Physics Solutions (Practical)

Section A: Multiple Choice

1. **Answer:** $v = k\sqrt{d}$, where k has units of $m^{1/2}s^{-1}$

Working: Taking ln on both sides,
$\ln v = \ln(k\,d^n) \rightarrow \ln v = \ln k + \ln d^n \rightarrow \ln v = \ln k + n \ln d$
This is in the form y = c + mx, so the gradient is n.
Since gradient = 0.5, n = 0.5 and so $v = k\,d^{0.5} = k\sqrt{d}$
Units are $ms^{-1} / m^{1/2} = m^{1/2}s^{-1}$.

2. **Answer:** None of them

Working: 1: No (gravitational potential energy is not constant)
2: No (at x = 0, the tension force equals the weight. In order for there to be a tension, there must be some extension so cannot be unstretched.)
3: No (in SHM it is acceleration which is opposite and proportional to displacement)
→ None of them

3. **Answer:** 7^o: violet (dimmest), 12^o: red (brightest)

Working: Grating has 300 lines per mm → slit separation is 3.3×10^{-6} m
This is larger than the visible spectrum wavelength
→ longer wavelength light will be diffracted more since it is closer to the slit separation → red light diffracted most (12^o), violet light diffracted least (7^o)
From the graph, longer wavelength (red) light is most intense and shorter wavelength (violet) is least
→ 7^o: violet (dimmest), 12^o: red (brightest)

4. **Answer:** When the temperature is high, the heater dissipates a larger amount of thermal power.

Working: Temp increases → thermistor resistance decreases → more p.d. across the heater → heater dissipates more power

5. **Answer:** $= (3.81 \pm 0.25) \times 10^{26}$ W

Working: Luminosity equation: $L = 4\pi r^2 \sigma T^4$
Mean value $= 4\pi(1.39/2 * 10^9)^2(5.67 \times 10^{-8})(5770)^4$
$= 3.81 \times 10^{26}$ W
% Uncertainty in r = 0.04/1.39 = 0.02878
% Uncertainty in σ = 0.005/5.67 = 0.00088
% Uncertainty in T = 9/5770 = 0.00156
Total % Uncertainty = 2*0.02878 + 0.00088 + 4*0.00156
= 0.06468
Absolute uncertainty = 0.06468 * 3.81 = 0.246 = 0.25
$= (3.81 \pm 0.25) \times 10^{26}$ W

6. **Answer:** $p = (\sqrt{2})/2$

Working: Displacement: $x = A\cos(\omega t)$
Force equation: $-kx = ma$
SHM definition: $a = -\omega^2 x \rightarrow \omega = \sqrt{(k/m)} \rightarrow m = k/\omega^2$
Velocity: $v = A\omega \sin(\omega t)$
EPE $= 1/2\ kx^2 = 1/2\ k\ (A\cos(\omega t))^2 = 1/2\ k\ A^2 \cos^2(\omega t)$
KE $= 1/2\ mv^2 = 1/2\ (k/\omega^2)\ (A\omega \sin(\omega t))^2 = 1/2\ k\ A^2 \sin^2(\omega t)$
Equate: $\sin^2(\omega t) = \cos^2(\omega t) \rightarrow \sin(\omega t) = \cos(\omega t)$
$\rightarrow \tan(\omega t) = 1 \rightarrow \omega t = \tan^{-1}(1) = 45^\circ = \pi/4$
$\rightarrow x = A\cos(\pi/4) = A\ (\sqrt{2}/2)$

7. **Answer:** **2** and **3** only

Working: 1: No (volume is proportional to temperature at constant pressure, so if true, Process I and III would be straight lines)
2: Yes (constant temperature → no change in internal energy
Increase in volume → work done by the gas → heat absorbed to conserve energy
3: Yes (constant temperature → no change in internal energy
Decrease in volume → work done on the gas → heat released to conserve energy
→ **2** and **3** only

