2021 HSC Physics
Marking Guidelines

Section I

Multiple-choice Answer Key

Question	Answer
1	B
2	C
3	D
4	B
5	A
6	D
7	C
8	D
9	C
10	B
11	A
12	D
13	B
14	A
15	C
16	B
17	C
18	A
19	A
20	D

Section II

Question 21 (a)

Criteria	Marks
• Correctly calculates the magnitude of the maximum torque	2
• Provides some relevant information	1

Sample answer:

$\tau = nIAB\sin\theta = 1 \times 14 \times 0.1 \times 0.07 \times 0.40 \times \sin(90^{o})$

$\tau = 0.04\ Nm$

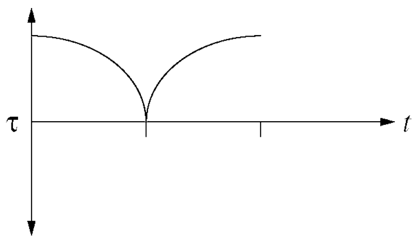
Question 21 (b)

Criteria	Marks
• Correctly describes changes in magnitude of torque throughout one half-rotation	2
• Provides some relevant information	1

Sample answer:

The torque begins at a maximum and decreases to zero at 90º from the initial position. The torque then increases to a maximum at 180º from the initial position.

Answers could include:



Question 22

Criteria	Marks
• Correctly compares angular and instantaneous velocities of *X* and *Y*	3
• Correctly compares instantaneous velocities OR • Correctly compares angular velocities, and magnitude or direction of instantaneous velocities	2
• Provides some relevant information	1

Sample answer:

The angular velocities of *X* and *Y* are equal. The instantaneous velocity of *X* is twice that of *Y*. The directions of instantaneous velocities for *X* and *Y* are the same.

Question 23

Criteria	Marks
• Provides a thorough description of the use of fields by Thomson and Millikan to determine properties of the electron	4
• Provides some description of the use of fields by Thomson and Millikan to determine properties of the electron OR • Provides a thorough description of the use of fields by either Thomson or Millikan to determine properties of the electron	3
• Shows some understanding of the use of fields by Thomson and/or Millikan to study the electron	2
• Provides some relevant information	1

Sample answer:

Thomson used electric and magnetic fields to balance forces on electrons, allowing him to calculate the charge to mass ratio of electrons. Millikan used electric and gravitational fields to levitate charged droplets, allowing him to determine the charge on the electron.

Question 24

Criteria	Marks
• Correctly calculates the magnitude of the induced emf	3
• Provides some working for calculating the magnitude of the emf	2
• Provides some relevant information	1

Sample answer:

$$\Phi = \Delta B_{\parallel} A = 0.15 \times 0.02 = 0.003\ Wb$$

$$\varepsilon = -N\frac{\Delta\Phi}{\Delta t} = -35\frac{(0 - 0.003)}{0.4} = 0.3\ V$$

Question 25 (a)

Criteria	Marks
• Identifies two changes in energy of satellite	2
• Provides some relevant information	1

Sample answer:

The gravitational potential energy and kinetic energy of the satellite both increase as it moves into orbit.

Question 25 (b)

Criteria	Marks
• Correctly calculates the orbital radius	3
• Provides some working for calculating the orbital radius	2
• Provides some relevant information	1

Sample answer:

