Concepts of Physics: Final Exam

14 December 2022

Name: SOLUTION **Total:** /100

Instructions

- There are 26 questions on 13 pages.
- Show your reasoning and calculations and always explain your answers.

Physical constants and useful formulae

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

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

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

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

$$\text{net force} = \text{mass} \times \text{acceleration} \qquad F = ma$$

$$\text{Earth's gravitational force} = \text{mass} \times 9.8 \qquad F = m \times 9.8$$

$$\text{gravitational force} = 6.67 \times 10^{-11} \times \frac{\text{mass}_1 \times \text{mass}_2}{\text{distance}^2} \qquad F_{\text{grav}} = 6.67 \times 10^{-11} \times \frac{m_1 \times m_2}{d^2}$$

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

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

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

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

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

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

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

Physical constants and useful formulae

useful energy output = efficiency × energy input	$E_{\text{output}} = \varepsilon \times E_{\text{input}}$
$\text{energy input} = \dfrac{E_{\text{output}}}{\text{efficiency}}$	$E_{\text{input}} = \dfrac{E_{\text{output}}}{\varepsilon}$
$\text{frequency} = \dfrac{1}{\text{time per cycle}}$	$f = \dfrac{1}{T}$
wave speed = wavelength × frequency	$s = \lambda \times f$
$\text{frequency} = \dfrac{\text{wave speed}}{\text{wavelength}}$	$f = \dfrac{s}{\lambda}$
$\text{wavelength} = \dfrac{\text{wave speed}}{\text{frequency}}$	$\lambda = \dfrac{s}{f}$
speed of light $= 3.0 \times 10^8$ m/s	$c = 3.0 \times 10^8$ m/s
photon energy $= 6.63 \times 10^{-34}$ Js × frequency	$E_{\text{photon}} = 6.63 \times 10^{-34}\,\text{Js} \times f$
$\text{frequency} = \dfrac{\text{photon energy}}{6.63 \times 10^{-34}\,\text{Js}}$	$f = \dfrac{E_{\text{photon}}}{6.63 \times 10^{-34}\,\text{Js}}$
$\text{number of photons} = \dfrac{\text{total energy}}{\text{photon energy}}$	$N = \dfrac{E}{E_{\text{photon}}}$
total energy = number of photons × photon energy	$E = N \times E_{\text{photon}}$
$\text{width central region} = \dfrac{2 \times \text{wavelength}}{\text{slit width}} \times \text{screen distance}$	$w = \dfrac{2\lambda}{a}\,d$
$\text{particle wavelength} = \dfrac{6.63 \times 10^{-34}\,\text{Js}}{\text{mass} \times \text{speed}}$	$\lambda = \dfrac{6.63 \times 10^{-34}\,\text{Js}}{m \times v}$

Question 1

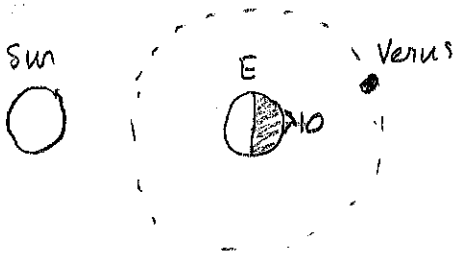
Consider the following possible models of the solar system:

1. **Geocentric model:** Each planet orbits Earth at a constant rate in a perfect circle, whose center is at Earth.
2. **Heliocentric model:** Each planet, including Earth, orbits the Sun in a perfect circle, whose center is at the Sun.

Consider observing the planet Venus. In the heliocentric model the orbit of Venus is between Earth's orbit and the Sun and Venus orbits at a different rate (different number of days to complete one orbit) to Earth.

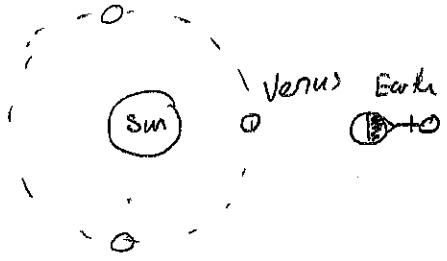
a) For **each** model, describe whether the model predicts that it would be possible to view Venus from Earth at midnight.