8. **Answer:** 1 %

Working: Time to fall: s = ?, u = 0, v = ?, a = -9.8, t = ?
Distance fallen, $s = 4.9t^2$
Additional time for the sound to travel back: t = d/c = 20/330 = 0.0606
→ calculated (sound corrected) $s = 5(t - 0.0606)^2$
→ $20 = 5(t - 0.0606)^2$ → t = 2.0606
→ % uncertainty in s = 2 * % uncertainty in t
= 2 * 0.01/2.0606 = 0.009706 = approximately 0.01 = 1%

9. **Answer:** **2** only

Working: 1: No (component perpendicular decreases going further horizontally, and field strength weakens also → overall decreases
2: Yes (circle is equidistant from the charge)
3: No (additional component from plate → changes everywhere)
→ **2** only

10. **Answer:** The rate of change of the flux is maximum when the plane of the loops is perpendicular to the plane of the paper.

Working: First: No (EMF induced is proportional to the area of the loops perpendicular to the field (this changes so is not constant))
Second: Yes (it is a maximum since when perpendicular to the paper → parallel to magnetic field → angle = 0 → cos(0) = 1).
Third: No (proportional to sin(ωt))
Fourth: No (due to larger loop: e.m.f. = 2ABω sin(ωt), due to smaller loop: e.m.f. = ABω sin(ωt), Net e.m.f. = larger - smaller (opposite orientation) = ABω sin(ωt) = equal.

11. **Answer:** **1**, **2** and **3**

Working: Using Fleming's left hand rule,
Force on AB goes into the paper
Force on CD comes out of the paper
Torque = force (one of them) * perpendicular distance between
= BI|AB| * |AD|
→ All of them

12. **Answer:** Diffraction effects could be a problem because the distance between the transmitting antennas is comparable to the wavelength.

Working: 600 MHz → wavelength = (3 x 10^8)/(600 * 10^6) = 0.5 m (same order of magnitude as separation (1m)) → fourth option

13. **Answer:** About 12% of the electricity generated is lost in the distribution network.

Working: Distribution network (the National Grid) transmits current through much larger distances than appliances → higher resistance → energy lost. Not due to inefficiencies since the figures already take into account power station losses and inefficiencies due to appliances are after consumption so are not considered.

14. **Answer:** Inaccurate measurement of the true length of the test wire.

Working: The wire will typically not be perfectly straight so the measured length can be shorter than the actual length. The wire could also be accidentally moved slightly between readings and when placing the jockeys/electrical contacts.

15. **Answer:** **1**, **2** and **3**

Working: 1: Yes (there will be additional losses due to kinetic energy and slight losses by air resistance during motion → motor puts in more energy to overcome these than calculated → motor seems less powerful than it actually is)

2: Yes (height measurement is 3 s.f. → negligible, time measurement is using a slow-motion camera → negligible, mass of discs can be 95-105 g → significant error compared to others.

3: Yes (since if the masses move too fast, the kinetic energy of the masses will start to become significant (dependent on v^2) which will require correction to the formula)

Section B: Standard Questions

16.

a. i) An oscillating motion where the acceleration of the system is **opposite and proportional** to the displacement (from the equilibrium position).
Or
A system for which $\boldsymbol{a = -\omega^2 x}$, where a is the **acceleration**, ω is the angular frequency and x is the **displacement** from an equilibrium position.
[1 mark]

ii) A (forced) oscillating system which is (externally) **driven** at a **frequency** which is the **same** as its own **natural frequency**. [1 mark]

b. i) Any two from:
The angle of oscillation must be small
No damping/air resistance/friction
The string is taut/does not go slack during the motion
The string is inextensible/rigid/does not break [1 mark each]

Do **not** allow: mass (of bob/string) must be small/negligble, any definition of SHM (e.g. isochronous, acceleration proportional to negative displacement etc.)

ii) There is a **component of tension**/**acceleration due to tension** [1 mark] in the string, which is **proportional to the** (ignore “negative”) (angular) **displacement** [1 mark] of the mass.

c. Measurements:

angle measured **with protractor** stated or shown on the diagram
(or: **ruler** used to measure initial and subsequent **displacement**/**amplitude** then **calculation of angle** using trigonometry) [1 mark]
stop-watch/(high resolution) timer/data-logger to measure time stated or shown on the diagram [1 mark]

