \times \text{KE}/\text{mass}} \qquad v = \sqrt{\frac{2 \times KE}{m}}$$

$$\text{gravPE} = \text{mass} \times 9.8 \times \text{height} \qquad PE = m \times 9.8 \times h$$

$$\text{height} = \frac{\text{gravPE}}{\text{mass} \times 9.8} \qquad h = \frac{PE}{m \times 9.8}$$

$$\text{power} = \frac{\text{energy gain}}{\text{time elapsed}} \qquad P = \frac{E}{t}$$

$$\text{energy} = \text{power} \times \text{time elapsed} \qquad E = P \times t$$

$$\text{efficiency} = \frac{\text{useful energy output}}{\text{energy input}} \qquad \varepsilon = \frac{E_{\text{output}}}{E_{\text{input}}}$$

$$\text{useful energy output} = \text{efficiency} \times \text{energy input} \qquad E_{\text{output}} = \varepsilon \times E_{\text{input}}$$

$$\text{energy input} = \frac{E_{\text{output}}}{\text{efficiency}} \qquad E_{\text{input}} = \frac{E_{\text{output}}}{\varepsilon}$$

Physical constants and useful formulae

electron charge $= -1.6 \times 10^{-19}$ C	proton charge $= +1.6 \times 10^{-19}$ C
$\text{current} = \dfrac{\text{charge}}{\text{time}}$	$I = \dfrac{Q}{T}$
$\text{charge} = \text{current} \times \text{time}$	$Q = I \times T$
$\text{time} = \dfrac{\text{charge}}{\text{current}}$	$T = \dfrac{Q}{I}$
$\text{Voltage} = \dfrac{\text{energy}}{\text{charge}}$	$V = \dfrac{E}{Q}$
$\text{Energy} = \text{voltage} \times \text{charge}$	$E = V \times Q$

Question 1

Three carts slide along a horizontal surface. At one moment their masses and speeds are as indicated. Rank the carts in order of increasing kinetic energy, indicating which is smallest and which is largest.

Cart	Mass	Speed
A	3.0 kg	4.0 m/s
B	6.0 kg	3.0 m/s
C	6.0 kg	2.0 m/s

$KE = \frac{1}{2} \times mass \times speed^2$

A: $\frac{1}{2} \times 3.0\,kg \times (4.0\,m/s)^2 = 24\,J$

B: $\frac{1}{2} \times 6.0\,kg \times (3.0\,m/s)^2 = 27\,J$

C: $\frac{1}{2} \times 6.0\,kg \times (2.0\,m/s)^2 = 12\,J$

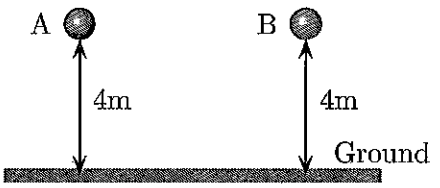
smallest → largest

C → A → B

/4

Question 2

Two identical balls are thrown upward above the ground. At one moment their positions are as illustrated and ball A moves up with speed 6 m/s while ball B moves down with speed 6 m/s. Which of the following (choose one) is true?



Energy = KE + PE

$\frac{1}{2} \times mass \times (speed)^2$ (same) → $mass \times 9.8 \times height$ (same for both)

i) The total energy of A is smaller than the total energy of B.

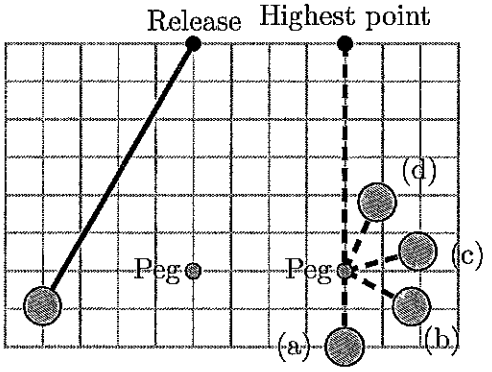
ii) The total energy of A is the same as the total energy of B.

iii) The total energy of A is larger than the total energy of B.

/3

Question 3

A pendulum (a small ball that swings from a string) is released from rest at the indicated position. The string encounters a "peg" in its path. Which (choose one) indicates the highest point that the pendulum ball reaches after the string strikes the peg?