Geocentric at midnight



Venus is possibly visible at midnight

Heliocentric at midnight



Venus is never visible at midnight

b) Can possible observation (or not) of Venus be used to decide whether one of these models is incorrect? Explain your answer.

Check if Venus is visible at midnight. If it is not then geocentric cannot be correct. If it is then heliocentric cannot be correct.

/4

Question 2

A block of pure copper has mass 5.0×10^2kg. A single copper atom has mass about 1.0×10^{-25}kg. Which of the following (choose one) is the number copper atoms in the block?

i) 5.0×10^{-27}
ii) 5.0×10^{-23}
iii) 5.0×10^{23}
iv) 0.2×10^{27}
v) 5.0×10^{27}

$$\text{number atoms} = \frac{\text{total mass}}{\text{mass single atom}}$$

$$= \frac{5.0 \times 10^2 \text{kg}}{1.0 \times 10^{-25} \text{kg}}$$

$$= 5.0 \times 10^{27}$$

/3

Question 3

A flask contains exactly 200 molecules of carbon dioxide (CO_2). How many atoms are present in this flask?

i) 200
ii) 400
iii) 600
iv) 800

each molecule has 3 atoms

$\Rightarrow$ 600 total

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Question 4

A sample of carbon monoxide (CO) is decomposed into carbon and oxygen. This yields 4 lb of oxygen. Note that the mass of a single atom of carbon is 3/4 the mass of a single atom of oxygen. Determine the total mass of carbon produced.

The number of carbon atoms is the same as the number of oxygen atoms. So

$$\text{total mass carbon} = \frac{3}{4} \text{ total mass oxygen}$$

$$= \frac{3}{4} \times 4\text{lb} = 3\text{lb}$$

3lb

/4

Question 5

Gas is injected into a container and subsequently kept at a fixed temperature. At one instant some of the gas is removed from the container via a valve to the outside. This is done so that the temperature of the gas remains constant. Consider the pressure of the gas within the container after the removal of some of the gas in comparison to before the removal. Which of the following (choose one) is true?

i) The pressure after is the same (as before) since the temperature is the same.
ii) The pressure after is the same since the strength of the collisions of the molecules is the same as before.
iii) The pressure after is larger since the molecules have more room to move.
iv) The pressure after is smaller since there are fewer collisions with the walls per second.

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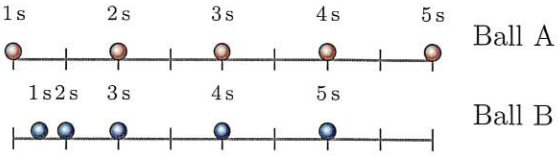
Question 6

Two balls slide along horizontal surfaces. The positions of the balls are recorded at intervals spaced 1 s apart. These are illustrated in the diagram. Which of the following (choose one) is true **for the period from 3 s to 5 s?**



Speed A = 2 units/s same as B. Both A, B have zero acceleration from 3-5s.

i) Speed of A is the same as that of B and acceleration of A is the same as that of B.
ii) Speed of A is larger than that of B and acceleration of A is the same as that of B.
iii) Speed of A is the same as that of B and acceleration of A is larger than that of B.
iv) Speed of A is larger than that of B and acceleration of A is larger than that of B.

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Question 7

A 100 kg toy spacecraft travels in a straight line with a constant speed of 30 m/s before its rockets are fired. The rockets are fired and, for a period of 2 s, exert a constant force of 300 N in the direction in which the spacecraft travels. The rockets turn off after this point.

a) Determine the acceleration of the spacecraft while the rockets are firing.

$$\text{acceleration} = \frac{\text{force}}{\text{mass}} = \frac{300\,\text{N}}{100\,\text{kg}} = 3\,\text{m/s}^2$$

2

b) Determine the speed of the spacecraft at the moment that the rockets are turned off.

Speed increases by 3 m/s each second
⇒ increases by 6 m/s in 2 s
⇒ goes from 30 m/s → 36 m/s

3

/5

Question 8

The following two objects move horizontally as described.