Conclusion:
compare periods for different angles stated/implied (or: plot period against angle) [1 mark]

major difficulty:
angle of swing decreases during the timing of the swing (due to damping/friction/resistive forces) [1 mark]

solution:
e.g. measure time for ¼, ½ or 1 swing accurately (using electronic timer/data logger) OR use data logger with motion sensor to record many swings and analyse how the period changes over time OR video the motion with onscreen timer and analyse [1 mark]

d. Obtain a set of readings for: mass m, time period and calculate frequency using **f = 1/T** [1 mark]. Plot graphs of f against 1/m and f against 1/m [1 mark]. The graph which is a straight line through the origin provides the correct relationship. [1 mark]
(**Not** number of oscillations in a set time)

Reference to one method of improving reliability e.g. counting more than 5 oscillations to find T or f, taking repeat measurements of T or f (and average values), time oscillations from equilibrium position. [1 mark]

Allow: product method using two or more points [1 mark]
Select the relation which gives a constant product [1 mark]
Or
Allow: use of log-plots: plot ln f against ln m [1 mark]
If gradient= -1 then f proportional to 1/m or if gradient = -0.5 then f proportional to 1/m [1 mark]

e. kinetic energy (of masses and spring), gravitational potential energy (of mass and spring), elastic (potential/strain) energy of spring. [1 mark]

KE: zero (at lowest point), increasing to max at equilibrium point, decreasing to zero (at highest point) [1 mark]
GPE: increases (as masses rise from lowest to highest point) [1 mark]
EPE: decreases (as masses rise from lowest to highest point) [1 mark]

17.

a. Gravitational Force: attractive; long-ranged. [1 mark]
Strong Nuclear Force: attractive at larger distances and repulsive at short Distances [1 mark]; short-ranged (of the order of 10^{-14} m). [1 mark]
Electrostatic Force: repulsive between protons and zero between neutrons and protons/neutrons [1 mark]; long-ranged [1 mark].

b. Most of the alpha particles aimed at the gold foil went straight through, and some Were deviated through small angles [1 mark];
Hence, most of the atom is empty space [1 mark];
A very small number of alpha particles were scattered through large angles (more than 90^o) [1 mark];
This showed the existence of a tiny positive nucleus [1 mark];
The size of the nucleus is about 10^{-14} m. [1 mark]

18. Diagram:

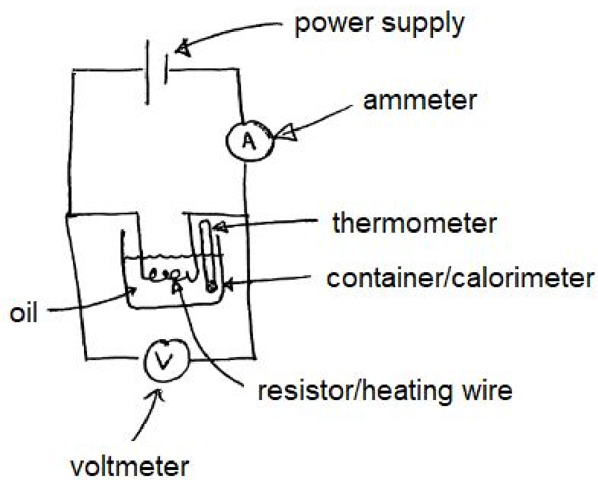

Diagram: Oil in (insulated) container;
Electrical heater fully immersed in oil;
Thermometer/temperature sensor [1 mark]

Electrical circuit: ammeter in series, voltmeter in parallel with heater/joulemeter in parallel with heater;
Power supply / + and - to indicate polarity marked on wires [1 mark]

Measurements: Measure mass of oil/use known mass of oil
Measure change in temperature/initial and final temperature
Measure current, p.d. and (fixed) time/energy [1 mark]

Calculations: $E = Pt = IVt$; $E = mc\Delta T \rightarrow c = E/(m\Delta T)$ or $c = IVt/m\Delta T$ [1 mark]

Uncertainties: Any two from
Heat losses (affects ΔT): minimise by using initial T below and final T same amount above, room temperature.
Temperature varies throughout oil: minimise by stirring before taking temperature readings
Some energy is required to raise the temperature of the container/heater: allow by including this in the calculation.
Temperature will continue to rise after the heater is turned off (due to convection effects): find the maximum temperature reached [2 marks]