Option (b) initial energy = PE ⇕ same PE

At max height energy = PE

⇓

same height

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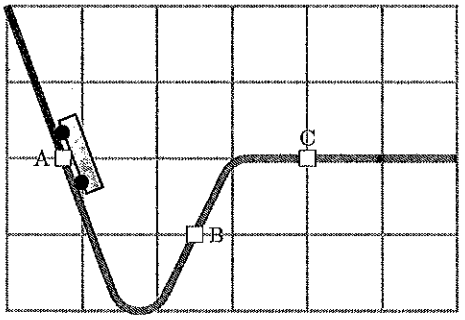
Question 4

A 4.0 kg cart slides along the illustrated track. At point A the potential energy of the cart is 80 J and the cart's speed is 5.0 m/s. Ignore friction and air resistance.



a) Determine the total energy of the cart at point A.

$E = KE + PE$

$KE = \frac{1}{2} \times \text{mass} \times (\text{speed})^2 = \frac{1}{2} \times 4.0\,\text{kg} \times (5.0\,\text{m/s})^2 = 50\,\text{J}$

$E = 50\,\text{J} + 80\,\text{J} = 130\,\text{J}$

b) The potential energy of the cart at point B is 40J. Determine the kinetic energy and speed of the cart at point B.

$E = KE + PE$

$130\,\text{J} = KE + 40\,\text{J} \quad \Rightarrow \quad KE = 90\,\text{J}$

$$\text{Speed} = \sqrt{\frac{2KE}{\text{mass}}} = \sqrt{\frac{2 \times 90\,\text{J}}{4.0\,\text{kg}}} = \sqrt{45\,\text{m}^2/\text{s}^2}$$

speed = 6.7 m/s

c) Determine the speed of the cart at point C, which is the same height as point A.

Here PE = same as at A

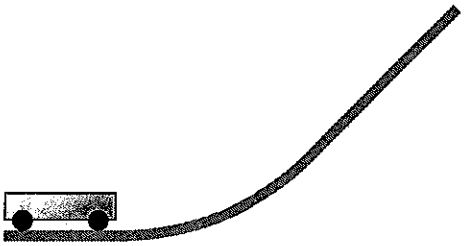
$\Rightarrow$ KE same as at A

$\Rightarrow$ speed same as at A $\Rightarrow$ 5.0 m/s

/8

Question 5

A 2.0 kg cart slides along the illustrated surface. At the bottom of the ramp the cart has kinetic energy of 500 J. The height of the top of the ramp above the base is 50 m. The cart ascends the ramp. There is no friction or air resistance.



a) Describe how the kinetic energy changes (i.e. increases, decreases or stays the same) as the cart ascends the ramp. If the kinetic energy does change, describe what type of energy it is converted to.

KE decrease since object slows
PE increases since height increases KE → PE

b) Will the cart reach the top of the ramp? Explain your answer.

The total energy at bottom is $E = KE + PE = 500J + 0J$

At highest $KE = 0 \Rightarrow PE = 500J$

$$\text{height} = \frac{PE}{\text{mass} \times 9.8} = \frac{500J}{2.0 \times 9.8} = 26m$$

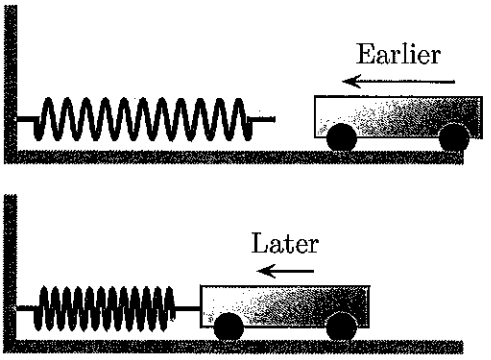
Can only get to 26m $\Rightarrow$ NO

	KE	PE	Total
Bottom	500J	0	500J
Highest Pt.	0	500J	500J

/6

Question 6

A cart slides along a horizontal surface towards a spring that is initially relaxed. The cart hits the spring and compresses the spring while slowing down. Zog correctly reasons that, as the spring is compressed, the carts kinetic energy decreases but he cannot understand where the energy goes. Describe the form of energy into which the kinetic energy is transformed as the spring compresses. Ignore friction and air resistance.



Into elastic energy

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Question 7

Three bulbs consume electrical input energy and produce useful energy in the form of light. Which of the following (choose one) ranks the bulbs' efficiency?