1. **Block of metal:** Mass 10 kg, constant speed 4 m/s right.
2. **Block of wood:** Mass 0.25 kg, constant speed 10 m/s right.

Which of the following (choose one)is true?

i) The net force on the metal block is larger than the net force on the wood block.
ii) The net force on the metal block is smaller than the net force on the wood block.
iii) The net force on the metal block is the same as the net force on the wood block.

Explain your answer.

Both are moving with constant speed in a straight line. So both have acceleration = 0

net force = mass x acceleration

= 0

So net force = 0 for each. /5

Question 9

Two identical rocks lie on a horizontal surface. Zog pushes one of the rocks and Geraldine pushes the other. There is no friction between the rocks and the surface. A third person, Leka, observes that during a particular period of time, Zog's rock speeds up from 10 m/s to 15 m/s. During the same period of time Geraldine's rock speeds up from 2 m/s to 10 m/s. Is the force exerted by Zog on his rock the same as, larger than or smaller than the force exerted by Geraldine on her rock? Explain your answer.

net force = mass x acceleration.

Need to check acceleration.

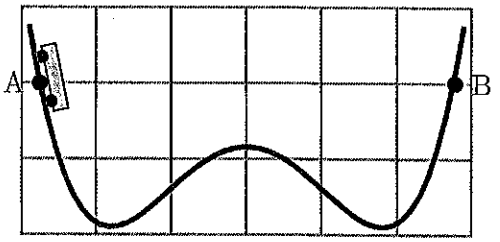
For Zog accel = change speed / time = 5 m/s / time

For Geraldine " = 8 m/s / time

Acceleration smaller for Zog ⇒ net force smaller for Zog /5

Question 10

A cart slides along the illustrated frictionless track; air resistance is negligible. The cart can easily pass the bends in the track. The cart is initially at rest with its midpoint at the same level as point A and is then released. Which of the following (choose one) is true?



i) The cart's midpoint passes through point B and keeps going higher than that.
ii) The cart does not passes the bump in the middle of the track.
iii) The cart's midpoint passes the bump but stops before reaching B.
(iv) The cart's midpoint just reaches B and it reverses direction at that point.

Briefly explain your choice.

Energy is conserved. Initially there is only potential energy.
At the highest point on right there is also only potential energy.
So potential energy is same on either side
⇒ height same on either side

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Question 11

A 5.0kg cannonball is fired directly upwards from the ground by a cannon, which supplies a total energy of 2000J to the cannonball. Will the cannonball be able to reach a height of 60m above the ground? Explain your answer.

If it gets to 60m above grand it will have potential energy

PE = mass × 9.8 m/s² × height

= 5.0kg × 9.8 m/s² × 60m = 2940J

It does not have this energy initially so it cannot reach that height.

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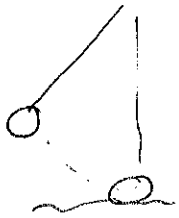
Question 12

A child can swing from a rope across a small lake. Initially he is holding the rope while at rest on a platform higher than the lake. The rope is tight. He then leaves the platform and swings, barely touching the water in the lake. Ignore air resistance.



a) What type of energy does the child have while at rest on the platform? Explain your answer.

Potential since height $\neq 0$
and there is no kinetic since speed $= 0$

b) Into what other type of energy is this converted as the child drops toward the surface of the lake? Explain your answer.

Kinetic since the child will speed up and kinetic $= \frac{1}{2} \times \text{mass} \times \text{speed}^2 \neq 0$

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Question 13

A 60 kg skier is at rest at the the top of a hill and has potential energy 3000 J. The skier reaches the bottom of the hill with speed 5.0 m/s.

a) Determine the kinetic energy of the skier at the bottom of the hill.

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

$= \frac{1}{2} \times 60\text{kg} \times (5.0\text{m/s})^2 = 750\text{J}$

b) Does the kinetic energy at the bottom of the hill equal the potential energy at the top of the hill? If not, what form of energy accounts for the missing or excess energy at the bottom of the hill?

It is much less.

It was converted into thermal energy.