19. $F = ma$ / by Newton's second law if the force is constant and acceleration decreases then mass must increase [1 mark]
So the mass of an accelerated electron must increase. [1 mark]

20.

a. Aristotle thought weight and acceleration are directly proportional [1 mark]; Galileo thought that all objects fall with the same acceleration [1 mark]

b. i) gradient of the graph is decreasing to zero [1 mark]
so resultant force approaches zero / drag increases up to weight [1 mark]

ii) In order for an equation to be valid, dimensions/units on both sides must be equal
Dimensions of F = unit N = kg m s^{-2} (mass * length * $time^{-2}$) [1 mark]
Dimensions of $k * v^a * A^b * \rho^c = (m\ s^{-1})^a\ (m^2)^b\ (kg\ m^{-3})^c$
$= kg^c\ m^{a + 2b - 3c}\ s^{-a}$ [1 mark]
Equating mass dimension: $kg = kg^c \rightarrow c = 1$ [1 mark]
Equating time dimension: $s^{-2} = s^{-a} \rightarrow a = 2$ [1 mark]
Equating length dimension: $m = m^{2 + 2b - 3} \rightarrow = m^{2b - 1} \rightarrow 2b - 1 = 1 \rightarrow b = 2$
[1 mark]
(may be found in any order: a = 2, b = 1, c = 1)

iii) k is a constant for a particular parachutist (same body shape etc) [1 mark]

iv) The true relationship may not be of the form assumed in part ii), or

21. Equipment:
GM tube, counter or rate-meter and lead plates used
Micrometer or vernier calliper (to measure thickness of plates). [1 mark]

Description:
Measure counts for a specific time and hence the count-rate for each thickness of lead;
Vary the thickness of lead and record the count-rates;
Plot a graph of count-rate against thickness and determine the half thickness of lead
The graph given is used to determine the photon energy. [1 mark]

Safety:
Do not point source at person;
Keep a safe distance between you and source;
Use tongs to handle source. [2 marks]

Quality of results:
The counts are recorded over a long period of time
Background radiation taken into account/subtracted [2 marks]

22.

a. i) sinusoid [1 mark]
Not wave/periodic

ii) The magnitude of the e.m.f. induced in the coil is equal to the rate of change of the (magnetic) flux linkage in the coil [1 mark]

b. Plan:

Vary the speed of rotation of magnet using motor control;
Expect to see amplitude of signal increase and period of waveform decrease;
Measure (maximum) e.m.f. (V) and period (T) for each setting from oscilloscope screen. [2 marks]

Measurements:
maximum e.m.f. measured from peak to peak distance on graticule and using V/cm scale setting;
Period of rotation measured along t-axis of graticule and using s/cm time base Setting [2 marks]

Analysis:
Record table of V, T and (calculate and record) f = 1/T. ;
Plot graph of V against f [1 mark]

Conclusions:
A straight line graph through origin is required to validate Faraday's law.
[1 mark]

23.

i) RC = V/I * Q/V [1 mark] = Q/I = t (measured in seconds) [1 mark]
(can also use units instead of quantities)

ii) Connect a voltmeter/data-logger/oscilloscope across the resistor (or capacitor) or an ammeter in series with the resistor; [1 mark]
A stopwatch is started when the switch is opened and stopped when the p.d./current decreases to 37% of its initial value; [1 mark]
The time constant is the time taken for the p.d. or the current to decrease to 37% of its initial value. [1 mark]

iii) Mean value = Q = $(2.4 \times 10^{-9}) * \exp(-0.20/(40000 * 75 * 10^{-6}))$
$= 2.245 \times 10^{-9} = 2.2 \times 10^{-9}$ [1 mark]
Uncertainty equation is $\%Q = \%Q_0 + \%(t/RC)$
= (0.1/2.4) + (0.005/0.20) + (1/40) + (3/75) = 0.1317 = 13% [1 mark]
$\rightarrow Q = (2.2 \pm 0.3) \times 10^{-9}$ C = 2.2 ± 0.3 nC [1 mark]