$$\frac{r^3}{T^2} = \frac{GM}{4\pi^2}$$

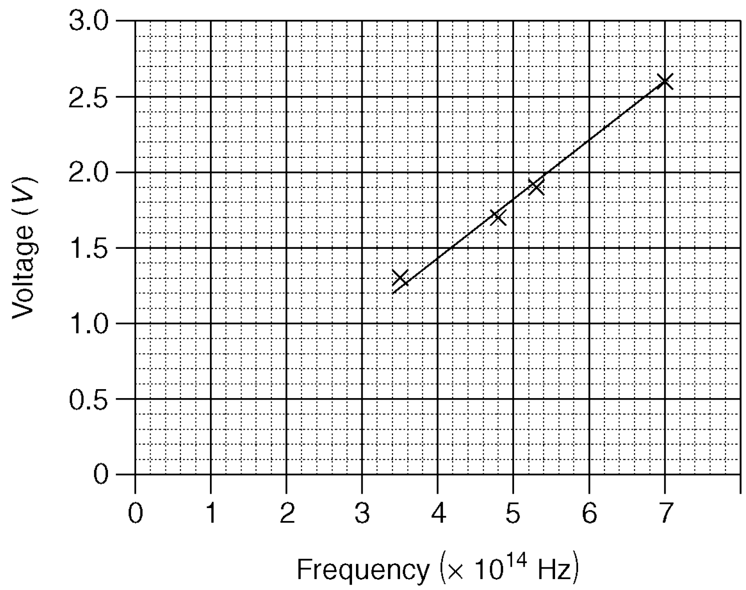
$$\frac{r^3}{\left(\left(24 + \frac{40}{60}\right) \times 60 \times 60\right)^2} = \frac{6.67 \times 10^{-11} \times 6.39 \times 10^{23}}{4\pi^2}$$

$$r = 2.0 \times 10^7 \text{ m}$$

Question 26 (a)

Criteria	Marks
• Uses appropriate scale • Correctly plots data points • Draws line of best fit	3
• Correctly plots some data points using an appropriate scale OR • Correctly plots all data points OR • Correctly plots some data points and draws a line of best fit OR • Provides a substantially correct graph	2
• Correctly plots some data points OR • Provides an appropriate scale OR • Draws a line of best fit	1

Sample answer:



Question 26 (b)

Criteria	Marks
• Proposes a better method to calculate *h* and justifies the method	3
• Proposes a better method to calculate *h* OR • Proposes some improvement with a reason	2
• Provides some relevant information	1

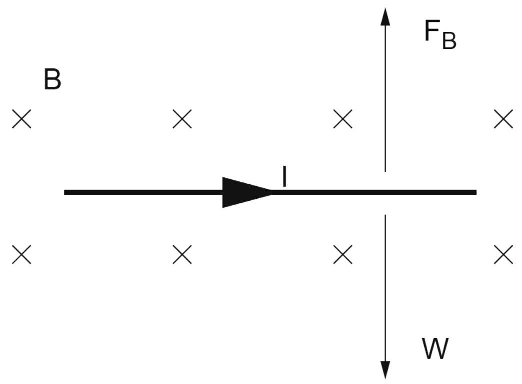
Sample answer:

The gradient of the line of best fit could be calculated from the graph, and substituted into the equation to calculate *h*. This takes more data points into account, increasing the accuracy.

Question 27 (a)

Criteria	Marks
• Proposes a suitable orientation of *B* and *I* and supports answer with a diagram showing labelled forces	3
• Proposes a suitable orientation of *B* and *I* OR • Uses a diagram showing labelled opposing forces to propose an orientation of *B* and *I*	2
• Provides some relevant information	1

Sample answer:



Answers could include:

Any appropriate orientation of *B* and *I*.

Question 27 (b)

Criteria	Marks
• Calculates mass per unit length • Explains why that is the maximum possible value	3
• Calculates mass per unit length OR • Provides some working to calculate mass per unit length and identifies that it is the maximum possible value	2
• Provides some relevant information	1

Sample answer:

$$W = F_B$$

$$mg = lIB\sin\theta$$

$$\frac{m}{l} = \frac{IB\sin\theta}{g} = \frac{2.3 \times 1.2 \times \sin 90^{\circ}}{9.8} = 0.28 \text{ kgm}^{-1}$$

Once mass per unit length exceeds this amount, the force due to the magnetic field cannot suspend the rod against its weight.