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Question 14

An old steam engine takes in 500 J of input energy and provides 100 J of output energy. Determine the efficiency of this engine.

$$\text{Efficiency} = \frac{\text{useful energy out}}{\text{input energy}} = \frac{100\,\text{J}}{500\,\text{J}} = 0.20$$

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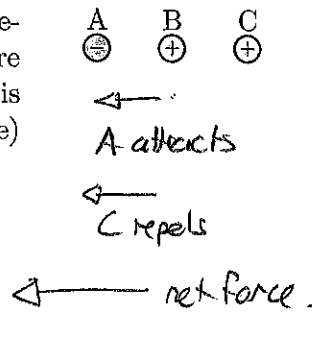
Question 15

Three charged particles are held at fixed locations. The distances between adjacent charges are the same and the sizes of their charges are the same. The charge in the middle (B) is initially held at rest and is then released. After it is released, which of the following (choose one) will it do?



i) Remain at rest.
ii) Move left.
iii) Move right.

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Question 16

A negatively charged particle, labeled B, is held at rest. Various ions (atoms that were neutral but have gained or lost an electron) are brought near to B.

a) A sodium ion is a neutral sodium atom that has lost an electron. Will B repel or attract the sodium ion? Explain your answer.

The sodium ion is positive since it lost negative charge.

It will be attracted to B since opposites attract

b) A chlorine ion is a neutral sodium atom that has gained an electron. Will B repel or attract the chlorine ion? Explain your answer.

The chlorine ion is negative since it gained negative charge

It will be repelled from B since like repel

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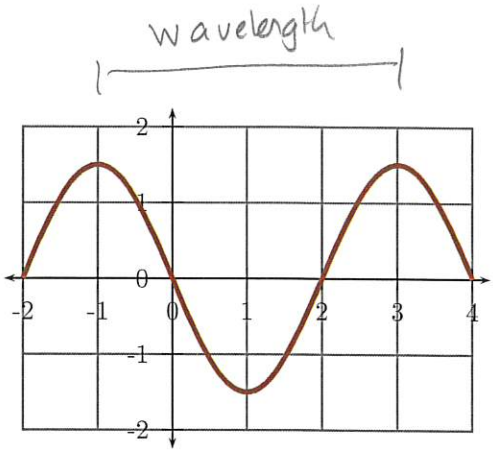
Question 17

A snapshot of a wave on a string is as illustrated. The axis units are meters. The frequency of the wave is 10Hz. Determine the wavelength and speed of the wave.



wavelength = 4m

speed = wavelength x frequency

= 4m x 10Hz

= 40 m/s

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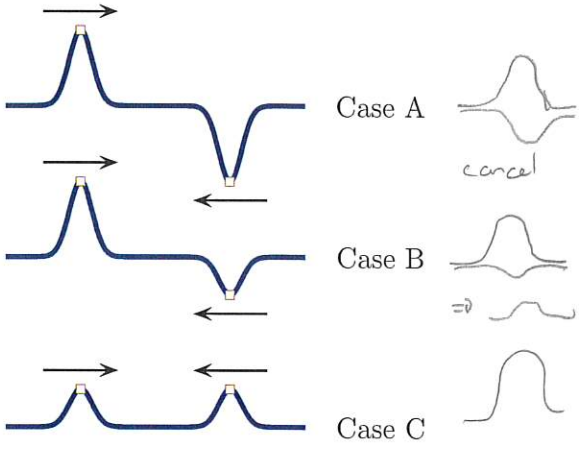
Question 18

Various pulses on a string approach each other as illustrated. Which of the following is the rank of the peak height of the string at the moment that the pulses overlap (i.e. when the parts marked by the squares reach the same horizontal position)?



i) All three same.
ii) A largest, B middle, C smallest.
iii) B largest, C middle, A smallest.
iv) C largest, B middle, A smallest.

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Question 19

Red light has a lower frequency than green light. A red light source and a green light source each produce the same power (energy per second). Which of the following (choose one) is true?

i) The red light source produces more photons in one second than the green light source.
ii) The red light source produces fewer photons in one second than the green light source.
iii) The red light source produces the same number of photons in one second as the green light source.

Red photon has smaller energy = h x freq

so need more red photons.