Bulb	Input Energy	Light Energy
Red bulb	100J	20 J
Blue bulb	100J	10 J
Green bulb	50J	15 J

$\frac{20}{100} = 0.2$
$\frac{10}{100} = 0.1$
$\frac{15}{50} = 0.3$

i) Red most efficient, green middle, blue least efficient.
ii) Red and blue same and most efficient, green least efficient.
iii) Red most efficient, blue middle, green least efficient.
iv) Green most efficient, red middle, blue least efficient.

/3

Question 8

An engine has an efficiency of 0.25 (25%) and produces 1000 J of useful work. Determine the amount of energy that must be supplied to the engine in order to do this.

$$\text{input} = \frac{\text{output}}{\text{efficiency}} = \frac{1000\text{J}}{0.25} = 4000\text{J}$$

/3

Question 9

A kettle consumes 1500 W of electrical power and takes 5.0 min to boil one liter of water.

→ $5.0\text{min} \times 60\text{s} = 300\text{s}$

a) Determine the total energy used by the kettle to boil 100 liters of water.

one liter
Energy = Power x time
$= 1500\text{W} \times 300\text{s} = 450000\text{J}$

100 liters
$100 \times 450000 = 45\,000\,000\text{J}$

b) Suppose that the utility company charges \$0.05 per 1000000 J (one million Joules). Determine the cost to boil 100 liters of water.

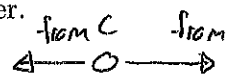
Needs $100 \times 450000\text{J} = 45.000.000 = 4.5 \times 10^7\text{J}$
$= 45$ million J

$45 \times 0.05 = \$2.25$

/5

Question 10

Three charged particles are held at fixed locations. The distances between adjacent charges are the same. The particle on the right is negatively charged. It is observed that there is no net force on the charge on the left (A). Is the particle in the middle (B) positive, negative or neutral? Explain your answer.

If A negative  => B attracts => B +ve

If A positive  => B repels => B positive

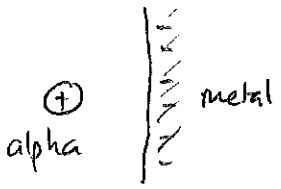
Either way positive

/4

Question 11

An alpha particle consists of two protons and two neutrons. The alpha particle is held near to a negatively charged piece of metal and then released. Describe how it moves (i.e direction and speed) immediately after release. Explain your answer.

α is positive since protons are positive
=> metal attracts



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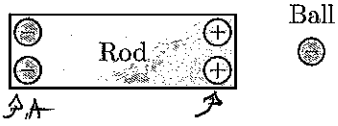
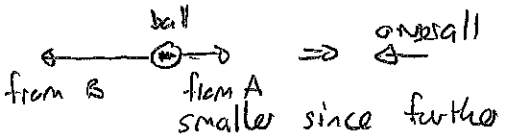
Question 12

A negatively charged ball is near to a small metal rod. This causes the some of the charges in the rod to separate as illustrated; the rest of the bar is neutral.



a) Which of the following (choose one) is true?

i) The rod attracts the ball.
ii) The rod repels the ball.
iii) The rod neither attracts nor repels the ball.



b) Which of the following (choose one) is true?

i) The ball attracts the rod.
ii) The ball repels the rod.
iii) The ball neither attracts nor repels the rod.

similar to A

/6

Question 13

A phone charger produces a current of 2.2 A when connected to the phone. The power delivered by the charger is 20 W.

a) Determine the total charge that flows into the phone during 60 min.

charge = current × time time = 60 min × 60s

= 3600s

= 2.2 A × 3600

= 7920C

b) Determine the total energy supplied by the charger during 60 min.

energy = power × time

= 20W × 3600s = 72000J

/5

Question 14

Electrons flow through a wire connected to a bulb. A measurement indicates that exactly 5000 electrons flow into the bulb every second. Which of the following (choose one) is true regarding the size of the current that flows into the bulb?

i) The size of the current is less than 5000 A.
ii) The size of the current is exactly 5000 A.
iii) The size of the current is more than 5000 A.

charge = 5000 × charge on e electron

$= 5000 \times 1.6 \times 10^{-19}$

$= 8 \times 10^{-16}$C

/3

current = $\frac{8 \times 10^{-16}\text{C}}{1\text{s}}$

$= 8 \times 10^{-16}$A