Question 28 (a)

Criteria	Marks
• Calculates distance to star as seen by observer on Earth	3
• Provides some working to calculate distance to star	2
• Provides some relevant information	1

Sample answer:

$$t = \frac{t_0}{\sqrt{1 - \frac{v^2}{c^2}}}$$

$$15 = \frac{9.4}{\sqrt{1 - \frac{v^2}{c^2}}}$$

$$v = 0.779c$$

$$s = ut = 0.779 \times 15 = 12\, ly$$

Question 28 (b)

Criteria	Marks
• Outlines how special relativity imposes a limitation on the maximum velocity of the spaceship	2
• Provides some relevant information	1

Sample answer:

Relativistic momentum would approach infinity as v approaches c. This means that an infinite force would be required to accelerate it further, limiting the velocity.

Question 29

Criteria	Marks
• Shows a comprehensive understanding of how the nature of the electron differs between the THREE models	5
• Outlines the nature of the electron in each model showing a sound understanding of the differences	4
• Outlines the nature of the electron in TWO models OR • Identifies a feature of the electron in each of the THREE models showing some understanding of the differences	3
• Identifies features of the electron in the model(s)	2
• Provides some relevant information	1

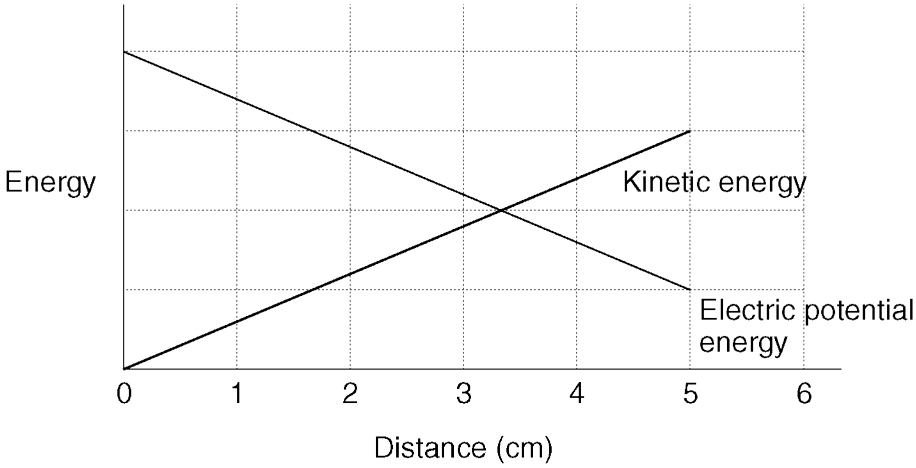
Sample answer:

Bohr proposed that the electron was a negatively charged particle which orbits the nucleus at quantised energy levels. De Broglie's model subsequently proposed that the electron instead had a dual wave/particle nature, and existed in stable standing waves around the nucleus. In contrast, Schrödinger's model described the electron as having a wave nature with properties that could be predicted by his wave equation.

Question 30 (a)

Criteria	Marks
• Correctly sketches the *KE* of the proton	2
• Provides some relevant information	1

Sample answer:



Question 30 (b)

Criteria	Marks
• Provides a relevant explanation of how the motion of the electron would differ from that of the proton	3
• Describes ways in which the motion of the electron would differ from that of the proton OR • Outlines ONE way in which the motion of the electron would differ from that of the proton and provides some explanation	2
• Provides some relevant information	1

Sample answer:

The electron will move in the opposite direction to the proton. The electron would experience an equal force to the proton but in the opposite direction, as its charge has the same magnitude but opposite sign.

Because the mass of the electron is significantly smaller, it would experience a much higher acceleration.

Answers could include:

References to other relevant features of motion such as time.