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Question 20

Light with a single frequency is incident on an atom. The energy of each photon is 20×10^{-19} J. The energy of the atom *before the light is incident on it* is 100×10^{-19} J. The atom can absorb energy from the light and cannot release the energy. Is it possible that the energy of the atom after absorption of photons is 130×10^{-19} J? Explain your answer.

The atom can only absorb whole photons. So its energy could increase by 20×10^{-19} J

40×10^{-19} J

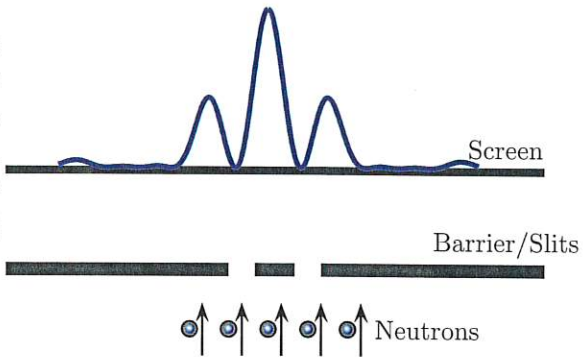
60×10^{-19} J

It cannot increase by 30×10^{-19} J

/4

Question 21

Neutrons are fired, one at a time, toward a double slit arrangement. A screen is placed beyond the slits and the locations at which neutrons arrive on the screen can be determined. The probability of arrival at various locations on the screen is graphed above the screen on the diagram. Which of the following (choose one) does this experiment demonstrate?



i) Each single neutron behaves like a wave.

ii) Each single neutron splits into two neutrons which pass through the slits separately.

iii) Each single neutron passes through one slit and then distributes itself across the screen.

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Question 22

Neon has the following stable isotopes: $^{20}_{10}$Ne, $^{21}_{10}$Ne, and $^{22}_{10}$Ne. Which of the following is true?

i) Each has 10 neutrons and 10 protons.

ii) Each has 10 neutrons but the number of protons varies.

iii) Each has 10 protons but the number of neutrons varies.

iv) Both the number of protons and the number of neutrons varies.

$^{20}_{10}$Ne 10 protons 10 neutrons

$^{21}_{10}$Ne 10 protons 11 neutrons

$^{22}_{10}$Ne 10 protons 12 neutrons

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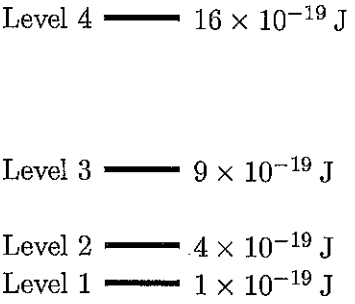
Question 23

The four lowest energy levels of an artificial atom are as illustrated.



a) Which jump between energy levels results in emission of a photon with the smallest frequency? Explain your answer.

frequency = $\frac{\text{energy change}}{6.63 \times 10^{-34}\ \text{Js}}$

Need smallest energy change level 2 → level 1

b) How many distinct frequencies of light can this atom produce? Explain your answer.

There are six distinct energy changes ⇒ six frequencies

4 → 3 3 → 2
4 → 2 3 → 1
4 → 1 2 → 1

/5

Question 24

Nitrogen-16 is unstable and decays into oxygen-16 via: ${}^{16}_{7}\text{N} \rightarrow {}^{16}_{8}\text{O} + \text{particle}$. What type of decay (choose one) is this?

i) Alpha decay.
ii) Beta decay.
iii) Fission.
iv) Fusion.

Number of protons increased by 1

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Question 25

Sodium-24 has a half life of 15hr. At an initial instant, a sample consists of 8g of sodium-~~24~~. 24
How much sodium-24 will remain after 45hr? Explain your answer.

Half lives	Time	Mass
0	0 hr	8g
1	15 hr	4g
2	30hr	2g
3	45hr	1g

1g remains.

/4

Question 26

A meteorite strikes the surface of Earth. Explain whether carbon-14 radioactive dating will enable one to determine the age of the meteorite.

No. Carbon-14 dating works for organic matter that has been able to ingest carbon.

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