Question 31

Criteria	Marks
• Provides details of the current in each galvanometer and initial movement of each cart • Provides a comprehensive explanation of the observation when the switch is closed	7
• Provides details of the current in each galvanometer and initial movement of each cart • Provides an explanation of current and movement of carts	6
• Provides some details of the current and initial movement • Provides some explanation	4–5
• Provides some details of the current and/or initial movement OR • Provides some explanation	2–3
• Provides some relevant information	1

Sample answer:

When the switch is closed, a constant direct current will be observed on G_1. This current will create a magnetic field in the solenoid with a south pole facing cart 2. As this field is generated, the solenoid on cart 2 experiences a momentary change in magnetic flux, inducing an emf and a current in the solenoid. By Lenz's law, the direction of this current opposes the original change in flux, forming a south pole facing cart 1, and causing a momentary deflection of G_2 in the opposite direction to the current in G_1.

The equal and opposite magnetic repulsion of the south poles causes the carts to move away from each other. To conserve momentum, cart 1 will have half the initial velocity of cart 2 since its mass is double that of cart 2.

Answers could include:

Reference to Faraday's law, the conservation of energy or Newton's law.

Question 32

Criteria	Marks
• Justifies how well the observations model Hubble's evidence	5
• Provides some justification for how well the observations model Hubble's evidence	4
• Relates aspects of the investigation to the expansion of the universe	2–3
• Provides some relevant information	1

Sample answer:

As the elastic is stretched, each marking moves by an amount proportional to its distance from the fixed end. This successfully models Hubble's observation that more distant galaxies are receding from Earth at greater rates, proportional to their distance from Earth.

However, a limitation of the investigation is that it can only model expansion in one dimension whereas Hubble's evidence showed that the universe is expanding in three dimensions.

Answers could include:

Other benefits or limitations of the model, such as:

- The investigation only examines a change in position of the markings, while Hubble measured speed of galaxies.
- As the elastic stretches, the markings themselves will stretch. Hubble did not find that the galaxies were spreading out.

Question 33

Criteria	Marks
• Provides comprehensive quantitative analysis of each experiment • Shows a comprehensive understanding of how results from the experiments support two different models of light	9
• Provides quantitative analysis of each experiment • Shows a thorough understanding of how results from the experiments support two different models of light	8
• Provides aspects of quantitative analysis of each experiment • Relates the experiments to two different models of light	6–7
• Provides aspects of analysis of experiment(s) • Provides information about relevant models of light	4–5
• Provides information about relevant model(s) of light AND/OR • Includes quantitative information	2–3
• Provides some relevant information	1

Sample answer:

In Experiment *A*, a pattern of bright and dark regions will be observed on the screen. The spacing between adjacent regions can be calculated:

$$d \sin\theta = m\lambda$$

$$5 \times 10^{-5} \sin\theta = 1 \times 400 \times 10^{-9}$$

$$\theta = 0.46^{\circ}$$

$$s = 3 \times \tan 0.46 = 0.024 \text{ m}$$

The pattern is explained by the wave model where light waves from the slits arrive at the screen causing bright regions at points of constructive interference and dark regions at points of destructive interference. This supports the wave model of light.

In Experiment *B*, photoelectrons are emitted from calcium but not nickel. The particle model of light can be used to calculate the photon energy of incident light:

$$f = \frac{c}{\lambda} = \frac{3.00 \times 10^{8}}{400 \times 10^{-9}} = 7.50 \times 10^{14} Hz$$

$$E = hf = 6.626 \times 10^{-34} \times 7.50 \times 10^{14} = 4.97 \times 10^{-19} J$$

This energy is higher than the work function of calcium but not nickel, explaining why one photon has enough energy to liberate a photo electron from the calcium sample, supporting the particle model of light. The particle model can be further applied to calculate the kinetic energy of photoelectrons emitted from the calcium sample.

$$K_{max} = hf - \phi = 4.97 \times 10^{-19} - 4.60 \times 10^{-19} = 3.70 \times 10^{-20} J$$

Question 34 (a)

Criteria	Marks
• Accounts for the relative values of *KE* at t_0, t_1 and t_2	4
• Accounts for some of the relative values of *KE*	3
• Shows some understanding of the changes in *KE*	2
• Provides some relevant information	1

Sample answer:

After the mass is launched at t_0, downwards gravitational acceleration reduces the vertical velocity of the mass until it is zero, at time t_1. The *KE* is a minimum here but is not zero since the horizontal component of its velocity is unaffected by gravity. After t_1, the kinetic energy of the mass increases again as the vertical component of motion increases under the influence of gravity until it strikes the ground at t_2. The kinetic energy at t_2 is greater than the value at t_0 as the mass has lower GPE than at t_0.

Question 34 (b)

Criteria	Marks
• Correctly calculates time of flight	3
• Shows some working to calculate time of flight	2
• Provides some relevant information	1

Sample answer:

At t_0 find u_y $\quad KE = \frac{1}{2}mv^2 \quad v^2 = 2\frac{(864)}{3} = 576$

so $v = 24$

Using Pythagoras, $\quad 24^2 = u_y{}^2 + 13.76^2 \quad$ **so** $u_y = 19.66\ \text{ms}^{-1}$

At t_2 find v_y $\quad KE = \frac{1}{2}mv^2 \quad v^2 = 2\frac{(1393)}{3} = 928.7$

so $v = 30.47$

Using Pythagoras, $\quad 30.47^2 = v_y{}^2 + 13.76^2 \quad$ **so** $v_y = 27.19\ \text{ms}^{-1}$

To calculate time of flight $\quad v_y = u_y + a_g t \quad$ **so** $\quad t = \frac{(v_y - u_y)}{a_g}$

$$= \frac{27.19 - (-19.66)}{9.8}$$

$$= 4.8\ \text{s}$$

Answers could include:

Calculations using $\Delta u = mg\Delta h$.

Question 35 (a)

Criteria	Marks
• Correctly calculates the energy released in one decay	3
• Shows some working to determine energy release	2
• Provides some relevant information	1

Sample answer:

$$\Delta m = (234.0409 + 4.0026) - 238.0495 = -0.006u$$

$$\Delta m = 0.006 \times 1.661 \times 10^{-27} = 9.966 \times 10^{-30}\ \text{kg}$$

$$E = mc^2 = 9.966 \times 10^{-30} \times (3 \times 10^8)^2 = 9.0 \times 10^{-13} J$$

Question 35 (b)

Criteria	Marks
• Correctly calculates the energy produced during the ten years	3
• Shows some working to determine the energy produced during the ten years	2
• Provides some relevant information	1

Sample answer:

$$\lambda = \frac{\ln 2}{t_{\frac{1}{2}}} = \frac{\ln 2}{87.7} = 0.0079 y^{-1}$$

$$N_t = N_0 e^{-\lambda t} = 9 \times 10^{24} \times e^{-0.0079 \times 10} = 8.316 \times 10^{24}$$

$$\Delta N = 9 \times 10^{24} - 8.316 \times 10^{24} = 6.84 \times 10^{23}$$

$$E = 6.84 \times 10^{24} \times 9.0 \times 10^{-13} = 6.2 \times 10^{11} J$$

2021 HSC Physics
Mapping Grid

Section I

Question	Marks	Content	Syllabus outcomes
1	1	Mod 5: Projectile Motion	PH12-12, PH11/12-5
2	1	Mod 6: Charged particles, Conductors and Electric and Magnetic Fields	PH12-13, PH11/12-4
3	1	Mod 8: Deep inside the Atom	PH12-15
4	1	Mod 7: Light and Special Relativity	PH12-14, PH11/12-6
5	1	Mod 7: Electromagnetic Spectrum Mod 8: Origins of the Elements	PH12-14, PH12-15, PH11/12-5
6	1	Mod 8: Origins of the Elements	PH12-15, PH11/12-5
7	1	Mod 6: Electromagnetic Induction	PH12-13, PH11/12-5
8	1	Mod 7: Light: Wave Model	PH12-14, PH11/12-5
9	1	Mod 5: Motion in Gravitational Fields	PH12-12, PH11/12-5
10	1	Mod 6: Applications of the Motor Effect	PH12-13, PH11/12-6
11	1	Mod 7: Light: Quantum Model	PH12-14, PH11/12-5
12	1	Mod 5: Circular Motion Mod 6: Application of the Motor Effect	PH12-12, PH12-13, PH11/12-5
13	1	Mod 8: Quantum Mechanical Nature of the Atom	PH12-15, PH11/12-5
14	1	Mod 5: Motion on Gravitational Fields	PH12-12, PH11/12-7
15	1	Mod 7: Light: Wave Model	PH12-14, PH11/12-6
16	1	Mod 7: Light and Special Relativity	PH12-14, PH11/12-6
17	1	Mod 6: The Motor Effect	PH12-13, PH11/12-6
18	1	Mod 5: Projectile Motion Mod 6: Charged Particles, Conductors and Electric and Magnetic Fields	PH12-12, PH12-13, PH11/12-6
19	1	Mod 8: Properties of the Nucleus	PH12-15, PH11/12-6
20	1	Mod 5: Circular Motion Mod 6: Charged Particles, Conductors and Electric and Magnetic Fields Mod 7: Light: Quantum Model	PH12-12, PH12-13, PH12-14, PH11/12-6

Section II

Question	Marks	Content	Syllabus outcomes
21 (a)	2	Mod 6: Applications of the Motor Effect	PH12-13, PH11/12-4
21 (b)	2	Mod 6: Applications of the Motor Effect	PH12-13, PH11/12-7
22	3	Mod 5: Circular Motion	PH12-12, PH11/12-5
23	4	Mod 8: Structure of the Atom	PH12-15, PH11/12-7
24	3	Mod 6: Electromagnetic Induction	PH12-13, PH11/12-4
25 (a)	2	Mod 5: Motion in Gravitational Fields	PH12-12
25 (b)	3	Mod 5: Motion in Gravitational Fields	PH12-12, PH11/12-4
26 (a)	3	Mod 7: Light: Quantum Model	PH12-14, PH11/12-4

Question	Marks	Content	Syllabus outcomes
26 (b)	3	Mod 7: Light: Quantum Model	PH12-14, PH11/12-5
27 (a)	3	Mod 5: Motion in Gravitational Fields Mod 6: The Motor Effect	PH12-12, PH12-13, PH11/12-6
27 (b)	3	Mod 5: Motion in Gravitational Fields Mod 6: The Motor Effect	PH12-12, PH12-13, PH11/12-4
28 (a)	3	Mod 7: Light and Special Relativity	PH12-14, PH11/12-4
28 (b)	2	Mod 7: Light and Special Relativity	PH12-14, PH11/12-6
29	5	Mod 8: Quantum Mechanical Nature of the Atom	PH12-15, PH11/12-7
30 (a)	2	Mod 6: Charged Particles, Conductors and Electric and Magnetic Fields	PH12-13, PH11/12-5
30 (b)	3	Mod 6: Charged Particles, Conductors and Electric and Magnetic Fields	PH12-13, PH11/12-6
31	7	Mod 6: Electromagnetic Induction	PH12-13, PH11/12-6
32	5	Mod 8: Origins of the Elements	PH12-15, PH11/12-6
33	9	Mod 7: Light: Wave Model Mod 7: Light: Quantum Model	PH12-14, PH11/12-7, PH11/12-4
34 (a)	4	Mod 5: Projectile Motion	PH12-12, PH11/12-5
34 (b)	3	Mod 5: Projectile Motion	PH12-12, PH11/12-4
35 (a)	3	Mod 8: Properties of the Nucleus	PH12-15, PH11/12-4
35 (b)	3	Mod 8: Properties of the Nucleus	PH12-15, PH11/12-4, PH11/12-5